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# Exchange Market Pressure of Japan: An Empirical Estimation of the GR Model

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**Abstract**

This study of exchange market pressure has been carried out to estimate the GR monetary model to the post-recession period, i.e., from 2009: IV to 2020: II, of the Japanese Economy. The main objective of the paper is to empirically analyze the relationship of the Exchange Market Pressure (EMP) with various determinants, for Japan in the selected period. It explains the variation in the magnitude and direction of exchange rate pressure as a result of any change in its determinants. The estimations and analysis have been made within the framework of a bilateral model consisting of Japan and the US Economy.

The main findings of the paper are:

a. The percentage change in Japan's Real GDP was significant and had a positive relationship with Exchange Market Pressure.
b. In contrast to the GR Model, the authors found a positive relationship between percentage change in Japan's domestic credit and EMP.
c. The percentage change in US's High-Power Money and percentage change in US's GDP had a positive impact and negative impact respectively on Japan's EMP, which is in line with the GR Model's estimation. Although the significance of both the variables was low.
d. Multicollinearity and high pairwise correlation existed between percentage change in USA's Real GDP and US's High Power Money Supply for the sample period of analysis while running the original model. Thus, we re-ran the model without taking into consideration US's High Power Money Supply and the results improved substantially with all the other variables becoming statistically significant.

**Keywords:** exchange market pressure, exchange rates, reserves, debt, money supply, GDP.

JEL Classification: C02, C43, E00, F31, F4.

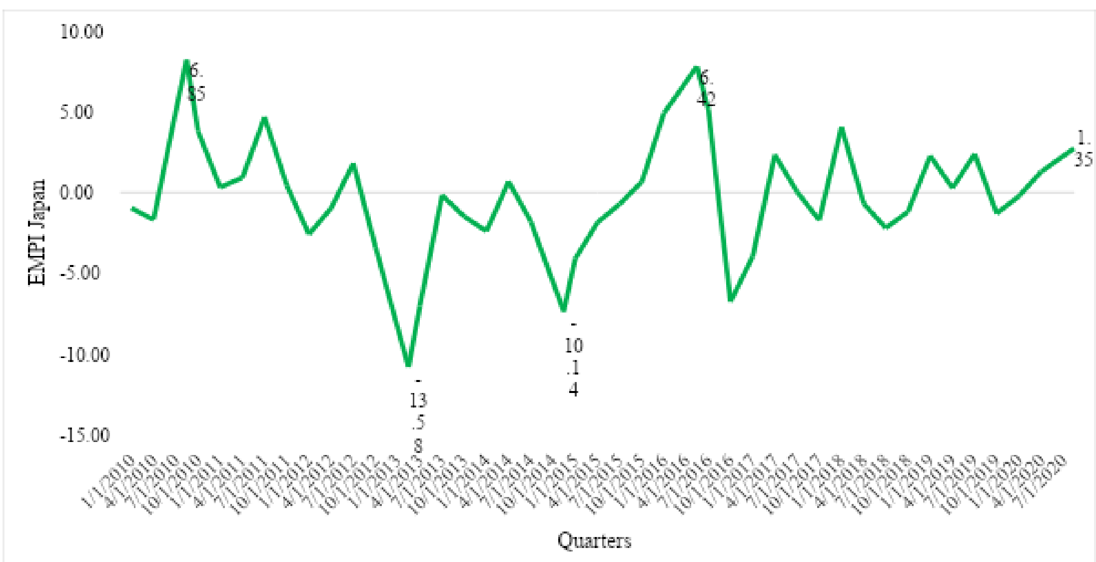
## 1.0 Introduction

Girton and Roper (1977) used the Exchange Market Pressure (EMP) index to evaluate and explain the pressure on a currency. It describes EMP as the magnitude of money market disequilibrium that can be rectified through changes in reserve or in exchange rates. The GR model empirically studies the extent to which monetary policy can be formulated independently in open economies. It is the first model to give a formula for creating an unweighted EMP index and as a structural model in the monetary framework, it treats exchange rate and official reserve changes together by highlighting the determinants of the Exchange Market Pressure. EMP index is the sum of the rate of change of reserve of a country with respect to its previous period's monetary base and rate of appreciation of its exchange rate. It measures the magnitude of external imbalance and quantitatively provides the amount of intervention required to achieve a preferred exchange rate.

This index has been extensively utilized by several international financial organizations. The Bank of International Settlement used it during the European Exchange Rate Mechanism crisis of 1992. The IMF in its World Economic Outlook (2009) also used the index as a component to determine the Emerging Market Financial Stress Index (EMFSI). As per the status under IMF Articles of Agreement, Japan became a member of the IMF on August 13, 1952. The exchange and trade control systems are operated mainly by the Ministry of Finance (MOF), Ministry of International Trade and Industry (MITI), and Bank of Japan (BOJ) working as a government agent (IMF,1999). According to the IMF's de-facto classification system, the exchange rate regime of Japan was Free Float during the period 2009-2018.

The behavior of a currency is dependent and conditional upon the de-facto exchange rate regime and at certain times on the other management policies related to the exchange rate as well. Because of the extreme fluctuations in the exchange rates, comprehending the role of domestic and external factors in influencing the exchange market pressure is essential. These fluctuations are integral issues to be scrutinized while coming up with policy considerations especially for export-oriented countries, as they affect the financial stability of an economy. This paper is an attempt to empirically study those determinants of EMP that are responsible for the downward or upward pressure on the Japanese Yen. The EMP indices are based on the Market Exchange Rates (MER). The reason why we have chosen Japan for our analysis is that it is considered to be the world's third-largest economy and one of the most advanced economies of South-east Asia. It is also a very important source of global capital and credit. The sample period of our analysis is 2009-IV to 2020- II, the quarters have been taken as per the standard financial year that begins from April 1st and ends on 31st March. Furthermore, there have been no existing studies on empirically testing the GR Model on the Post-Global Financial Crisis Recession period (2009 IV to 2020 II) of Japan. During major economic events, the relationship of the EMP index with its determinants changes significantly. Thus, for our analysis, we take the post-global financial crisis period, starting from 2009-IV, and make an empirical study to estimate the GR model for Japan's economy during our period of analysis.

