Estimating Exchange Market Pressure Index: New Approach

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Abstract

Over the last four decades the exchange rate has had an important role on economies. The exchange rate is so volatile that the prediction of it is challenging. Also, there have been several speculative attacks that have caused currency, financial and political crises in several countries. Policy makers had always been late to react against these crises in order to reduce the detrimental effects of them. Therefore, economists have tried to predict currency crises to use as a prior indicator of potential crises. Frankel and Rose (1996) developed the currency crush index. However, this index does not capture unsuccessful speculative attacks due to the construction.

So, Girton and Roper (here after GR) developed the exchange market pressure (EMP) index. They criticize some studies that just focus on intervention, while others try to explain foreign exchange rate market (forex). They combine intervention and forex by applying "the monetary approach to balance of payment". GR added a change in international reserves and exchange rate appreciation, which is called the EMP index. Now, the index has the ability to capture unsuccessful speculative attacks because it includes a change in international reserves. Hence, if money authorities intervene in the forex market, then the index reveals this involvement.

After two decades from GR studies, Eichgreen, Ross and Wyploz (1994, 1995,1996) came to argue that monetary variables do not have a power over exchange rate to explain. They constructed a model independent index, which is called precision index or signaling approach. Moreover, they claimed that money authorities have extensively used policy rate that indirectly effects the exchange rate. This is because a change in

interest rate absorbs some excess demand which causes that the depreciation rate to be less than what it would have been.

Even if the model independent EMP index is widely used, this precision weighting has some disadvantages because the weight cannot have connection with economy, so it can not be interpreted based on fundamentals. Hence, some economists prefer the model dependent index which is called the "elasticity approach", which allows economists make link this weight with fundamentals of an economy.

Hence, in my dissertation, I choose model dependent index because economists should make their conclusion and advice according to the economic model. Also, in this approach, it is not required to determine threshold in order to identify economic and politic crises. But, a certain cut off must be set in the model independent index. Generally, this cut off point is defined arbitrarily by economists, and they explain why they prefer this point based on their interpretation. Since the model dependent EMP index is employed in this dissertation, interpretations are based on economic variables and models.

A model dependent index is employed in this dissertation, and coefficients of the model is estimated by structural vector auto regression model (SVAR) in the second chapter. The SVAR has many advantages. First of all, we use all data in the estimation. The estimation method is full information maximum likelihood (FIML). Also, the endogeneity problem may be overcame by applying this approach. The second advantage is that contemporaneous matrix allow coefficient to be estimated simultaneously. Since exchange rate, international reserves, interest rate and domestic credit expansion influence each other contemporaneously, the coefficients in the model should be estimated at the same time.

To sum up our findings in this dissertation, the weights for international reserve and interest rate differential includes more coefficients. The coefficients of the domestic credit expansion equation directly affects the index. The rational expectations is considered in the model and estimation. By imposing the cross equation restriction, the estimation method now has an ability to expose the effect of the rational expectation. Moreover, even though many studies impose either the PPP or the UIP holds, those assumptions are relaxed in this chapter.

In the SVAR estimation, many coefficients are statistically significant. The coefficients' signs match up with expectations according to economic theories. Furthermore, the effect of the exchange rate over the international reserve is relatively big when we compare it to other coefficients. This result shows how important a variable is in the empirical model. When the EMP index is calculating, it is clearly seen that the elasticity of the international reserve with respect to exchange rate is close to zero. Generally, it is found close to three. But, the method has an ability capture three important points, which may cause lower elasticity.

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All praise is due to Allah, the Lord of the Worlds. Peace be upon His Prophet Muhammad.

After finished dissertation, the single name, the student's name, appears on it. The dissertation process requires formidable challenge and corporation with other people. This dissertation would not have completed without contributions from the following people.

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Chapter 1

Introduction

1.1 Introduction

After the Bretton Woods system collapsed, exchange rate volatility had increased over time all over the world. This situation caused profit opportunity for speculative investors to make more money. Central banks have intervened to the forex market in order to reduce volatility of the exchange rate. However, especially developing countries did not have enough international reserve to protect their currency, which caused currency crises such as the Pezo problem in Mexico, Brazil in 1999, in Turkey in 2001, Argentina in 2002, etc.

During the last two decades, many countries have let the exchange rate freely float. Starting in developed countries, central banks have reduced their intervention policy into the foreign exchange rate market, so the exchange rate is determined by the market condition. On the other hand, some countries has had a shortage of foreign currency in supply because of the structure of that economies. This crates the fragility to adverse shock on forex market. Therefore, such fragility yields ambiance for currency crises.

