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Chapter 6

Analysis of the Role of Exchange Rate Volatility in Monetary Policy Conduction in OECD Countries: Empirical Evidence from Panel-VAR Models

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Additional information is available at the end of the chapter

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Abstract

In this study, panel vector autoregression (PVAR) models are employed to examine the relationships between industrial production growth rate, consumer price inflation, short-term interest rates, stock returns and exchange rate volatility. More specifically, I explored the consequences of the dynamics detected by the models on monetary policy implementation for 10 OECD countries. This study indicates that factors that may cause a rise in short-term interest rates with respect to the USA can lead to volatility in exchange rates and thus macroeconomic instability. It is also implied that sustaining macroeconomic growth and decreasing inflation can result in increased export performance, which in turn provides the amount of US dollars to curb volatility in US dollar quotations. Accordingly, this study reveals that high importance should be given to both monetary and non-monetary factors in the open-economy framework to detect the possible impacts on trade and capital flows by dynamic stochastic general equilibrium (DSGE) models. Due to their exchange rate risk of economic agents, I also suggest that the economic policy makers of these countries had better create a theoretical framework including financial frictions, economic agents' preferences and different shocks to smooth the variations in exchange rates and minimise the negative outcomes of Brexit.

Keywords: panel vector autoregression, exchange rate volatility, monetary policy, macroeconomic and financial stability, OECD countries

1. Introduction

After the collapse of the Gold standard system in 1971, the vast majority of countries have abandoned fixed exchange rates for floating systems, which in turn lead to an increased

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volatility in exchange rates. The transmission of various endogenous and exogenous economic shocks to macroeconomic variables has increased. In the era of financial globalisation process, monetary policy authorities have given a high weight to reduce the negative consequences of exchange rate variations on inflation dynamics because exchange rate volatility among the major currencies has continued in the 2000s. In order to curb exchange rate volatility, policy makers and researchers employ quantitative models to determine which macroeconomic and financial factors can be important. According to [1], it can be asserted that exchange rate volatility can both be explained by monetary and non-monetary factors. Financial openness can be regarded as another crucial factor influencing the relationship between exchange rate volatility and macroeconomic variables. Herein, it should be noted that macroeconomic and financial variables may have different impacts on nominal and real exchange rate volatility.

It has generally been acknowledged that real exchange rate is under the influence of macroeconomic variables more than nominal exchange rate. The study conducted by [2] has been recognised as a pioneering approach, exposing that unexpected nominal shocks would lead to an overshooting of nominal and real exchange rates in the short-run under perfect capital mobility. Those implications were also supported by [3], who showed that increases in real exchange rate volatility are more attributable to shocks of exchange rates and interest rates compared to the stickiness of goods prices because the latter took more time to adjust. In line with dynamic stochastic general equilibrium (DSGE) models, it can be assumed that there may be imperfect capital mobility across international borders causing differentiation in the response of exchange rate volatility in macroeconomic and financial shocks according to the perfect capital mobility. For instance, [4] adopted a DSGE model with endogenous portfolio choice to understand whether gross foreign asset holdings and asset trading help to curb real exchange rate volatility. Coeurdacier and Gourinchas [4] suggested the application of various hedging strategies to reduce exchange rate volatility. On the hand, the impact on real exchange rate volatility can change according to the computation methods of [5] and thus it can be put forward that monetary policy authorities may take wrong policy measures to maintain macroeconomic stability. Although [5] found little evidence of significant differences in the responses of macroeconomic and financial variables to the overall volatility vis-à-vis volatility attributed to the high-frequency components, I transformed the exchange rate volatility series into its frequency components, generated filtered series with inverse discrete Fourier transform (IDFT) and included them in my empirical model. Accordingly, it is assumed that fixed exchange rates are not supposed to change, and thus, exchange rates have no volatility, whereas exchange rates are expected to be more volatile in floating exchange rates. Parallel to the Taylor-rule framework, this paper focuses on the interactions between the industrial production growth rate, consumer price inflation, short-term interest rates, stock returns and exchange rate volatility by employing panel VAR (PVAR) methodology for 10 OECD countries outside the Euro area (Canada, Czech Republic, Iceland, Israel, Korea, Mexico, Norway, Poland, Sweden and the United Kingdom). More specifically, the impacts of industrial production growth rate, consumer price inflation, short-term interest rates and stock returns on exchange rate volatility are examined for those countries. Countries included in the panel

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data set have both floating currency regimes and the capital control regimes that are not classified as "Wall" according to the IMF, because it is intended to make interpretations for the cases that exchange rate and capital control policies cannot be implemented to curb exchange rate volatility. In line with [6], the roles of dynamic interdependencies (DI), static interdependencies (SI) and cross-section heterogeneities (CSH) are considered by imposing the plausible restrictions into the estimation process of PVAR modelling. This type of modelling allows us to explore the effects of volatility in exchange rates of the United Kingdom on the variations in the exchange rates of other countries under investigation since Brexit has been recognised as a global risk factor for currency markets. The aims of this study are: (i) to determine the proportion of changes in dependent variables that are due to their own shocks, versus shocks from the other variables by estimating variance decompositions (VDCs) of PVAR models and (ii) to trace the responsiveness of the dependent variables in PVARs to shocks for each of the variables by computing impulse response functions (IRFs). The main hypothesis of this paper tests whether industrial production growth, consumer price inflation, short-term interest rates, share prices have the considerable amount of impact on volatility in exchange rates. Therefore, the research question of this study is formulated as follows: whether changes in the variables under investigation and the interactions between them lead to changes in the monetary policy stance of countries under investigation. The policy implications and suggestions derived from this study may shed light on the optimal approach for monetary policymakers to use in these countries.