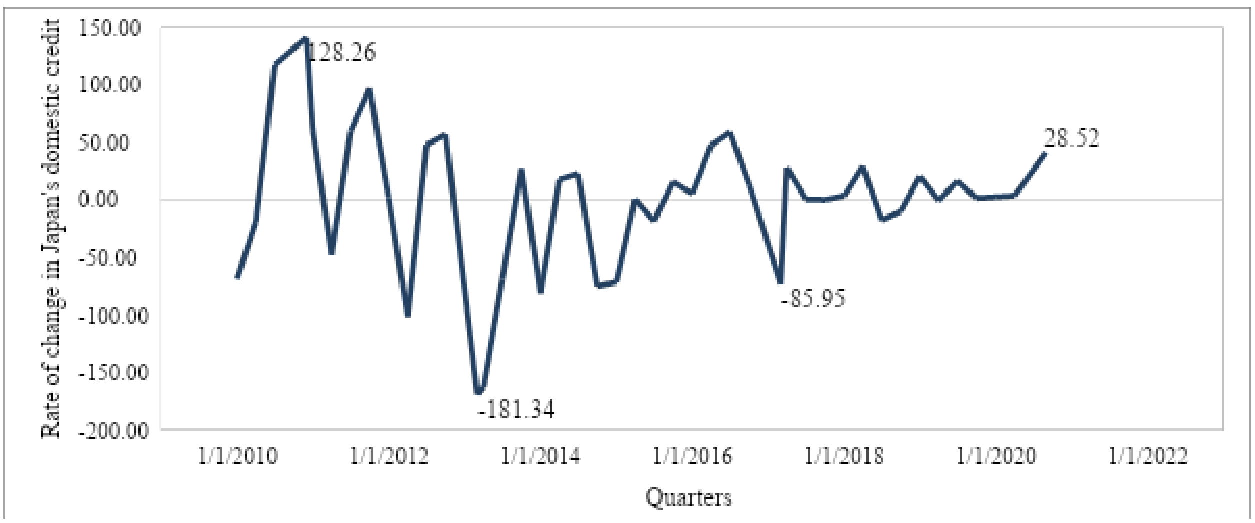
*Figure 1 Exchange Market Pressure Index of Japan*




In Fig. 1 a graph of the behavior of the Exchange Market Pressure of Japan from 2009-IV to 2020-II has been presented. As evident from the graph, the maximum value of the Exchange Market Pressure Index (EMPI) is 6.85 in 2010-II, and the minimum value is –13.578 in 2012-IV. The graph is negatively skewed, slightly towards the left, with its skewness value being –0.897.

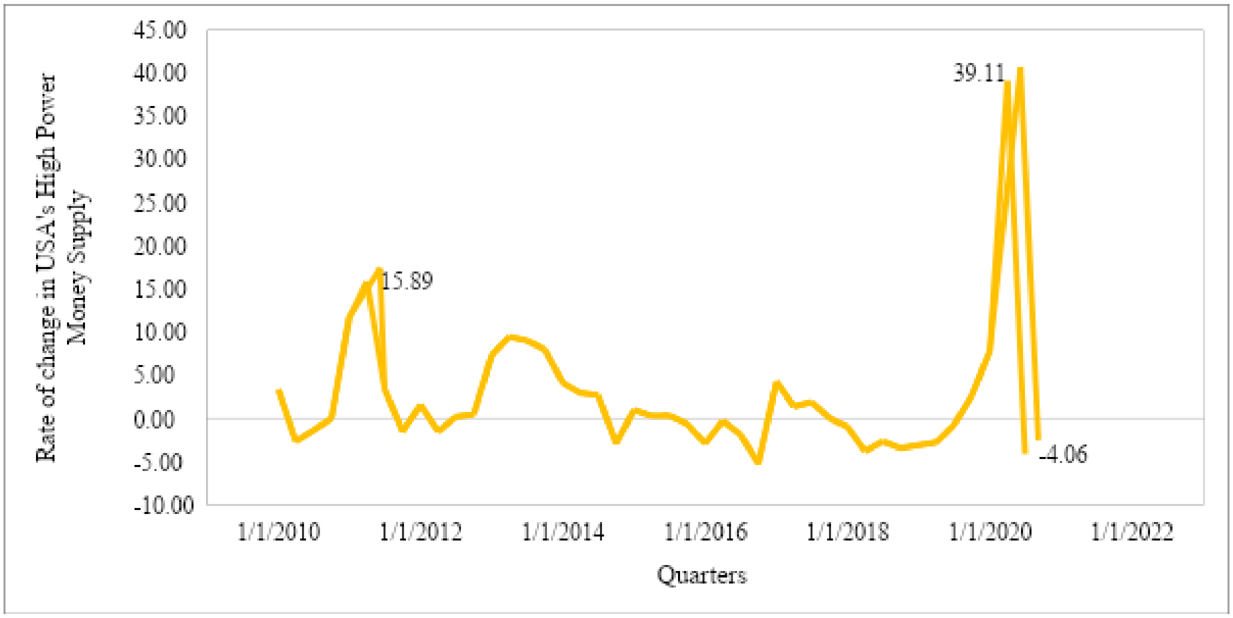
The mean of the EMPI is –0.468 and the median is –0.224. The median being moderately greater than the mean further justifies the slight left skewness of the graph. Japan's EMPI is more volatile on the negative side than the positive side. The standard deviation of the data is 3.9975 with its coefficient of variation being 8.5326. This considerably high value of the standard deviation denotes that the EMPI data is spread out with respect to its Mean. The 5% percentile and 95% percentile of the Japan's EMPI is –9.5172 and 6.1655 respectively, indicating that 5% of the Japan's EMPI lies below –9.5172, and 95% of the Japan's EMPI lies below 6.1655 during our sample period of study. In Figs 2,3,4,5 the time series plots of our four independent variables of study have been presented.