Basic definition of the exchange rate market pressure (EMP) is the summation of weighted change of official reserve which is scaled by money base, and exchange rate appreciation / depreciation. Later, some papers include interest rate changes. The EMP is important because the

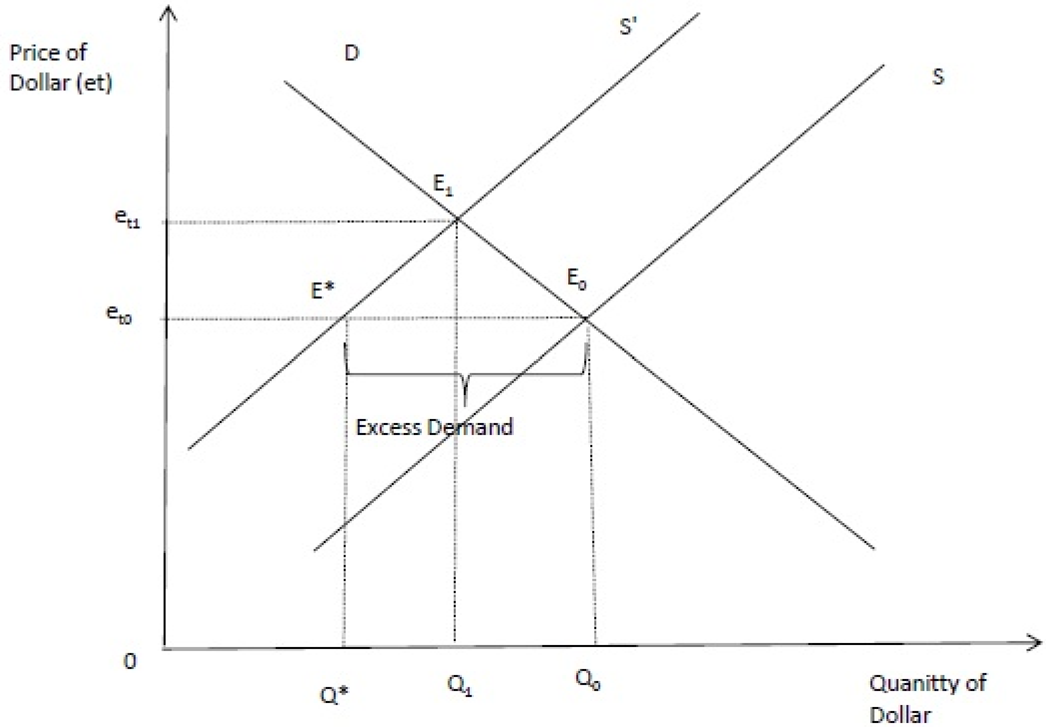


Figure 1.1: Excess Demand in Forex Matket

exchange rate may not be good indicator for the representing how much excess demand on foreign money has in an economy, because central banks have three different tools that the excess demand on foreign money can be reduced. First, money authority can allow exchange rate change to absorb this excess demand. Second tool is direct intervention to the forex market. Finally, interest rate can be risen to reduce excess demand for foreign currency. Furthermore, money authority can choice some combination of these three options. Three variables directly affect other macroeconomic variables such as output level, inflation, trade deficit. Moreover, the change of these policy variables may cause a change in multinational investment decision. Hence, the estimating of the EMP is crucial because of the effects on investment, output level and determining of forthcoming currency crises.

The idea behind of the EMP index is shown in Figure 1.1 and 1.2. Figure 1.1 represents excess demand in the forex market. Let assume foreign currency demand is D. The exchange rate will be set on the intersection demand and supply which is representing by e_{t0}. For any reason the supply curve S shifts to the S' then there exist excess demand which is shown $|Q^{*}Q_{0}|$. Actually exchange rate should depreciate and it will be on e_{t1} and the equilibrium should be E_{1}.

However it is assumed that money authority hikes interest rate to reduce excess demand. Now, since interest rate is higher than before some international investors may not flow out heir money from this country which causes the supply curve shift to to S" (Figure 1.2). In this case, excess demand for foreign currency is less than before. The actually exchange rate willl be set on e_{t2} instead of e_{t1}. Even though money authority did not intervene to forex market directly, an increase in the interest rate causes decreasing of the excess demand which makes to equilibrium level of exchange rate is less than what is would have been. Therefore, actual exchange rate may be bias to be indicator for how much pressure on domestic money since a change in interest rate which causes exchange rate is less than what is should be. Thus, EMP index show us what exchange rate should be when money authorities holds international reserve and interest rate constant.