2. Literature review

The unprecedented momentum and the changes in global financial integration in the last two decades have led to an ever-increasing interest among researchers to understand the linkages between exchange rate volatility and monetary policy. Thus, there have been a variety of contributions to the literature using different quantitative techniques. In this respect, the previous approaches analysing the consistency of the theoretical framework for interactions between exchange rates and interest rates can be useful for discerning precise implications for monetary policy. Additionally, monetary policy authorities can employ different policy tools in terms of liquidity management in financial markets. Herein, after the 2008–2009 Global Financial Crisis, short-term interest rates in many developed countries approached the zero bound and thus the effectiveness of monetary policy is reduced. In this process, quantitative easing policies have been adopted by the FED, the ECB, Bank of Japan and Bank of England which may significantly influence the volatility in major currencies. For this purpose, [7] investigated the possible effects of monetary aggregates in the determination of exchange rates. The results of [7] indicated that accounting for major structural break points in monetary variables leads to empirical results that are statistically consistent with predictions from theoretical monetary models of exchange rate determination. Thus, the usage of modes including monetary factors to analyse exchange rate volatility was supported. When the scientific literature is examined, it has been recognised that VAR-type of models can be adopted to examine the impacts of

monetary policy shocks on exchange rates. For instance, [8] found that the effect of a positive innovation in monetary policy is associated with an exchange rate appreciation in developed economies; it leads to significant depreciation in currencies of developing economies.

Factors affecting foreign exchange rates may depend on the level of development of countries, as well as on monetary and non-monetary factors. In other words, nominal and real factors can have considerable amount of impact on exchange rate volatility; the study by [9] can be regarded as a pioneering approach in that extent. [9] extended the traditional parity condition model by including non-parity factors, namely, trade, productivity and foreign reserves using panel techniques for quarterly data series over 55 years. [9] obtained outcomes supporting both purchasing power parity (PPP) and International Fisher Effect (IFE) theorems. Moreover, the non-parity factors significantly influenced the exchange rates of Canada, Japan, the United Kingdom and the United States. In a similar approach to [1, 9] analysed the factors which may affect the real exchange rate volatility. [1] also considered the role of both trade and financial openness to formulate the optimal combination of international trade and financial measures for lowering exchange rate volatility. [1] investigated the variations in the real exchange rates for 82 countries from 1974 to 2013 with OLS and IV methods and concluded that the composition of trade and financial openness matters for the stabilisation of reel exchange rates. More specifically, [1] suggested that policies that aim to reduce real exchange volatility should focus on: (i) the composition of financial openness as measured by the type of capital flows (i.e. equity vs. loan-related) and (ii) the role of the structure of trade (i.e. manufacturing vs. non-manufacturing) in the transmission process of shocks to real exchange rate. Herein, it can be asserted that the type of capital control regime is a crucial factor which may vary the impacts on exchange rate volatility. Additionally, the deregulation of financial markets in the era of financial globalisation process has led to an increase in cross-border capital flows, which are widely believed to be an important role on exchange rates. Similarly, it can be inferred that consequences of macroeconomic and financial factors on exchange rate volatility may differ according to the exchange rate regime. Moreover, [10] stressed that exchange rate volatility differed between countries with a floating regime, even if their macroeconomic fundamentals were similar.

In terms of the effects of financial variables and exchange rate volatility, the role of international portfolio flows has become indispensable. There studies in the literature analysing the relationship between exchange rates and flows focus on developed economies [11–13], the minority of the contributions to the literature in the relevant topic for developing countries are conducted by [14–16]. Most recently, [17] studied the effects of equity and bond portfolio inflows on exchange rate volatility using monthly bilateral data for the US vis-a-vis seven Asian developing and emerging countries. Using GARCH models and Markov switching specifications with time-varying transition probabilities in addition to a linear regression model, [17] found that high (low) exchange rate volatility is associated with equity (bond) inflows from the Asian countries towards the US except for the Philippines. Thus, it was suggested by [17] that capital controls could be an effective tool to stabilise the volatility in exchange rates. Along with macroeconomic factors, exchange rates can be highly influenced by variations in different financial markets during periods of prevalent financial integration processes. Herein, it can be asserted that exchange rate volatility can be affected by the volatility in stock returns and vice versa. [18] investigated the possible impacts of the volatility of stock returns in the US, the United