*Figure 2 Time series plot of Percentage Change in Japan's Domestic Credit ($d_j$)*



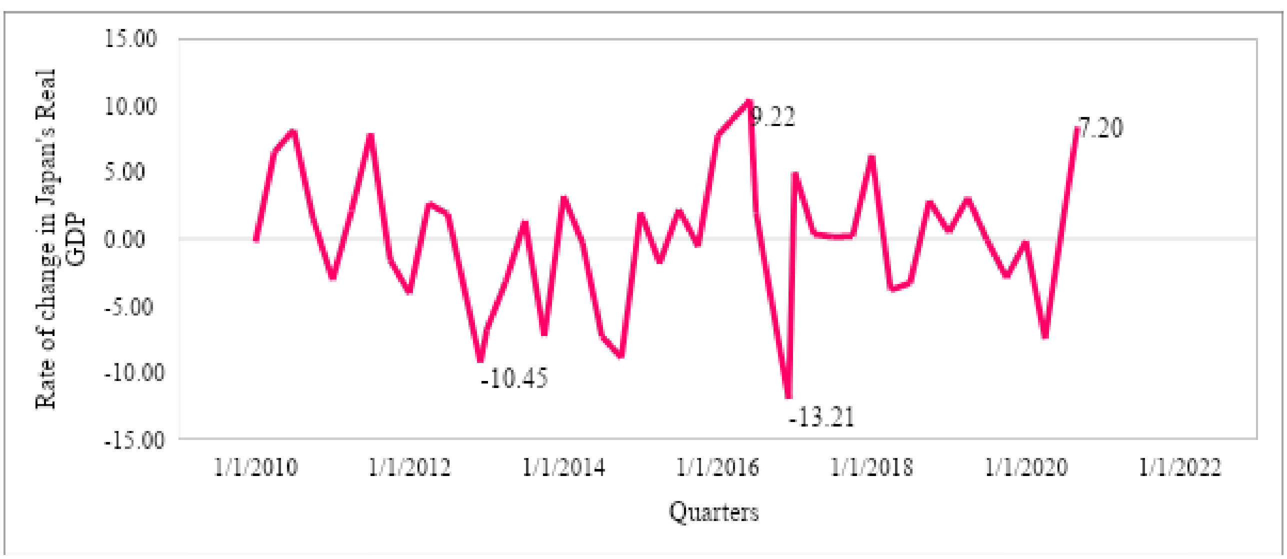

For $d_j$ (Percentage Change in Japan's domestic credit with respect to its previous period monetary base) the minimum percentage change is a decrease of 181.34 and the maximum percentage change is an increase of 128.26. The mean percentage change is –2.28, and the median is 3.2767, with the plot being left skewed. The standard deviation and coefficient of variation are 63.636 and 27.883, thus indicating that the data is greatly scattered.

*Figure 3 Time series plot of Percentage Change in USA's High Power Money Supply ($h_u$)*



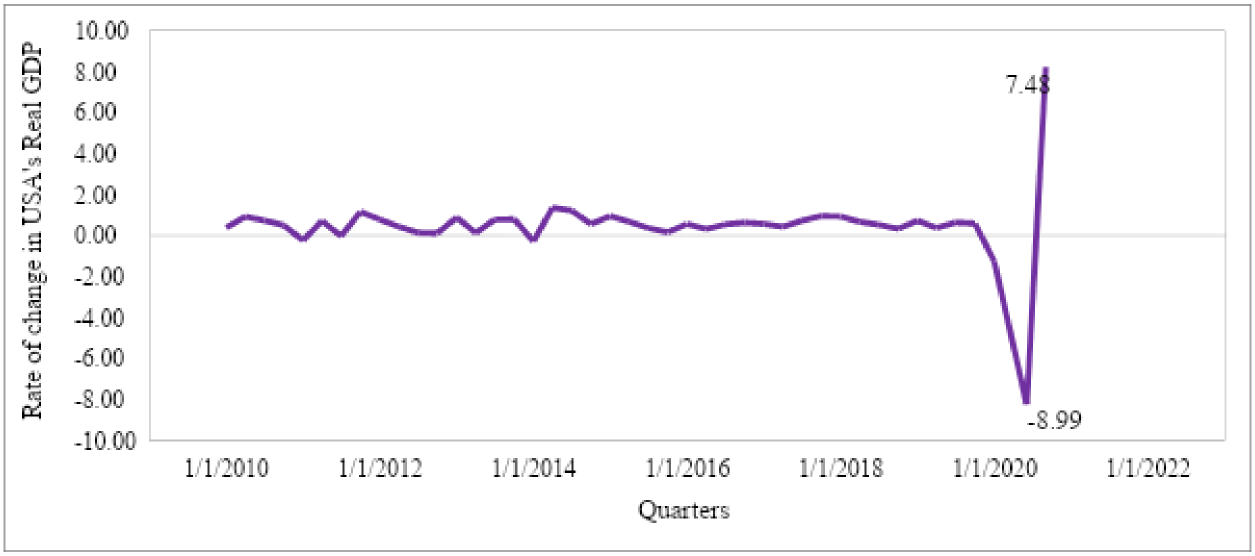

For $h_u$ (Percentage Change in USA's High-Power Money Supply), the mean is 2.2870 and the median is –5.2246, thus indicating that the plot is right-skewed (Skewness value: 3.1693). The minimum and maximum percentage change in the high-power money supply of the USA is 5.2246 decrease and 39.109 increase respectively.

*Figure 4 Time series plot of Percentage Change in Japan's Real GDP ($y_j$)*



For $y_j$ (Percentage Change in Japan's Real GDP) the mean percentage change is –0.0546, and the median is 0.19367, with the data values being slightly left-skewed. The minimum percentage change is a 13.206 decrease in real GDP, while the maximum percentage change is a 9.2176 increase in real GDP.

*Figure 5 Time series plot of Percentage Change in USA's Real GDP ($y_u$)*




For $y_u$ (Percentage Change in USA's Real GDP) the minimum and maximum change is 8.986 decrease and 7.4787 increase respectively. The mean is 0.46372, and the standard deviation is 1.8710. The median is 0.56641, suggesting that half of the observations understudy lie below 0.56641.

An interesting result can be formulated from Figs. 3,4,5. During the 1st quarter of 2020, there is a sudden decline in the growth rate of the USA's real GDP ($y_u$) while the change in high power money ($h_u$) has increased sharply. This period also marks the beginning of the global pandemic due to Covid-19, which further resulted in demand-supply shocks to the world economy. This sudden shock has led to sharp declines in a change in real GDP. However, in order to sustain demand and balance the economy the high-powered money supply had to be increased. The effect can also be seen for the Japanese Economy, a fall in percentage change of Japan's Real GDP, the reason here can be attributed as; the halt at imports and exports to and from the countries were impacted considerably and Japan being an export-oriented country had to face this abrupt shock. But, during the second quarter of 2020, the conditions appear somewhat opposite. The percentage change in Real GDPs ($y_j$ and $y_u$) have risen while that of change in the USA's high power money supply ($h_u$) has fallen considerably, the reason being opening up of countries for trade and by this time the people, after facing the havoc of 1st quarter, started hoarding goods as a result of which $h_u$ dips.