EMP index introduced in the Girton-Roper(1977) seminal paper. They criticized previous research because some studies just concatenated on international reserves and others focused on exchange rate. However, realized exchange rate can be influenced by interventions. So, their argument that some pressure could be offset or absorbed by intervening to the forex market. After three decade past, money authorities have changed their instruments. Nowadays, interest rate is the most important tool for the central banks in order to lead to an economy. Excess demand in the forex market can be affected by hiking in interest rate.

There are lots of researches on the index to calculate pressure on forex market. Two type indexes are employed. The first one is the model-dependent approach. This approach uses the monetary approach to balance of payment. The results from model dependent approach will be biased due to endogenous problem that Girton-Roper (here after GR) mentioned. In this study, we focus on theory based EMP. On the other hand, second type of index is model independent. This index is called precision weighting or mechanical index. Eichengreen, Ross, and Wyploz (here after ERW) criticize model dependent index. Their argument is that macroeconomic variables have lees power to explain exchange rate, so mechanical index can be used instead of model dependent

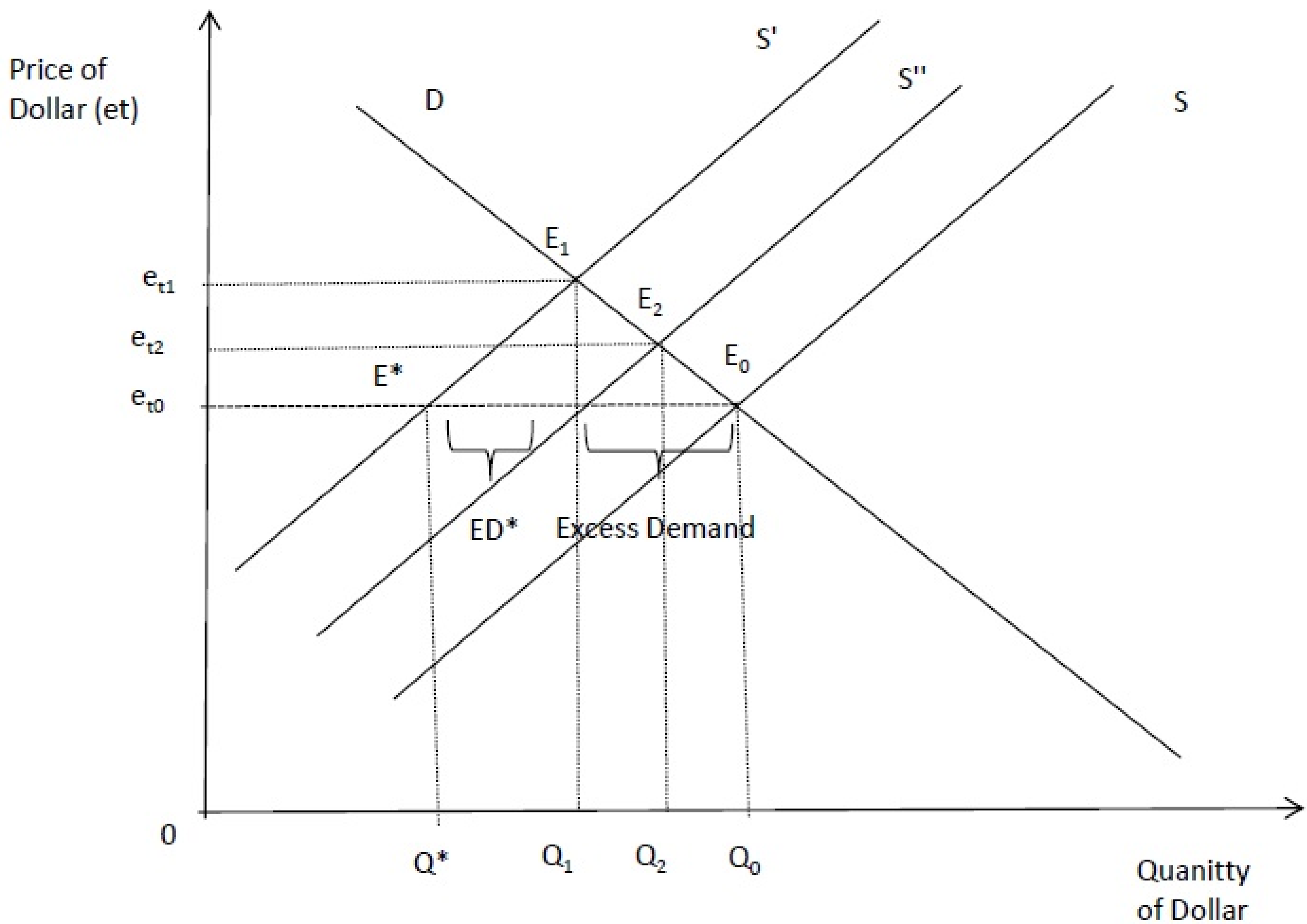


Figure 1.2: Reducing Excess Demand

index. Their index has three parts. The first one is exchange rate change. International reserve is second index. The last part is interest rate differential. Each part has different wight. The weight is inverse of its variance. But precision weighting is scope out of these dissertation.