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Kingdom and Japan on the volatility of exchange rate changes using EGARCH modelling. [18] found that volatility of home stock returns had a considerable impact on the volatility of exchange rate changes, implying the validity of the asset approach models for exchange rates and the integration of financial markets among these countries. [19] revealed that bilateral exchange rate volatility (relative to creditor countries) was negatively influenced by the stock of external debt, while optimal currency area variables were relatively important for explaining bilateral exchange rate volatility for industrial countries. Similarly, [20] investigated the cross-country differences in the long-run volatility of the real exchange rate both for developing and industrial countries by including trade shocks, output shocks, country characteristics and currency crisis in ARCH estimations. The long-run real exchange rate of developing countries was between 2 and 2.5 times larger than that of industrial countries due to the fact that developing countries had larger shocks (both real and nominal) or to differences in the sensitivity of the real exchange rate to these shocks. Moreover, [20] stressed that after controlling for shocks and sensitivities, differences in residual volatility were strongly correlated with the level of development and to the degree of diversification in the economy. Based on the theoretical and empirical framework of [20, 21] used an enhanced specification by including nominal shocks (categorised as: domestic monetary variables, budget and trade balances and financial market variables) and inflation shocks to model real exchange rate, nominal exchange rate and relative price volatility for developing and industrialised countries. [21] also showed that nominal and real exchange rates had similar (and high) volatility in industrialised countries, whereas nominal exchange rate volatility was considerably higher than real exchange rate volatility in developing countries. Furthermore, [21] found that inclusion of nominal factors led to a sizable reduction in real exchange rate volatility spread between developing and industrialised countries, assuming that all explanatory factors affect real exchange rate volatility through the changes in nominal exchange rate and price level. Using MGARCH and TVCC-MGARCH models to determine the role of monetary, real, and financial variables on nominal exchange rate volatility, [22] investigated the case of selected EMU members and candidate countries. Volatility in the Polish zloty/euro and the Hungarian forint/euro forex markets were affected by the monetary-side of the economy according to the ex-ante analysis. Ex-post analysis of [22] indicated that forex markets in France, Italy and Spain were influenced by monetary and real shocks.

Transmission of import prices to inflation is an important factor identified by monetary policy authorities for price stability, thus variations in exchange rates have been recognised as the major determinant of the degree of pass-through. For the case of emerging countries, [23] stated that implementation of a 'flexible inflation targeting' regime entailed a de facto managed-floating exchange rate with foreign exchange interventions and moderate exchange rate volatility, while 'strict inflation targeting' implied a fully flexible exchange rate regime. In their study, a panel data set for 37 countries was analysed with pooled OLS with time dummies. [23] showed that inflation targeting caused higher exchange rate instability than alternative regimes. Foreign exchange interventions in some inflation targeting countries were more effective in lowering volatility than in non-inflation targeting countries. More specifically, [23] found that foreign exchange interventions in inflation targeting countries played a useful role in containing the exchange rate volatility, especially negative interventions (sales of foreign reserves). However, [24] suggested that optimal monetary policy and the Taylor rule did not prevent exchange rate volatility, whereas pegged exchange rate was better at

stabilising exchange rate volatility. Additionally, [25] stated that volatility of some macroeconomic variables should change in order to reduce real exchange rate volatility. By using a VAR model for New Zealand, [25] found that output and inflation volatility should be increased by approximately 10–15% and 0–15%, respectively to reduce real exchange rate volatility by approximately 25%. [26] developed a type of DSGE model and introduced trend inflation, policy credibility, policy uncertainty and the competitive structure of goods markets for attaining the inflation target. [26] found that stabilising the exchange rate involved a trade-off between real stability and inflation stability and the best monetary policy rule was to stabilise prices of non-traded goods. Similarly, [27] constructed a DSGE model with sticky-prices to analyse the influences of monetary policy on real exchange rate dynamics. [27] emphasised that if a monetary policy rule had a strong interest rate smoothing component, these kinds of models failed to generate high real exchange rate persistence in response to monetary shocks. Increasing policy inertia might decrease real exchange rate persistence, in the presence of persistent monetary shocks.

Even though studies in the literature have analysed the interactions between exchange rate volatility financial and macroeconomic variables, only one study in the literature conducted by [5] examined the interactions between these variables using a PVAR model. They investigated the joint dynamics of exchange rate volatility, real GDP growth, foreign reserves, interest rates and equity index return for a panel set of 29 countries. [5] also analysed the interactions between variables for developing and developed countries separately using PVAR models; however, these countries may have different exchange rates, monetary policies and capital control regimes. Thus, this approach has a weakness since any common pattern cannot exist in the selected country groups. [5] assumed that the correlations between variables might differ in high volatile periods and economic shocks might influence high-frequency and low-frequency components of volatility differently. In this respect, both annual standard deviations of exchange rates and annual exchange rate volatility attributable to high-frequency components were incorporated into their PVAR models. Within this theoretical framework, [5] found weak empirical evidence for a significant difference in the responses of macroeconomic and financial variables to the overall volatility vis-à-vis the high-frequency components. Ref. [5] also found that the effects of exchange rate volatility on macroeconomic and financial variables were stronger for developing countries relative to developed economies. Furthermore, the exchange rate volatility in both measures was significantly related to real GDP, foreign reserves, interest rates and equity index. In this study, I considered the interactions between exchange rate volatility and macroeconomic and financial variables with PVAR modelling for a sample of 10 OECD countries outside the Euro area with floating currency regimes and capital control regimes not classified as "Wall" class according to the IMF. Even though these countries can be classified as developing and industrialised countries, I applied a panel procedure, since [21] implied that the inclusion of other nominal factors caused a sizable reduction in exchange rate volatility spread between developing and industrialised countries. However, dynamic cross-sectional differences were considered in this study, similar to [6], since the panel data set used contains countries with different macroeconomic characteristics. In this study, I took into account SIs and CSHs, occurring when the correlations between the errors of two countries' VARs are not zero and two countries have VARs with different coefficients. By selecting OECD countries implementing floating currency regimes and relatively liberal

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capital control regimes, I eliminate the weaknesses in estimation results which different currency and capital control regimes can cause and thus focus on making policy implications for countries with similar conditions.