## 2.0 Literature Review

Initially, Girton and Roper (1977) (G-R) gave the first index of Exchange Market Pressure (EMP). The model revolves around the central idea according to which, a rise in the rate of growth of domestic credit puts pressure on the currency. The other factors that put pressure on the currency can be through the rate of change of GDP, the growth rate of international GDP, and the rise in the rate of change of international money supply. The G-R model is a partial equilibrium monetary model wherein the two components of the EMP index are given equal weights, thus ignoring the theoretical and practical issues around the weights under different currency regimes.

Roper and Turnovsky (1980), later, presented a model of EMP in the ISLM framework by improvising the original G-R model. This model assigned different weights to the exchange market pressure's two components. Weymark (1995) constructs an EMP index based on an idea, where rather than the entire EMP manifesting as depreciation, a part is reflected in the changes of level of foreign exchange, i.e., how much EMP will be reflected in the central bank intervention will depend on the elasticity of EMP to foreign exchange reserve changes. It assigned different weights to EMP components: Exchange rate changes and reserve changes and additionally gave the concept of central bank intervention index. Further, keeping in mind that the above-mentioned models ignored rate of interest as a component of EMP, Pentecost et al. (2001) give a wealth augmented model of exchange market pressure, where EMP is made up of three components, namely, change in the nominal exchange rate and the growth in foreign reserves and weighted change in the short-term money market interest rate differential. All of these models are based on some mathematical models.

Eichengreen et al. (1996) (or ERW) used a simple weighted average of the three components of EMP. These weights are inverse variances for the individual components of EMP. In order to study the currency crisis and contagion, they used the quarterly panel data of 20 OECD countries for the period 1959-93. Their central finding is that a speculative attack elsewhere in the world increases the odds of an attack on a domestic currency by eight per cent (ibid p. 482). Kaminsky et al. (1998) suggested that a currency crisis occurs when the EMP index moves three standard deviations higher than its mean value. And, defining a currency crisis, using some multiples of standard deviation will work only when the EMP indices are normally distributed. However, in the case of speculative attacks, EMP does not tend to follow a normal distribution and as per Pontines and Siregar (2008) and Pozo and Amuedo-Dorantes (2003), EMP indices are not normally distributed in general. Therefore, it would be inappropriate to use standard deviation-based thresholds to identify currency crisis events. In such cases, Extreme Value Theory (EVT) is used to identify crisis events. A practical problem associated with the ERW approach is that the ERW measure will show infinite EMP for countries that follow a currency peg or fixed exchange rate because for such countries the value of the denominator (variance) will be zero. The World Economic Outlook uses the crisis threshold of ERW to define currency crises. All the above approaches do not include the possibility of a sudden speculative attack on a currency to cause deterioration in EMP leading to a currency crisis.

The sudden crisis in East Asia in 1997-98 resulted in a fall in forex reserves, huge depreciation of a currency, huge jumps in interest rates, or all three in a very short span of time. Flood and Garber (1984) and Krugman (1979) in their theories, with the help of their speculative attack model, try to explain the sharp rise in EMP. As per their model, speculators will force a currency peg to collapse if "shadow exchange rate"—the exchange rate that would have been if the rate was floating—is sufficiently different from the peg shadow floating exchange rate. If a country aims at expanding domestic credit, if it does not have enough foreign exchange reserves, it will lead to a currency crisis, because the speculators will attack the currency, in order to speed up the depleting forex reserves. Afterwards, a second-generation view is put forward by Obstfeld (1996), in which central banks may decide to abandon the defence of an exchange rate peg when the social costs of doing so, in terms of unemployment and domestic recession, becomes too large. One of its important findings is also that speculative attack depends on the relative payoff in a game-theoretic framework, irrespective of whether the country has a BOP problem or not. These two approaches emphasized the role of government finances and private sector finances in the East Asian currency crisis of 1997. Diamond and Dybvig (1983) proposed the theory of bank runs, in the third model while G. Corsetti et al. (1998) and Giancarlo Corsetti et al. (1999) proposed moral hazard as a possible explanation for the Asian crisis. S.C.W. Eijffinger and B.V.G. Goderis (2007) proposed the corporate balance sheet effect as a reason for the currency crisis. Gerlach and Smets (1995) emphasize the role of contagion.

Girton and Roper (1977) using the G-R model concluded that an increase in domestic credit, decrease in GDP results in depreciation and forex loss. Further Connolly and Da Silveira (1979), (C-S) for Brazil, during 1962-75 found that increase in domestic credit had a significant negative impact on the exchange market. Modeste (1981) studies Argentina and conducts a survey and finds that EMP is independent of the relative role of change in the exchange rate or forex reserve change. Hodgson and Schneck (1981) in their work found out that EMP models may suffer during disruptions and rearrangements or world money; this was carried out for seven advanced economies. Kim (1985), suggests that the relationship between EMP and domestic credit is comparatively stronger. He modified the C-S approach to the GR model. Ghartey (2002) empirically tested the G-R model and found that all the results reported are consistent with the theory and other empirical studies but the results are poor if the only percentage change in forex reserves is used as a component of the EMP. Paradhan et al. (1989) in their work concluded that an increase in the supply of money results in depreciation while putting pressure on the exchange market, by validating the G-R model in India’s context. There are other studies by Bahmani-Oskooee and Bernstein (1999) and Wohar and Lee (1992) for Japan.

Hallwood and Marsh (2003) incorporated and established the importance of expectation as an independent variable in the G-R equation. Mathur (1999) used a Modified G-R model (MGR) which stated that expectation of depreciation of currency increases exchange market pressure, and MGR performed better than the original because the original GR model takes a partial equilibrium approach to EMP. IMF World Economic Outlook (2009) has used the G-R index to gauge currency crises where the study creates EMP indices of 26 emerging economies for the time period 1997-2008. The conclusions derived suggested that the currency crisis can be captured by creating the EMP index as per the G-R model.

Spolander (1999), for Finland, found out that EMP decreased because of the reduction in forex intervention by the Bank of Finland, in the post-Markka's float using the Weymar Model. Nicholas & Sophia (2002) concluded, Bank of Greece intervened in the exchange market to stabilise the currency, post-1992. Jeisman (2005) found that due to intervention by the Reserve Bank of Australia pressure on the Australian Dollar (AUD) increased. Patnaik et al. (2017) established that before the Global Financial Crisis of 2007-08 the currencies of China, India, Brazil, Egypt, experienced appreciation.