1.2 Literature Review

GR (1977) described EMP by using the monetary approach to balance of payment. They used the money demand function, simple one price law for a small country, and money supply. Their argument is that money demand should be equal to money supply. Moreover, money supply has two components. The first component is the domestic credit expansion. Other, money expansion is caused by the change of the international reserves. Also, price is determined by one price law. They estimated their model by using OLS. They defined EMP as percentage change of exchange rate and reserve change as proportional to previous year money base. If the Bank of Canada increases the money supply ten percent, then exchange rate should depreciate 9.5 percent or lose international reserve the same amount or some combination of them.

Conolly and Silveira (1979) estimate EMP by using postwar data for Brazil. One price rule is used to find the effect of foreign price, too. It was concluded that data in Brazil is fairly well to explain the EMP especially after 1961. Up to 1961 a poor performance is estimated for Brazil. Modeste (1981) studied theConolly and Silveira's model for Argentina. Results are inferior. Coefficients for output and foreign price are not statistically significant. The sign of the coefficient of foreign price is opposite to the theory.

Kim (1985) estimated Conolly and Silveira's model for Korea, too. Purchasing power parity (PPP) is imposed. A negative relation between the change of the EMP and the rate of domestic credit expansion is found. It does not depend on its component and can be absorbed by using intervention policy. Burdekin and Burkett (1990) evaluated the performance of the GR economy for Canada. The paper extended the GR model specification to yield for unrestricted dynamics. The conclusion is that the EMP can be supported by the negative effect of the domestic credit growth. The tradeoff between the exchange rate and the international reserve movements can be revealed for the sequence of fixed and floating exchange rate regimes in Canada from 1963:1-1988:1. Burkett and Richards (1993) studied the index for Paraguay. The model indicated that external dependency conditions are captured by the EMP. The current accounts have negative effect on it. Furthermore, regional dependency can be observed by the regional EMP.

Weymark (1995) developed the general theoretical background for the EMP. [1] The index shows the attacks to the Canadian Dollar become more severe between 1981 and 1984. Spolander (1999) estimate the EMP for Finland. The result shows that intervention affects the reducing of EMP nearly 100%. They conclude that it is not easy to estimate the degree of the intervention. When an EMP or intervention policy is calculated, sterilized intervention in the top industrial countries should be considered. Also, including monetary reaction function makes important change to the EMP and intervention policy. Recently, the Bank of Finland did not intervene into the exchange rate market, in other words, exchange rate market became able to more freely floating. Reducing the intervention activities causes decreasing of the EMP. Makka appreciation can be observed instead of depreciation during later periods of estimation. Tanner (2002) estimates the EMP for several developing countries by using VAR. It is assumed that PPP holds. The EMP captured the severity of economic crises. In this estimation, interest rate differential and domestic credit expansion stand for monetary policy. The EMP is affected by monetary policy shock. The result is that to reduce the EMP, central banks should follow tighter monetary policy. However, results depend on ordering both the interest rate differential and the EMP. Moreover, sterilized intervention has a positive effect of EMP on domestic credit expansion.

Iwata and Tanner (2007) estimated the EMP for several emerging markets. The change of domestic credit expansion explained 7% of total variance in Brazil. For The Mexican peso, the period was divided by two sub periods. Pre crisis domestic credit expansion explained 10% of

[1] She estimates the structural coefficient by using the money demand function and the purchasing power parity equation. However, output level is important role to determination of exchange rate. Moreover, interest rate also may change according to a change in world interest rate. Excluding such important variables the estimated coefficient can be biased. Also, estimation will be biased due to the endogeneity problem. Furthermore agents' expectations have substantial impact on level of macroeconomic variables such as interest rate, inflation, output level, and of course exchange rate.

variance, however after the crisis it explained 14% of total variance. In the case of the Turkey had two sub periods, too. Domestic credit expansion explained 10% of variance in the early periods, on the other hand it explained 14% of total variance in the later periods. Staverek (2007) investigated the EMP index for four EU countries during the period 1993-2005 with quarterly data. Spolander model was used. The EMP magnitude is almost similar for three countries: Czech Republic, Hungary, and Slovakia; however, the magnitude of the EMP for Poland is different. It is found that EMP was lower and less volatile during the floating exchange rate arrangement. Moreover, entering the ERM II period leads to increase the EMP index, which is surprising.