3. Research methodology

The relationship between exchange rate volatility and macroeconomic and financial variables was examined using PVAR models estimated over the period 1999:M1 to 2017:M6[1], considering the availability of data for all countries. This paper contributes to the literature by incorporating the differences between interest rate policies of monetary authorities reflected in the short-term interest rates. As reflected in the ordering of variables in PVAR models, the critical importance is given to the exchange rate volatility in the models since exchange rate volatility can be harmful to the economy by raising the risk factor for domestic firms trading internationally and increased prices to hedge against the additional risk premium. I also considered the fact that volatility in exchange rates may have negative consequences on real economic activity via changes in international competiveness. Within Cholesky decomposition, I assumed that variations in exchange rates influence economic activity, referring to the change in industrial production and inflation, particularly through the trade channel. Accordingly, I assumed that changes in economic activity affect the monetary policy stance, which in turn influences the share market. Within this context, I sought to show the effects of exchange rate volatility on GDP, consumer prices, short-term inflation, and share prices, and discuss the possible impacts of exchange rate volatility on economic and financial conditions for the following periods by estimating IRFs and VDCs. Since the study used month data, I particularly considered the role of SI in the estimation process of PVAR modelling. The main motivation of this paper was to test whether changes in the variables under investigation and the interactions between them led to changes in the monetary policy stances of Canada, Czech Republic, Iceland, Israel, Korea, Mexico, Norway, Poland, Sweden and the United Kingdom. Due to the United Kingdom's high vulnerability to financial shocks, the possible impacts of Brexit are also taken into account in this study by analysing the consequences of the shocks in the volatility of exchange rates in the United Kingdom on currency markets and global economy. The motivation to analyse the possible impacts of Brexit through the exchange rates is that there has been a high amount of variation in the British pound/US dollar following the Brexit vote.

To carry out my empirical exercise, daily exchange rate data (exchange rate of a currency against the US dollar) were employed to compute quarterly standard deviations, which measured the overall volatility ($volex_t$). I constructed the filtered series ($filvolex_t$) with IDFT, using a subset of the frequency spectrum of the original exchange rate volatility series.[2] PVAR model specifications took into account the role of DI, SI and CSH by searching for the plausible restrictions in the model and thus the second PVAR model used the filtered series

[1]Although panel models generally use annual data for empirical analysis, there are also studies in the literature that use panel-type models with monthly and quarterly data [28, 30].

[2]I selected the number of steps as 20 for the magnitude and the phase. Alternative frequency component indexes revealed little difference in terms of the results and thus the robustness of the results was verified.

in order to examine the interactions among variables. Industrial production growth rate ($indg_t$) was expressed as the percentage of changes in the related index (base year 2010 = 100) over the previous period. I also incorporated consumer price inflation ($cpri_t$), referring to the change in CPIs (base year 2010 = 100) over the previous period of the current year. The difference between short-term interest rates ($dirt_t$) was computed by subtracting immediate central bank interest rates in the US (irt_t^{usa}) from the immediate central bank interest rates of each country (irt_t^c). I computed the stock returns (sto_t) as the percentage of change in the stock market index (base year 2010 = 100) from the previous month. On the other hand, the consequences of the financial crisis of 2007–2009 for the relations between the variables were incorporated with dummy variables taking the value of 1 for the period from 2008:M1 to 2017:M6. I used the database from the OECD and databases from the relevant central banks. All series were in levels and they were derived using plausible techniques. The ordering of variables in PVAR models was:$filvolex_t$, $indg_t$, $cpri_t$, $dirt_t$, sto_t, respectively. Although theoretical assumptions can lead to changes in the identification of VAR-type of models, alternative ordering of PVAR models' variables showed no significant differences, supporting the robustness of estimation results in this study. Panel root tests with different assumptions showed that the variables were stationary at levels, even at the 1% significance level.[3] Thus, I employed PVAR modelling due to the theoretically accepted interactions among the variables.

4. Results and discussion

PVAR models are a useful tool for macroeconomic policy analysis since there is no need to impose a prior constant on the relationship between the variables. Within this framework, it is necessary to impose the same underlying structure for each cross-sectional unit (country), while a constraint may be violated in practice. Because fixed effects could be correlated with the regressors due to lags in the dependent variable, I employed the Helmert procedure to eliminate the fixed effects similar to [28]. Thus, the lagged regressors were incorporated as instruments to estimate the coefficients of the PVAR model with the GMM procedure. Estimation of PVAR 1 was implemented by choosing the optimal lag order in the PVAR specification and the moment condition. More specifically, I employed the moment and model selection criteria (MMSC), which is analogous to the Akaike Information criterion (AIC), the Bayesian Information Criterion (BIC), and the Hannan-Quinn Information Criterion (HQIC). Hereby, I performed VDCs analyses and computed IRFs and based on a PVAR (1) model. Following [6], I considered the role restrictions involving DIs, SIs and CSHs in PVAR 2. There is DIs if one country's lagged variables affect another country's variables. SIs mean that the correlations between the errors in two countries' VARs are not equal to zero, while there are CSHs if two countries have VARs with different coefficients. In other words, there exists homogeneity when the coefficients on the own lagged variables for the two countries are equal.

[3]Panel unit root test results can be provided upon request.