According to Khawaja and Din (2007), the money supply is mainly used to manage exchange market pressure, this was evident when they used the Granger causality test for Pakistan. They found that interest rate was used to manage EMP in a period of liberalized capital account and capital account, whereas during the period of capital control, domestic credit was used to manage EMP. Tanner (2002) presented a study and found that in most cases the sign of the effect aligns with the G-R model of EMP, this was done for 32 emerging countries. However, there are a few in which domestic credit and EMP are positively related. The study shows that empirical proof of the association between domestic credit and EMP is somewhat weightier than that linking interest rate differential and EMP (ibid).

Gochoco-Bautista and Bautista (2005) in their study suggested that contracting domestic credit and raising interest rate differential reduces EMP. He used the VAR model by Tanner and presented a Granger causality test of the EMP. Malet et al. (2005) established a positive and double-direction relationship between EMP and domestic credit, and that EMP affects growth negatively. They also observed and further noticed that output growth played a part in affecting EMP and higher interest rates resulted in higher EMP, reflecting devaluation expectations. The results of Mandilaras and Bird (2008), after using the ERW measure of EMP, indicates that an increase in foreign debt increases pressure on the currency to depreciate. They chose weights for each component, to construct the EMP index, which was the ratio of the variance of each component to the variance of all the components taken together. Guru & Sarma (2017) found out that, India faced thirteen currency stress periods during 1992-2012, using the ERW model.

**3.0 Methodology and Model Specification**

The original model given by Girton and Roper for Canada was:

$$EMP_t = r_c + e_c = -\phi_c d_c + \phi_u h_u + \beta_c y_i - \beta_u y_j + v \qquad -1.1$$

$e_c$: Rate of appreciation of domestic currency of Canada in terms of international currency (Dollars) at time t.

$r_c$: Rate of change of forex reserve of the domestic country (Canada) wrt to its previous period's monetary base at time t.

$d_c$: Percentage change in the domestic credit of Canada wrt to its previous period's monetary base at time t.

$h_u$: Percentage change in the international high power money supply (USA's) at time t.

$y_i$: Percentage change in the domestic real GDP of Canada at time t.

$y_j$: Percentage change in the international real GDP of the USA at time t.

$\nu$: Error term

The GR model estimates the data for Canada during the sample period 1952-74 and puts forward the above-mentioned relationship. It suggests that with the increase in domestic debt and international GDP the value of the domestic currency decreases, while with the increase in domestic GDP and international high-power money supply the value of the domestic currency increases.

In this paper, we estimate the magnitude and direction in which the domestic and international variables of interest impact the Exchange Market Pressure of Japan and determine how consistent their relationships are during the sample period of our analysis. The US Economy is one of the leading economies of the world, with the dollar often being used as a standard currency, it has been taken as a proxy to the Rest of the World Economy.

We have estimated the following model for Japan for the sample period (2009: Q4 to 2020: Q2).

$EMP_t = e_j + r_j = -\beta_1 d_j + \beta_2 h_u + \beta_3 y_j - \beta_4 y_u + \nu_t$ -1.2

$e_j$ : Rate of appreciation of Japanese Yen in terms of US Dollars at time t.

$r_j$ : Rate of change of forex reserve of Japan wrt to its previous period's monetary base at time t.

$d_j$ : Percentage change in Japan's domestic credit wrt to its previous period's monetary base at time t.

$h_u$ : Percentage change in the USA's high power money supply at time t.

$y_j$ : Percentage change in Japan's real GDP at time t.

$y_u$ : Percentage change in the USA's real GDP at time t.

$\nu_t$: Error term

**4.0 Data Description**

As per the G-R Model, our study consists of the dependent variable Exchange Market Pressure (or EMP), which is the summation of the rate of change in foreign exchange reserves of Japan with respect to its previous period's monetary base and rate of change in the exchange rate of Japanese Yen in terms of US Dollars. The independent variables used in the study are growth rates (or quarter-to-quarter percentage change) of Japan's Real Gross Domestic Product (GDP), Japan's Domestic Credit, the USA's Real Gross Domestic Product (GDP), and the USA's High power money supply respectively.

The source of data on the rate of change in the exchange rate of Japanese Yen in terms of US Dollars is the U.S. Bureau of Economic Analysis, Board of Governors, Federal Reserve USA. Thereafter a quarter-to-quarter appreciation in the rate of exchange of Japan has been calculated.

To calculate the rate of change in foreign exchange reserves of Japan with respect to the monetary base, the data for Forex reserve of Japan (USD Million) is collected from International Monetary Fund's dataset, thereby using the row International Reserves, Official Reserve Assets, SDRs, US Dollars RAFASDR_USD Millions.

The data for the Monetary base of Japan is taken from the Bank of Japan where the data is seasonally adjusted and has the unit: 100 million yen. Hence, to maintain a uniform unit throughout our analysis the data has been converted to USD by multiplying each figure to its corresponding period's spot exchange rate of USD per JPY, and finally, the entire dataset has been represented in absolute figures of USD Million. The data for the spot exchange rate has been taken from the U.S. Bureau of Economic Analysis, Board of Governors, Federal Reserve USA. Then a quarter-to-quarter percentage change has been calculated in accordance with the GR Model using the formula ((Current quarter's Forex Reserve – Previous quarter's Forex Reserve)/ Previous quarter's Monetary base) * 100. As the Exchange Market Pressure Index is the sum of percentage change in Forex reserve with respect to the previous period's monetary base and rate of appreciation of Japanese yen in terms of USD, we add these two terms to determine the Exchange Market Pressure Index of Japan for all the quarters under study.

The source of the USA data (Real GDP and High-power money supply) is the U.S. Bureau of Economic Analysis, Board of Governors, Federal Reserve USA. The USA's Real GDP is available with the base year 2012 (USD Billion), the values are then converted to USD Million. Since the available dataset was the absolute values of the GDP while the model suggests the percentage change, therefore, the absolute values are converted and calculated using the formula, ((Current quarter's Real GDP-Previous quarter's Real GDP)/ Previous quarter's Real GDP) *100, i.e., on a quarter-to-quarter percentage change basis.

Furthermore, as there was no direct data available for the High-powered money, it is calculated as the addition of US Reserves and US Currency in Circulation (USD Million). A quarter-to-quarter percentage change is calculated in the USA high power money supply, in compliance with the model. The formula used for the calculation is ((Current quarter's High-powered Money-Previous quarter's High-powered Money)/ Previous quarter's High-powered Money) *100.