Klassen and Jager (2011) improved the EMP index. The new index was constructed by using an exchange rate model. EMP index should not include first difference of interest rate but it should have level of interest rate. The model still has a combination of the relative exchange rate, the official reserve interventions, and the interest rate level scaled by exchange rate market turnover. According to their results new EMP index for EMS crises is improved for France, Italy and the United Kingdom between 1992 and 1993. Also, the result for Asian crisis in 1997-1998 confirms for Hong Kong, Korea and Thailand.

The second type of EMP index is model-independent. Eichengreen, Rose, and Wyplosz, (1996) argue that macroeconomic variables has less power to empirically explain to the exchange rate. They developed a model independent index that it can be used to identify economic crises in an economy. The index was contracted by change of exchange rate, change of international reserved differential with two countries and change of interest rate differential with two countries. Each component of the index was weighted by inverse of its variance.They use EMP to determine economic crises in a country. Since Germany has a strong economy they take the difference of interest rate for a European country from Germany.

Sachs, Tornell and Velasco (1996) used the same formulation on ERW(1996), but they discuss the weight of each component. They divide EMP index of ERW by total variance. Kaminsky, Lizondo and Reinhart (1998, 1999) changed the weight of the EMP. Since the index is multiplied with variance of exchange rate, the weight of the exchange rate is one. They conclude that international reserve change is a much better signal to predict crises.

Pomtines and Siregar (2008) discussed the bias of the EMP index when a country has high inflation overtime. They constructed the index by using real exchange rate. Their results depend on the approach, so they conclude that there is no certain approach to be signaling to identify crises. Frankel and Xie (2009) estimate the EMP index for five countries. They defined the change of EMP which is equal to summation of percentage change of local currency and change in international reserves scaled by money base.

Aizenman, Lee and Sushko (2010) derived three different EMP indexes. The paper investigates the importance of financial and trade factors for EMP. Emerging markets' openness is fast which causes significant debt reduction during the recent financial crises. This causes collapsing of international trade. Financial factors are more important than trade factors. The closeness of the US is another important factor to predict financial crises. EMP (Standardized) performs well.

The aim of dissertation is the estimation of the coefficients in order to calculates weights for the exchange rate market pressure index for Canadian economy. I try to fill some shortage of the literature for estimation of the coefficients for the weights based on economic models. First of all the exchange rate equation represents some combination of PPP and interest rate rule, and the fundamental of an economy. Next, the structural model is estimated by full information maximum likelihood (FIML). SVAR approach allows to estimate many structural parameters easily. Moreover this approach allow us both estimating contemporaneous-structural parameters and exposing of the agents' expectation on the structural parameters. P-order lagged values figure out the effects of rational expectation by following Keating(1990) with putting cross-equation restrictions in the SVAR. Therefore, another important contribution is agents' expectation with the structural model. Finally, log-linear assumption is dropped down when the elasticity of international reserve with respect to the exchange rate is estimated by agnostic identification.

The structure of the this dissertation follows as the SVAR model. This dissertation will be finished by a conclusion.

Chapter 2

SVAR Analysis

In this chapter, I estimate coefficients to calculate elasticity by using Structural Vector Autoregressive model with rational expectations. Rational expectational variables make it difficult to estimate. However, agents' behavior is important. If it is not considered then our index may show bias.

The dynamics of a small economy is set up by structural equations, in the model. Price level has rational expectation in the dynamic IS curve and dynamic Philips curve equations. One way of solving rational expectation is plugging all equations into the money demand function equation, then it should be solved for expectation variable. The solution for each expectational variable should plug into first two equations. The second way is by following Keating(1990), taking expectation at time t and t-1, then subtracting each other gives another solution by using law of iterated expectation. The second approach is used because it is not sure that the solution from the first way is the correct representation of rational expectation. However, the second model uses information from data by estimating closed form of SVAR.

Next, dynamics of a small economy is set up. The economy is determined by six equations. The first three equations are the dynamics of the system. The following three equations show monetary policy rules. The assumption is that Bank of Canada set these three equations in order to conduct monetary policy.