Based on a PVAR (1) model, I do not ignore any restrictions since the model with all DI, SI and CSH restrictions performed better than any other alternatives, similar to [6]. The dimension of the panel data set used in this study was near the panel data set of [6], while I employed the same prior hyperparameters to produce priors since the performance of this type of PVAR model was verified by [6]. In this respect, Stochastic Search Specification Selection S4, which allows updating priors from the data, was used in PVAR 2.[4]

4.1. Variance decomposition analysis results

I used the variance decomposition analysis based on PVAR 1 model to determine the degree of importance of each variable included in the model. **Table 1** shows that exchange rate volatility in PVAR 1 was of great importance for understanding the variations over the 36-month period, parallel to [9, 21], implying that the PPP theory may be consistent. FEVDs revealed that changes in economic activity play an important role in the variations in exchange rate volatility in contrast to [5]. Up to the following 36th month, industrial production growth accounted for nearly 10% of the variation in exchange rate volatility, while inflation dynamics explained a minimum of 15%. These findings revealed that the mechanism, through which supply and demand dynamics influence exchange rate volatility, is critically important for monetary policy authorities aiming at financial and economic stability in line with [22]. By implementing variance decomposition analysis, I highlighted the role of economic agents' preferences under alternative constraints in an open-economy framework in each country. The variance decomposition exercise also showed strong interactions among economic activity and currency markets in these countries, whereby the structure of foreign trade and competiveness level of firms are critical factors in terms of lowering exchange rate volatility in each country parallel to [20]. On the other hand, VDCs of PVAR 1 provided weak evidence for the effects of shocks in financial markets on exchange rate volatility in these countries in contrast to [17]. Increases in short-term interest rates and stock prices accounted for nearly 10% of the variation in exchange rate volatility in PVAR 1. The related findings implied that volatility in money markets and stock markets may not cause a high amount of volatility in currency markets in contrast to [18]. However, UIP can be consistent in these countries and changes in monetary policy stances may influence the value of both nominal and real exchange rates in line with [22], which in turn affects foreign competiveness. More precisely, the central banks of these countries may induce only a small degree of capital inflows and outflows that can affect currency markets by changing their monetary policy. Similarly, changes in firm values can have an impact on the variability of the current account balance and the need for foreign funds through the changes in the exchange rate values.

4.2. Impulse response analysis results

In **Figure 1**, the responses of exchange rate volatility to positive shocks in short-term interest rates are shown depending on the PVAR 1's impulse responses. Following an increase in the short-term interest rates relative to the US interest rate, the exchange rate volatility (filtered

[4]For the details of the identification of PVAR model with restrictions, see [6, 31].

Forecast horizon	VDCs				
	$filvolex_t$	$indg_t$	$cpri_t$	$dirt_t$	sto_t
1	.9477392	.0359672	.0001868	.0070239	.009083
12	.6723151	.1172815	.1621161	.0282486	.0200389
24	.6475916	.1191467	.1621421	.0516856	.0194341
36	.6314912	.1239062	.1588667	.0662796	.0194562

Table 1. VDCs of exchange rate volatility (filtered series) from PVAR 1.

series) may increase due to a flow of funds into the exchange rate market. This finding was consistent with the Mundell–Fleming (M–F) model and in line with [2, 5, 8, 17]. The IRFs implied that contractionary monetary policy implementations in these countries may lead to a deterioration in stability in currency markets and also other financial markets, which, in turn, may negatively affect the foreign competiveness of these countries and deteriorate real economic activity. IRFs based on PVAR 1 also revealed that increases in inflation rates in these countries can be recognised as a factor negatively influencing economic stability and thus causing an increase in exchange rate volatility parallel to [5, 25]. Increases in inflation and contractionary monetary policy were crucial in terms of the determination of exchange rate volatility. Even though differences between positive and negative shocks may exist in VAR-type models, the actual difference between these two responses seems small and thus I am hard pressed to make the case for using the asymmetric model on economic grounds [29]. Thus, decreases in inflation and expansionary monetary policy stances in these countries may become factors causing stability in the currency market and other financial markets. On the other hand, it is important to determine the role of fluctuations in real economies on exchange