The source of Japan's total credit data is the Bank for International Settlement. Since the data for the total domestic credit was not directly available, it has been evaluated by adding total credit to the non-financial corporation, total credit to the private non-financial sector, and total credit to the government sector. The data available was in absolute figures of USD Billion. Thus, it is first converted into USD Million and then a quarter-to-quarter percentage change of credit with respect to the Monetary base of Japan is calculated. The formula used is ((Current quarter's Total domestic credit – Previous quarter's Total domestic credit)/ Previous quarter's Japan's Monetary base) * 100.

The source of Japan's Real GDP data is the U.S. Bureau of Economic Analysis, Board of Governors, Federal Reserve USA where the data is available having the base year 2015 being seasonally adjusted and having its unit - yen billion. The data has been converted to USD by multiplying each figure to its corresponding period's spot exchange rate of USD per JPY, and then has been represented in absolute figures of USD Million. A quarter-to-quarter percentage change is calculated using the formula ((Current quarter's Real GDP – Previous quarters' Real GDP)/ Previous quarter's Real GDP) * 100.

**5.0 Result**

Model 1: $EMP_t = e_j + r_j = \beta_1 d_j + \beta_2 h_u + \beta_3 y_j + \beta_4 y_u + \nu_t$ -1.3

Table 1 OLS, using observations for 2009:4-2020:2 (T = 43), Dependent variable: $EMP_t$ $(e_j + r_j)$

| | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* |
|---|---|---|---|---|
| const | −0.385533 | 0.285981 | −1.348 | 0.1856 |
| $d_j$ | 0.0410472 | 0.00496376 | 8.269 | 5.07e-010 *** |
| $y_j$ | 0.475975 | 0.0426122 | 11.17 | 1.44e-013 *** |
| $y_u$ | −0.274689 | 0.126787 | −2.167 | 0.0366 ** |
| $h_u$ | 0.0717493 | 0.0377944 | 1.898 | 0.0653 * |

| | | | |
|---|---|---|---|
| Mean dependent var | −0.468494 | S.D. dependent var | 3.997494 |
| Sum squared residual | 94.59645 | S.E. of regression | 1.577777 |
| R-squared | 0.859055 | Adjusted R-squared | 0.844219 |
| F(4, 38) | 52.89364 | P-value(F) | 5.04e-15 |
| Log-likelihood | −77.96538 | Akaike criterion | 165.9308 |
| Schwarz criterion | 174.7368 | Hannan-Quinn | 169.1781 |
| rho | −0.037844 | Durbin-Watson | 2.021010 |

LM test for autocorrelation up to order 4 - Null hypothesis: no autocorrelation

Test statistic: LMF = 0.194425 with p-value = P (F (4, 34) > 0.194425) = 0.939625

LM test for autocorrelation up to order 1 - Null hypothesis: no autocorrelation

Test statistic: LMF = 0.0573279 with p-value = P (F (1, 37) > 0.0573279) = 0.812092

Breusch-Pagan test for heteroskedasticity - Null hypothesis: heteroskedasticity not present

Test statistic: LM = 5.14785 with p-value = P(Chi-square (4) > 5.14785) = 0.272461

The result of the HAC OLS regression of the model has been presented in the table. The mathematical sign of the coefficient of variable $y_j$ is positive, $y_u$ is negative, and $h_u$ is positive for our sample period of analysis, which is the same as what has been determined by the GR model. Whereas the coefficient of $d_j$ is positive which is inconsistent with the hypothesis of the GR model. The positive coefficients of $d_{j,}$ $y_{j,}$ $h_u$ which are 0.0410472, 0.475975, and 0.0717493 respectively denote that for one per cent increase in Japan's domestic credit, Japan's GDP, and US's High Power Money Supply, the EMP of Japan will increase by 0.0410472, 0.475975, and 0.0717493 points respectively. Let us suppose that Japan's domestic credit, Japan's GDP, or US's High Power Money Supply increases by 20% (0.2), that would result in the increase of the EMP by 0.82% (0.2*0.0410472) or 9.5% (0.2*0.475975) or 1.43% (0.2*0.0717493). The monetary authority of Japan can absorb this disequilibrium by augmenting their reserves, or by allowing their currency to appreciate. Both these measures resulting in the same magnitude can also be during a particular quarter. Assuming that the growth rate of the monetary base is initially zero. Setting Japan's domestic credit expansion at 0.2, will result in increasing the monetary base growth rate to (0.2+0.0082) 20.82%.

The mathematical sign of the coefficient of $d_j$ is positive contradicting the GR analysis where the sign of the coefficient associated with the domestic debt variable was negative. The reason can be attributed to the fact that the Exchange Market Pressure is the summation of percentage change in the exchange rate and forex reserve. The expansion in the credit brings about the depreciation of the currency, although the degree of increase in foreign exchange supersedes this depreciation. EMP will be negative when the currency is depreciating and/or loss in official reserves. The currency is depreciating, however, there are no losses in the official reserves because of the non-intervention of the Japanese government: MOF, MIT, and BOJ. The reason for the same can be interpreted as they don't wish to stabilize the currency, later let it depreciate to promote exports as the domestic demand of Japan is very low due to its ageing population. The official data available after the 1990s denote that there was some government intervention, however, during our period of study, it was not significant enough. Despite the credit expansion and resulting currency depreciation, Japan being an export-oriented country there was an increase in percentage change of reserves during our sample period of analysis.

The $y_u$ has a mathematical coefficient of −0.274689 in our estimation, denoting that for every one per cent increase in US GDP, the EMP of Japan will decrease by 0.274689 points. Supposing that there has been a 20% increase in the US's GDP in a particular quarter, the EMP of Japan would decrease by 5.49% (0.2*-0.274689). This can be absorbed by allowing the reserves of Japan to deplete at the rate of 5.49% of its monetary base, or depreciating their currency by 5.49%, or a combination of both in a quarter. If the economy wishes to only maintain a fixed exchange rate, the reserves should be depleted by 5.49%.

The extremely low p-value of the F statistics denotes the overall high significance of the entire model. The Adjusted R-squared value is high, 0.844% indicating that the variables included in the model account for 84% of determining the changes in EMP. The coefficients of the domestic variables $\beta_1$ (Japan's credit) and $\beta_3$ (Japan's GDP) are statistically significant at 5% since the associated p values are lower than 0.025 for two-tailed tests. While $\beta_2$ (US high power money supply) and $\beta_4$ (US GDP) are comparatively less significant than the above-mentioned variables because of the relatively higher p values of their coefficients.