2.1 Framework

In the first part of this section, we will discuss the structural vector autoregressive (SVAR) with rational expectation . Then, the empirical model will be introduced. After that, EMP indexes (old version and adding interest rate differentials) will be derived. Finally, elasticities for old and new indexes will be compared.

2.1.1 Theoretical Background

VAR analysis was a popular time series among macroeconomics because of its advantages. Many results especially can be deduced from impulse response analysis after Sims(1980). However, the relation between economic structure and VAR was disconnected. Many studies criticize this point. SVAR estimation overwhelms this problem. The contemporaneous matrix (A_0) makes connection between VAR and economic structure. Since SVAR uses variance covariance matrix from reduced form estimation, the method captures information from VAR.

However, rational expectation makes it difficult to estimate. Estimated coefficients are included both contemporaneous coefficients' matrix and expectational variables' matrix. i.e A^*. Therefore mapping is different from usual SVAR model.

Assume that p order SVAR model represents equation 2.1. A_0 matrix stands for contemporaneous coefficients' matrix. $A_1, \cdots, A_p$ are the lagged variables parameters. Also, closed form is equation 2.2. $B_1, \ldots, B_p$ are lagged variables coefficients' matrices. SVAR model mapping is from $(A_0, A_1, \cdots, A_p, \Sigma_\varepsilon)$ to $(B_1, \cdots, B_p, \Sigma_u)$. Since variance covariance matrix from VAR has n(n-1) free parameters, we need to impose n*(n -1) restriction on contemporaneous matrix.

$$A_0 Y_t = A^* E_t[Y_{t+1}] + A_1 Y_{t-1} + \cdots + A_p Y_{t-p} + + \varepsilon_t \tag{2.1}$$

$$Y_t = B_1 Y_{t-1} + B_2 Y_{t-2} + \cdots + B_p Y_{t-p} + u_t \tag{2.2}$$

where $\varepsilon_t \sim N(0, \Sigma_\varepsilon)$ and $e_t \sim N(0, \Sigma_u)$ [1]

[1] Σ_ε is diagonal and each diagonal should be estimated. Σ_u is variance covariance matrix for the reduced model.

Macroeconomics models have lagged effects in order to eliminate previous periods' effects. This macroeconomic analysis includes all variables lagged as is shown equation 2.1 and 2.1. The equation can be written as:

$$A_0 Y_t = A^* E_t[Y_{t+1}] + \tilde{\varepsilon}_t \tag{2.3}$$

where $\tilde{\varepsilon}_t = \sum_{i=1}^{p} A_{k,t-i} Y_{t-i} + \varepsilon_t^l$

$k = 1, \cdots, 8$ and $l = \{y, \pi, i, \Delta d_t, \Delta r_t, \Delta e_t, \pi^*, i^*\}$

On the other hand, when rational expectation is imposed; the mapping from $(A_0 - A \times B1, A_1 + A \times B1, \cdots, A_p + A \times B_p), \Sigma_\varepsilon)$ to $(B_1, \cdots, B_p, \Sigma_u)^2$. Since $B_1, \ldots, B_p$ is known, we need to put restriction on both A_0 and A^*. Since the number of reduced form does not change, it should have the exact same number of free parameters. Since both A_0 and A^* is nxn matrix, there is $2 \times (n \times n)$ coefficients to be estimated. Thus, we need to impose $n \times (3n-1)/2$ restrictions on A_0 and A^* matrices. In the estimation, to get just indentified model, there should be $n \times (n-1)/2$ free parameters in $(A_0 - A^* \times B_1)$ matrix. Moreover, the connection two variance covariance matrices as: $\Sigma_u = (A_0 - A^* \times B_1)^{-1} \Sigma_\varepsilon ((A_0 - A^* \times B_1)^{-1})$

2.1.2 Emprical Model and EMP

Even though numerous papers focus on how to calculate EMP index, they may have a bias outcomes because those papers do not consider some variables that affect estimation of coefficients for international reserves and interest rate. First, the effect of domestic credit expansion is ignored. They also passed up that their models do not have a capability to capture the contemporaneous relation between interest rate, domestic credit expansion, international reserves and exchange rate that previous studies lack. Third, the first two equations have price expectation which creates the dynamics model. This expectaional variables let put cross equation restriction in the SVAR, which captures agents' expectations. The last contribution is that new index is derived by adding interest

[2] This type of restriction is called cross equation restriction.

rate differential with a weight [3].