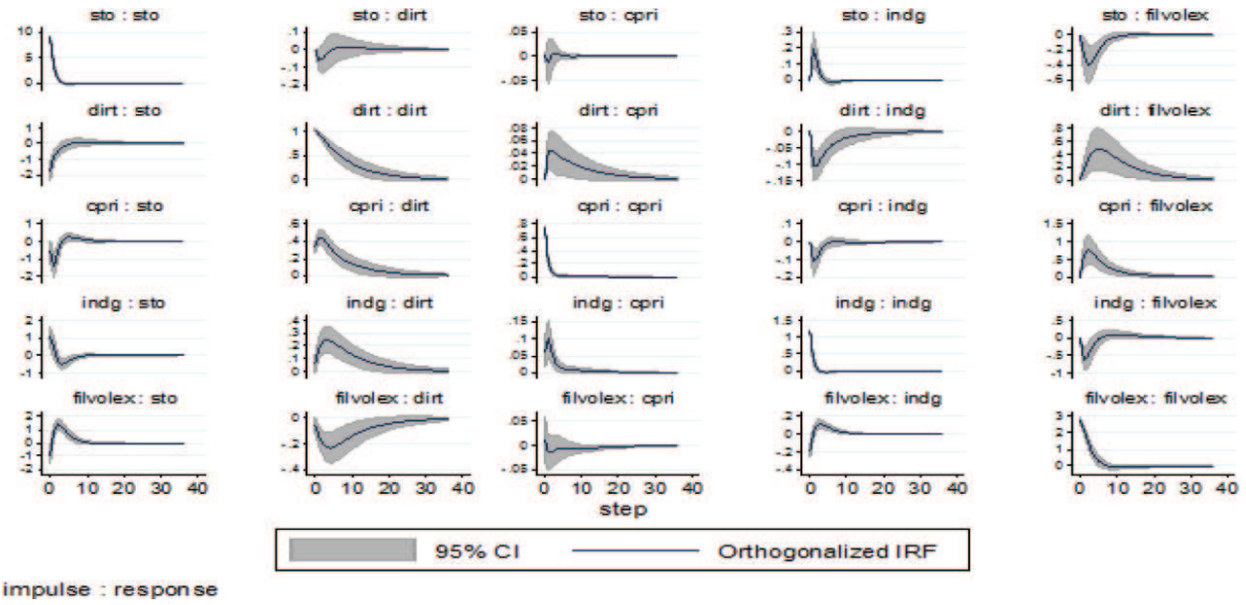


Figure 1. IRFs for the PVAR 1 with filtered exchange rate volatility.

rate volatility. Impulse response exercise revealed that increases in economic growth can positively affect financial and economic stability in line with [25], leading to a fall in exchange rate volatility. Economic growth in these countries may provide foreign currency related to the improvement of current account balance as predicted by the export-led growth hypothesis. Herein, the value of real exchange rates may influence the competiveness of these countries along with the need for foreign technology acquisition. The export-led growth hypothesis requires the liberalisation of foreign trade and capital flows, while IRFs of PVAR 1 indicated that increases in stock prices in these countries may make the financial markets attractive and thus increase the flow of funds into the domestic economy. Therefore, the development of financial markets and maintaining financial economic stability are important targets for economic policy makers to eliminate the negative consequences of exchange rate volatility. Additionally, IRFs exposed that both monetary and non-monetary factors may have a significant amount of impact to examine the volatility in exchange rates in OECD countries parallel to [1]. Herein, the monetary policy-makers in those countries should give a high importance to possible consequences of financial development and openness.

4.3. Search for restrictions in PVAR 2 model and impulse response analysis results

The implications of the Brexit vote have broad and direct economic and political fallout for the United Kingdom and Europe, while the vote is a factor triggering the anti-globalisation movements more generally. Additionally, it has been recognised that the United Kingdom's vote to leave the EU is set to be a long phase of uncertainty in financial markets. Following the Brexit vote, the pound has been a huge focus of attention in the financial markets; moreover, sterling has been down to a 31-year low against the dollar and it is expected that British pound/U.S. dollar will fall gradually. In this regard, it can be inferred that the search for plausible restrictions in the PVAR models may well reflect the impacts from the macroeconomic variables of the United Kingdom to Canada, Czech Republic, Iceland, Israel, Korea, Mexico, Norway, Poland, Sweden and vice versa. For the case of DI restrictions, these may go from one country to another; however, they do not have to go in the reverse direction. **Table 2** indicates that lagged values of the variables of the United Kingdom appear in the PVARs of all remaining countries, while only the lagged values of Iceland, Israel and Sweden can have an impact on the variables of United Kingdom. More precisely, the DI restrictions of the model imply that the determination of international transmission channels from the United Kingdom to the global economy should be determined. It can also be inferred that economic activity in countries with different exchange rate and capital control regimes can influence the economic performance in the United Kingdom through trade and financial channels, despite DI restrictions indicating the importance macroeconomic developments in Iceland, Israel and Sweden for the United Kingdom.

Along with DI restrictions, the relationship between the macroeconomic variables of the countries included in the PVAR 2 can be examined by the search for the SI restrictions. SI restrictions are symmetric in contrast to the DI restrictions; more specifically, if there are SIs from two countries, there are also SIs in the opposite direction. Hereby, we can determine whether the correlations among the errors of two countries are zero or non-zero. **Table 3** shows that among all countries under investigation, Iceland and Israel have SIs with every other country. More precisely, the United Kingdom is particularly under the influence of the changes in the

To	From	Number of DI restrictions
Canada	Czech Republic, Iceland, Israel, Korea, Mexico, Norway, Poland, Sweden, United Kingdom	9
Czech Republic	Canada, Iceland, Israel, Korea, Mexico, Norway, Poland, Sweden, United Kingdom	9
Iceland	Czech Republic, Israel, Sweden, United Kingdom	4
Israel	Iceland, Sweden, United Kingdom	3
Korea	Canada, Czech Republic, Iceland, Israel, Mexico, Norway, Poland, Sweden, United Kingdom	9
Mexico	Canada, Czech Republic, Iceland, Israel, Korea, Norway, Poland, Sweden, United Kingdom	9
Norway	Canada, Czech Republic, Iceland, Israel, Korea, Mexico, Poland, Sweden, United Kingdom	9
Poland	Canada, Czech Republic, Iceland, Israel, Korea, Mexico, Norway, Sweden, United Kingdom	9
Sweden	Canada, Iceland, Israel, Norway, United Kingdom	5
United Kingdom	Iceland, Israel, Sweden	3

Table 2. Countries where DI restrictions do not hold.