Here in model 1, As per the results of the Breusch Godfrey test, which are presented in Table 1, the LMF test statistic is greater than 1% (or 0.01) which further means that we will not reject the null hypothesis and there is no autocorrelation in the data. But there exists the problem of heteroskedasticity, thus we run a HAC OLS regression. Next, to check for stationarity we conduct the Augmented Dickey-Fuller (ADF) test, in this, the p values are low and all tau statistic values are also low which implies that the residuals of model 1 are stationary. See table 3 (in Appendix). After the Breusch Godfrey and ADF test, we also check for the pairwise correlation coefficient, and as per the results of Table 4 (in Appendix) it is evident that the pairwise correlation coefficient between $h_u$ and $y_u$ is relatively higher (VIFs are high, there exists multicollinearity as well). See Table 5 (in Appendix). In order to eliminate this problem, we re-run the model without taking into consideration the variable, $h_u$.

Model 2: $EMP_t = e_j + r_j = \beta_1 d_j + \beta_3 y_j + \beta_4 y_u + \nu_t$ -1.4

Table 2 OLS, using observations for 2009:4-2020:2 (T = 43), Dependent variable: $EMP_t$ ($e_j + r_j$)

| | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* | |
|---|---|---|---|---|---|
| const | −0.132632 | 0.203638 | −0.6513 | 0.5187 | |
| $d_j$ | 0.0396388 | 0.00467653 | 8.476 | 2.22e-010 | *** |
| $y_j$ | 0.473652 | 0.0440333 | 10.76 | 3.12e-013 | *** |
| $y_u$ | −0.473404 | 0.0487242 | −9.716 | 5.75e-012 | *** |

| | | | |
|---|---|---|---|
| Mean dependent var | −0.468494 | S.D. dependent var | 3.997494 |
| Sum squared residual | 99.92003 | S.E. of regression | 1.600641 |
| R-squared | 0.851123 | Adjusted R-squared | 0.839671 |
| F (3, 39) | 56.77281 | P-value(F) | 2.71e-14 |
| Log-likelihood | −79.14251 | Akaike criterion | 166.2850 |
| Schwarz criterion | 173.3298 | Hannan-Quinn | 168.8829 |
| rho | −0.068117 | Durbin-Watson | 2.086023 |

The above model, model 2, is carried out to do away with the problems faced in model 1. First, a HAC OLS regression is run with only three control variables (i.e., without taking into account $h_u$). The results of this model improve as the variable $y_u$ becomes more significant. In this updated model, there does not exist the problem of multicollinearity as well because all the Variance Inflation Factors (VIFs) are very low and the condition indices for Belsley-Kuh-Welsch are also low. See Table 6 (in Appendix). We again conduct the Augmented Dickey-Fuller (ADF) test to check for the stationarity of the residual term of the updated model, i.e., model 2. The results for this test are presented below. See table 7 (in Appendix). All the tau statistic values are below 1% and the p values are also very low, which proves that there is no unit root problem with the residuals of the model.

Thus, after all the analysis and diagnostics Model 2 appears more significant and suitable than Model 1 for Japan during our period of analysis i.e., 2009: IV-2020: II.

**6.0 Conclusion**

In this paper the GR Model for Japan over the sample period of 2009: IV – 2020: II has been empirically studied. We have used OLS regressions for estimating the models. The results from the model exhibited a positive relationship between Japan's EMP and growth rate of Japan's Real GDP, the growth rate of the USA's High Power Money Supply, and a negative relationship with a growth rate of the USA's Real GDP, which is in line and consistent with the findings of the GR Model. Although it is interesting to note that during our period of analysis the results show a positive relationship between Japan's EMP and the growth rate of Domestic Credit which is in contrast to that of the GR Model. Since EMP is the summation of the appreciation of exchange rate and change in the foreign exchange rate, the reason for the positive relationship can be interpreted as with the expansion of credit, the degree of increase in foreign exchange reserve by the government superseded the depreciation of Japanese Yen. This can also be interpreted in terms of intervention by the Japanese government. EMP will be negative with credit growth in the following two cases: if the rate of appreciation of the currency is negative and the rate of change in official reserve is negative or either of the two is negative and negative dominates the positive one. In the case of Japan what we have seen is that the rate of appreciation of the currency is negative but the rate of change in official reserve is positive and is higher than the negative rate of appreciation in currency – i.e., the official reserve has increased at a rate higher than the rate of depreciation of the currency.

The Domestic variables of Percentage Change in Japan's Real GDP and Percentage Change in Japan's Domestic Credit also turned out to be statistically significant. Upon putting the data of the residual of the model to the ADF test, it came out to be stationary. However, there existed the problem of multicollinearity and a high coefficient of pairwise correlation between percentage change in USA's Real GDP and USA's High Power Money Supply, respectively. To do away with the problem we re-ran a HAC OLS regression without the percentage change in USA's High Power Money Supply variable and the result improved notably. All the independent variables, growth rates of Japan's Domestic Credit, Real GDP, and USA's Real GDP became statistically significant, with theirs and the model's associated p values suggesting the better results.

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**Appendix**

Table 3 Augmented Dickey-Fuller Test for the Stationarity of the Residuals of Model 1.

| Augmented Dickey-Fuller test for Residuals of Model 1 |
|---|
| testing down from 9 lags, criterion AIC<br>sample size 42<br>unit-root null hypothesis: a = 1<br><br>test with constant<br>including 0 lags of (1-L) uhat9<br>model: (1-L) y = b0 + (a-1) *y (-1) + e<br>estimated value of (a - 1): -1.03756<br>test statistic: tau_c(1) = -6.73817<br>p-value 8.983e-007<br>1st-order autocorrelation coeff. for e: 0.072<br><br>with constant and trend<br>including 0 lags of (1-L) uhat9<br>model: (1-L) y = b0 + b1*t + (a-1) *y (-1) + e<br>estimated value of (a - 1): -1.10793<br>test statistic: tau_ct(1) = -7.25486<br>p-value 9.801e-007<br>1st-order autocorrelation coeff. for e: 0.057 |