The structural model is founded by equations 2.4 to 2.9.[4] Dynamic IS equation (2.4) gives the relation between output gap (y_t), real interest rate($i_t - E_t[P_{t+1}]$), and real exchange rate ($\pi_t - \Delta e_t - \pi_t^*$). Dynamic Philips equation(2.5) represents inflation (π_t) that is affected by output gap, nominal interest rate, real exchange rate, and expectation of inflation ($E_t[P_{t+1}]$). Money demand equation (2.6) is the main part of the system. Money demand is derived by inherited money demand(m_{t-1}), output gap, inflation, exchange rate, domestic interest rate and foreign interest rate (i_t^*). It is assumed that money authorities follow the last three equations to conduct the macro economy. The money authority sets domestic credit expansion (Δd_t) (2.7) by observing output gap, inflation and domestic interest rate. A change in international reserve (Δr_t) depends on all variables, including foreign inflation (π_t^*) and interest rate. The last one is exchange rate equation[5].

$$y_t = \phi_{10} + \phi_{13}(i_t - E_t[\pi_{t+1}]) + \phi_{16}[\pi_t - \Delta e_t - \pi_t^*] + \varepsilon_t^y \tag{2.4}$$

$$\pi_t = \phi_{20} + \phi_{21} y_t + \phi_{23} i_t + \phi_{26}[\pi_t - \Delta e_t - \pi_t^*] + \phi_{29} E_t[\pi_{t+1}] + \varepsilon_t^p \tag{2.5}$$

$$m_t^d = \phi_{30} + \phi_{31} y_t + \phi_{32}\pi_t + \phi_{33} i_t + m_{t-1}^d + \phi_{36}\Delta e_t + \phi_{38} i_t^* + \varepsilon_t^m \tag{2.6}$$

$$\Delta d_t = \phi_{40} + \phi_{41} y_t + \phi_{42}\pi_t + \phi_{43} i_t + \varepsilon_t^{\Delta d} \tag{2.7}$$

$$\Delta r_t = \phi_{50} + \phi_{51} y_t + \phi_{52}\pi_t + \phi_{53} i_t + \phi_{54}\Delta d_t + \phi_{56}\Delta e_t + \phi_{57}\pi_t^* + \phi_{58} i_t^* + \varepsilon_t^{\Delta r} \tag{2.8}$$

$$\Delta e_t = \phi_{61} y_t + \phi_{62}\pi_t + \phi_{63} i_t + \phi_{67}\pi_t^* + \phi_{68} i_t^* + \varepsilon_t^{\Delta e} \tag{2.9}$$

[3] Eichengreen, B., Rose, A. K., Wyplosz, C., Dumas, B., & Weber, A. (1995) discuss the effect of interest rate on the forex market exhaustively.

[4] Y is variables of the column vector, $Y = [y\ \pi\ i\ \Delta d\ \Delta r\ \Delta e\ \pi^*\ i^*]'$. ϕ_{kl} represents contemporaneous coefficients. Lower "K" stands for the equation number, and "l" refers to number of variables in ordering Y. For instance, ϕ_{32} is domestic inflation (second variable in the Y vector) coefficient in the third equation (money demand equation).

[5] Many studies demonstrate that purchasing power parity does not hold in the short term, while it holds in the long term. For PPP, Taylor(2006) and Rogoff(1996) provide excellent survey. Moreover, numerous papers state that interest parity rule helds only in the short term. "By the conception of the theory, uncovered interest rate parity rule must be hold in the short term" (Bekaert at all 2007). Also, a recent survey can be found in this study. If PPP is assumed then coefficients of domestic inflation and foreign inflation should be one. Also, in the first two equations, real interest rate coefficients must be one. If UIP holds, then coefficients of domestic and foreign interest rate must be one in the last question. During the estimation, it is assumed that neither PPP nor UIP holds.

2.2 Non- Recursive Structural Vector Autoregression with Rational Expectation

Exchange rate does not fit almost all econometric model, hat means researchers should be careful, when then they decide which econometric approach is employed. Some studies state that macroeconomic variables have less power to statistically explain exchange rate. Therefore, it is important when deciding the method. As it is mentioned previously, the first estimation is the non-recursive SVAR.

The SVAR has a lot of advantages. First of all, current values of variables are able to capture contemporaneous relation between each other. Hence, it is easy to reveal the elasticity of the change in international reserve and the semi elasticity of interest rate with respect to the change in exchange rate. Estimation is done by full information maximum likelihood method. Finally cross-equation restriction can capture the effects of rational expectation. Therefore, the SVAR approach is employed.