Country pairs		
C1	**C2**	**Number of CSH restrictions**
Canada	Iceland, Israel, Korea, Mexico, Norway, Poland, Sweden	7
Czech Republic	Iceland, Israel, Korea, Mexico, Norway, Poland, Sweden, United Kingdom	8
Iceland	Mexico, Norway, Poland, Sweden, United Kingdom	5
Israel	Korea, Mexico, Norway, Poland, Sweden, United Kingdom	6
Korea	Mexico, Norway, Poland, Sweden, United Kingdom	5
Mexico	Norway, Poland, Sweden, United Kingdom	4
Norway	Sweden	1
Poland	Sweden	1
Sweden	United Kingdom	1
Country pairs		
C1	**C2**	**Number of SI restrictions**
Czech Republic	Mexico	1
Iceland	Israel, Korea, Mexico, Norway, Poland, Sweden, United Kingdom	7
Israel	Korea, Mexico, Norway, Poland, Sweden, United Kingdom	6
Sweden	United Kingdom	1

Table 3. Countries where CSH and SI restrictions do not hold.

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economics of Iceland, Israel and Sweden. Additionally, SI restrictions implied that the macroeconomic developments in the United Kingdom may mostly be transmitted to the macroeconomic and financial variables of Iceland, Israel and Sweden.

Both DIs and SIs exposed the role of the economy of the United Kingdom for OECD countries, and thus, the possible negative consequences of Brexit on OECD countries should be assessed. SIs highlighted the importance of Iceland and Israel's economic performance for the United Kingdom and the rest of the OECD countries. I can interpret these phenomena as a reflection of the on-going impact of Iceland who has failed to guarantee British savings, and Britain's use of anti-terror laws to freeze the assets of Iceland's crisis-hit banks. SIs also implied the key role of Israel's economy in the international transmission channels in line with the fact that the Israeli economy has been ranked as one of the world's most durable economy in the face of crises; also, Israel is ranked second among foreign countries in the number of companies listed on US stock exchanges. Thus, I can assert that the channels through which the economic and financial crisis spread to the global economy should be clarified by the economic policymakers. On the other hand, 38 of the 45 possible CSH restrictions were not imposed. It was indicated that Canada, Czech Republic, Iceland, Israel, Korea and Mexico are the countries with the fewest heterogeneities with the other countries, whereas Norway, Poland, Sweden and the United Kingdom tend to have homogeneous VARs. The coefficients of the lagged variables of Norway, Poland, Sweden and the United Kingdom were the same; thus, it can be asserted that there may be similar patterns in the relationships between exchange rate volatility and macroeconomic and financial variables in these countries. Moreover, I can assert that the possible consequences of the Brexit phenomena on Norway, Poland, Sweden and the United Kingdom can be identical, leading to the need for similar macroprudential policies.

Additionally, I performed impulse response analysis, focusing on the effects of a positive shock in exchange rate volatility in the United Kingdom, whereupon the effects of Brexit on the variation in exchange rates and its consequences on economic activity were identified. More precisely, I detected the responses of the exchange rate volatility in Canada, Czech Republic, Iceland, Israel, Korea, Mexico, Norway, Poland and Sweden to a 1% increase in British pound/US dollar exchange rate volatility (filtered series) for the following 36 months. According to **Figure 2**, it can be seen that a positive shock in the volatility of British pound/US dollar exchange rate volatility does not lead to significant changes in the values of the currencies of all countries against the U.S. dollar except for the Czech Republic. PVAR 2, considering the role of DI, SI and CSH and restrictions in the estimation process, indicated that volatility in the US dollar/Czech koruna exchange rate may exhibit a statistically significant increase in the following months. Although it is generally recognised that Brexit can cause uncertainties and instability in currency markets, the impact direction of an increase in the volatility of British pound/US dollar on other currencies could not be determined statistically significantly. Additionally, the finding of PVAR 2 could be interpreted as showing that the negative consequences of Brexit may not be transmitted to the rest of the OECD economies and the world through exchange rate markets, despite the high amount of foreign-asset holdings of the United Kingdom.

Impulse responses computed from the PVAR 2 provided results supporting the assertion that the international transmission of Brexit's possible negative consequences can be detected by other channels. More precisely, the empirical exercise in this study suggested the identification