Table 4 Pairwise Correlation coefficients, using the observations 2009:4 - 2020:2 5% critical value (two-tailed) = 0.3008 for n = 43

| $d_j$ | $y_u$ | $y_j$ | $h_u$ | |
|---|---|---|---|---|
| 1.0000 | 0.0341 | 0.1379 | -0.1971 | $d_j$ |
| | 1.0000 | 0.2752 | -0.7170 | $y_u$ |
| | | 1.0000 | -0.2404 | $y_j$ |
| | | | 1.0000 | $h_u$ |

Table 5 Test for Multicollinearity Among Independent Variables for Model 1

Variance Inflation Factors

Minimum possible value = 1.0

Values > 10.0 may indicate a collinearity problem

$d_j$ 1.083

$y_j$ 1.103

$y_u$ 2.173

$h_u$ 2.195

VIF(j) = 1/ (1 - R(j)^2), where R(j) is the multiple correlation coefficient

between variable j and the other independent variables

Belsley-Kuh-Welsch collinearity diagnostics:

variance proportions

| lambda | cond | const | $d_j$ | $y_j$ | $y_u$ | $h_u$ |
|---|---|---|---|---|---|---|
| 3.004 | 1.000 | 0.019 | 0.012 | 0.028 | 0.005 | 0.005 |
| 0.942 | 1.786 | 0.000 | 0.860 | 0.029 | 0.001 | 0.000 |
| 0.673 | 2.113 | 0.458 | 0.018 | 0.009 | 0.012 | 0.001 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.355 | 2.909 | 0.002 | 0.087 | 0.709 | 0.014 | 0.030 |
| 0.026 | 10.767 | 0.520 | 0.023 | 0.224 | 0.969 | 0.964 |

lambda = eigenvalues of inverse covariance matrix (smallest is 0.0259168)

cond = condition index

note: variance proportions columns sum to 1.0

According to BKW, cond >= 30 indicates "strong" near linear dependence, and cond between 10 and 30 "moderately strong". Parameter estimates whose variance is mostly associated with problematic cond values may themselves be considered problematic.

Count of condition indices >= 30: 0

Count of condition indices >= 10: 1

Variance proportions >= 0.5 associated with cond >= 10:

| const | $y_u$ | $h_u$ |
|---|---|---|
| 0.520 | 0.969 | 0.964 |

Table *6* Test for Multicollinearity Among Independent Variables for Model 2

| Variance Inflation Factors | |
|---|---|
| Minimum possible value = 1.0 | |
| Values > 10.0 may indicate a collinearity problem | |
| | |
| $d_j$ | 1.019 |
| $y_u$ | 1.082 |
| $y_j$ | 1.102 |

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VIF(j) = 1/ (1 - R(j)^2), where R(j) is the multiple correlation coefficient between variable j and the other independent variables

Belsley-Kuh-Welsch collinearity diagnostics:

variance proportions

| lambda | cond | const | $d_j$ | $y_u$ | $y_j$ |
|---|---|---|---|---|---|
| 2.092 | 1.000 | 0.088 | 0.001 | 0.075 | 0.074 |
| 1.012 | 1.438 | 0.007 | 0.935 | 0.004 | 0.002 |
| 0.660 | 1.781 | 0.865 | 0.015 | 0.114 | 0.044 |
| 0.236 | 2.976 | 0.040 | 0.049 | 0.807 | 0.880 |

lambda = eigenvalues of inverse covariance matrix (smallest is 0.236253)

cond = condition index

note: variance proportions columns sum to 1.0

According to BKW, cond >= 30 indicates "strong" near linear dependence, and cond between 10 and 30 "moderately strong". Parameter estimates whose variance is mostly associated with problematic cond values may themselves be considered problematic.

Count of condition indices >= 30: 0

Count of condition indices >= 10: 0

No evidence of excessive collinearity

Table 7 Augmented Dickey-Fuller Test for the Stationarity of the Residuals of Model 2.

| Augmented Dickey-Fuller test for Residuals of Model 2 |
|---|
| testing down from 9 lags, criterion AIC |
| sample size 42 |
| unit-root null hypothesis: a = 1 |
| |
| test with constant |
| including 0 lags of (1-L) uhat4 |
| Model : (1-L) y = b0 + (a-1) *y (-1) + e |
| estimated value of (a - 1): -1.06837 |
| test statistic: tau_c(1) = -6.9364 |
| p-value 5.052e-007 |
| 1st-order autocorrelation coeff. for e: 0.063 |
| |
| with constant and trend |
| including 0 lags of (1-L) uhat4 |
| Model : (1-L) y = b0 + b1*t + (a-1) *y (-1) + e |
| estimated value of (a - 1): -1.11319 |
| test statistic: tau_ct(1) = -7.29451 |
| p-value 8.494e-007 |
| 1st-order autocorrelation coeff. for e: 0.052 |

*Figure 6 Regression residuals (observe-fitted) in Model 1*

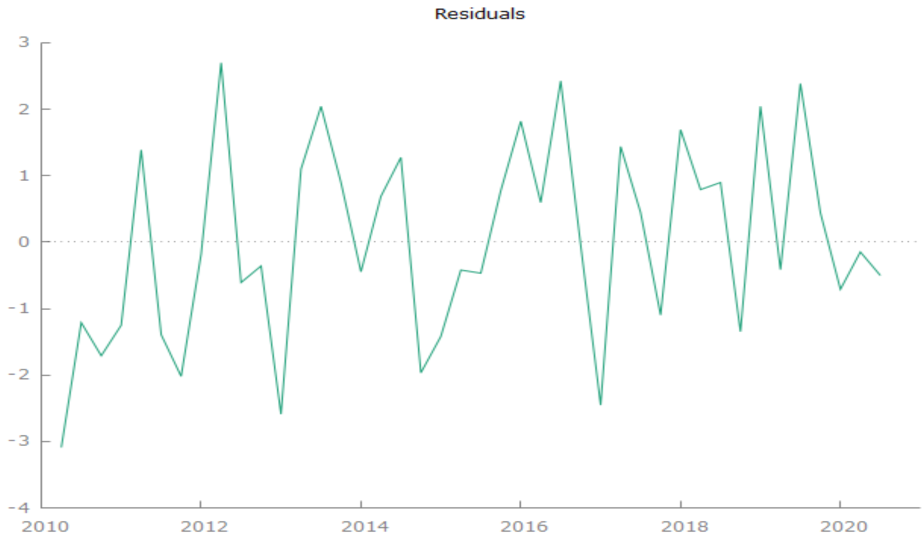


*Figure 7 Regression residuals (observe-fitted) in Model 2*