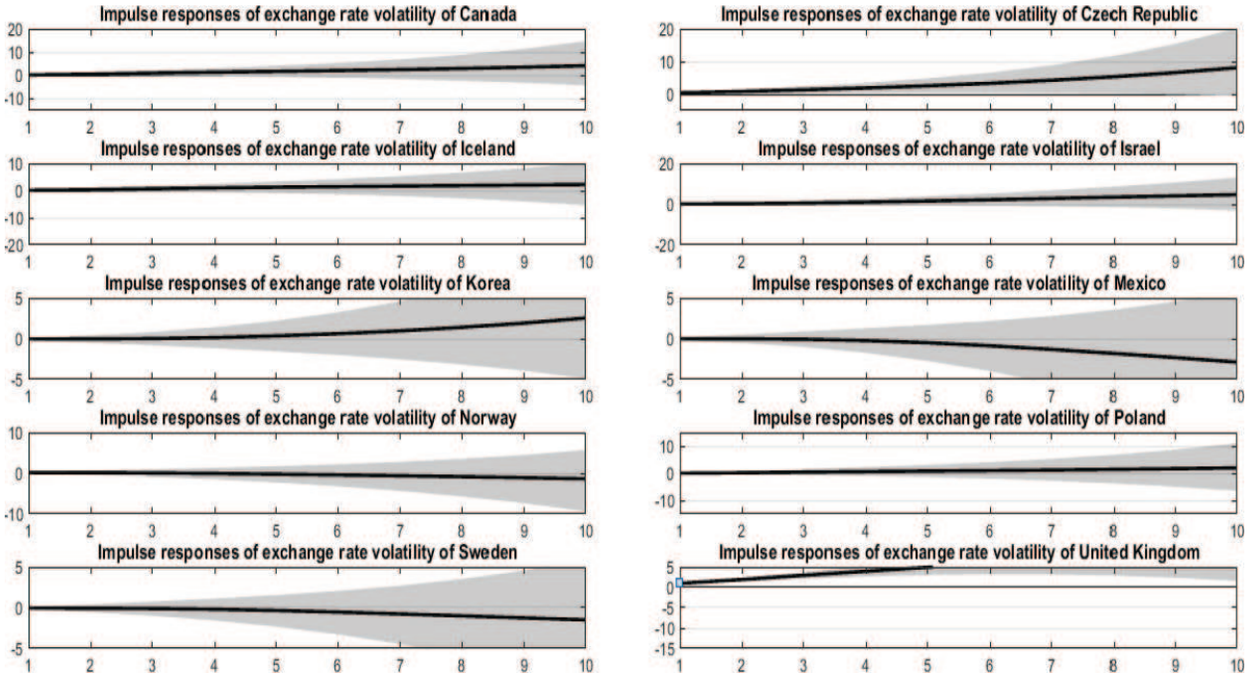


Figure 2. IRFs for PVAR 2 model with filtered overall exchange rate volatility.

of trade and financial channels in detail. Accordingly, I can infer that the possible impacts of a fall in the United Kingdom's export demand on OECD countries should be parameterized by the policy-makers to construct a plausible economic policy. More specifically, plausible quantitative models such as DSGE and VARs can be employed as an empirical framework to study the global effects of consumption and investment shocks. Along with the detection of interactions between consumption and investment patterns of the United Kingdom and OECD countries, my findings highlighted the major role of financial systems in the transmission of Brexit's consequences. It is critically important to determine the effects of the variations in the money and stock markets of the United Kingdom on OECD countries. Herein, the Bank of England's monetary policy decisions can play an important role when the proportion of foreign-asset holdings in the United Kingdom's financial system is taken into account.

5. Conclusions

The estimations of PVAR 1 model indicated that contractionary monetary policy implementation in Canada, Czech Republic, Iceland, Israel, Korea, Mexico, Norway, Poland, Sweden and the United Kingdom can lead to volatility in the exchange rates of these countries, which in turn may influence foreign competiveness and, thus, their current accounts negatively. The VDCs of PVAR 1 did not highly support IRFs, implying that the impacts of changes in short-term interest rates relative to the USA can be small in these countries. Nevertheless, changes in the monetary policy stance of the FED may induce a high amount of variation in macroeconomic and financial variables in the global economy and many economic relationships may be influenced by the FED's possible raising interest rate policy. Eventually, this process may also trigger other central banks to increase their short-term interest rates, which in turn deteriorates

the real economic activity and negatively affects macroeconomic and financial stability. In this respect, relatively low interest rate policies can be important in terms of decreasing and controlling the volatility in exchange rates. According to the IRFs for PVAR 1, industrial production growth can lower the exchange rate volatility, implying that a rise in economic activity in these countries can result in increased export performance, which, in turn provides the amount of US dollars to curb volatility in US dollar quotations. The VDCs of PVAR 1 obtained outcomes parallel to IRFs, revealing that factors causing an increase in aggregate demand and aggregate supply that control inflation and increase economic growth, can be determinative for lowering exchange rate volatility in Canada, Czech Republic, Iceland, Israel, Korea, Mexico, Norway, Poland, Sweden and the United Kingdom. In terms of lowering the exchange rate volatility, sustaining the development of the financial sector can also be crucial since the financial depth will increase. My findings showed that increases in stock returns in the countries considered can promote the flow of funds to domestic financial markets and decrease exchange rate volatility. In this respect, I suggest that monetary policy authorities in these countries employ an open economy DSGE model framework allowing for the role of different preferences and shocks to determine which factors may decrease exchange rate volatility.

Although my study does not focus on the determination of exchange rate and capital control policies to reduce the volatility in exchange rate in the OECD countries under investigation, I suggest that the monetary conducted by the monetary police authorities of those countries should consider the possible impacts of exchange rate shocks, capital and trade flows as shock process within DSGE model. Herein, Brexit has brought a new dimension to the discussion of international transmission mechanisms since it is generally recognised as a crucial factor that may lead to a high amount of variations in currency markets. The possible negative impacts of Brexit were also examined in this study and it was noted that the possible negative outcomes of Brexit cannot be investigated through the links in the exchange rates of OECD countries. Findings of this study implied the identification of other transmission channels by the central banks to analyse the consequences of Brexit, while a high amount of foreign-asset holdings of the United Kingdom can serve as an automatic stabiliser with regard to the trade channel. In this respect, PVAR 2 shows that the economic performance of the United Kingdom can be mostly interrelated with the macroeconomic and financial variables of Iceland and Israel.

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