There are many ways to identify structural VAR. The recursive identification includes a more stronger assumption then non-recursive identification. Using non-recursive identification allows the capture of the contemporaneous effects of exchange rate, international reserve and domestic credit expansion. This is the second contribution of this paper. System of equation is different from recursive order. The recursive order does not capture the cross contemporaneous effects because it is assumed that contemporaneous matrix is upper triangular.

The third contribution is that rational expectations are considered. Weymark and Siklos (2006) used the expectation in their models and estimated by vector error-correction model. However, to get statistically plausible results, many parsimonious equations were used that take that model out from the real economy. However, the model in this study does not include any parsimonious equations.

The last contribution is the exchange rate equation. The exchange rate equation is set up according to the following discussion. Many studies demonstrate that purchasing power parity does not hold in the short term, while it holds in the long term[6]. Moreover, numerous papers state that interest parity rule holds only in the short term[7]. Consequently, except the first term (output), other variables are the combination of PPP and UIP that means some periods PPP holds, while other periods UIP holds.

Next part, the index will be constructed according to the dynamic system. This index has two components as many studies have generally constructed. Moreover, another EMP index will be defined. Interest rate differential is added in the EMP with a different weight, which is called the semi elasticity of interest rate with respect to change of exchange rate.

2.3 Derivation of the EMP Index

Since the dynamic model is set up, the weight can easily be calculated for the change of international reserve. To get this weight, it is necessary to derive five equations into the interest rate equation. Then the policy rule equation can be easily found . If the policy rule equation is solved for the change of exchange rate, then the elasticity of international reserve with respect to exchange rate is manifested clearly.

The first part of the index is exchange rate appreciation, and the other part is the change in international reserve. Of course like Weymark(1995,1998), the change of international reserve has the weight.

To get EMP's inter-temporal coefficient, we plug equation 2.4 into equations 2.5 to 2.8. After that, we plug the inflation equation, the output gap equation, domestic credit expansion equation into the money demand equation. Finally, the mass equation is solved for the change of exchange rate. The following equation should have:

$$\Delta e_t = \mu_0 + \mu_3 i_t + \mu_5 \Delta r_t - \mu_7 \pi_t^* + \mu_9 E_t[P_{t+1|t}] + \varepsilon* \tag{2.10}$$

[6] For PPP, Taylor(2006) and Rogoff(1996) provides excellent survey. A Century of Purchasing-Power Parity

[7] *By the conception of the theory, uncovered interest rate parity rule must be hold in the short term* Bekaert at al(2007). Also, survey can be found this study

where $\mu_5 = -\frac{(1-\phi_{26}-(\phi_{21}\phi_{16})}{[\phi_{16}(\phi_{31}-\phi_{41})-(\phi_{21}\phi_{16}+\phi_{26})(\phi_{42}-\phi_{32})-\phi_{36}(1-\phi_{26}-\phi_{21}\phi_{16})]}$

We can rewrite equation 12 as

$$\Delta e_t = \mu_5 \Delta r_t + X + \varepsilon* \tag{2.11}$$

where

$X = [\mu_0 + \mu_3 i_t + \mu_9 E_t[P_{t+1|t}] - \mu_7 \pi_t^*]$

Hence, we can define EMP as

$$EMP_{1t} = \Delta e_t + \mu_5 \Delta r_t \tag{2.12}$$

The EMP_{1t} is the exact same as Weymark's definition. The difference is that the elasticity is more sensitive, and captures information from data.

Furthermore, after ERW's study, many studies add interest rate when calculating the EMP index with another weight due to the fact that money authority has used interest rate as a tolls to absorb some of excess demand in the forex. Therefore, the second EMP index can be defined as:

$$EMP_{2t} = \Delta e_t + \mu_5 \Delta r_t + \mu_3 i_t \tag{2.13}$$

$\mu_3 = \frac{\{(1-\phi_{26}-\phi_{21}\phi_{16}+\phi_{21}\phi_{13}+\phi_{23})[\phi_{13}(\phi 31-\phi_{41})+(\phi_{32}-\phi_{42})]+(1-\phi_{26}-\phi_{21}\phi_{16})(\phi_{33}-\phi_{43})\}}{[\phi_{16}(\phi_{31}-\phi_{41})-(\phi_{21}\phi_{16}+\phi_{26})(\phi_{42}-\phi_{32})-\phi_{36}(1-\phi_{26}-\phi_{21}\phi_{16})]}$

The new EMP now includes the interest rate in level with another weight. The first weight is the exactly same with the first index, however the second weight is the semi elasticity of the interest rate with respect to the exchange rate.

2.4 Data

In this analysis, I use the quarterly data from third quarter of 1981 to last quarter of 2011. Teh first variable is output gap, y, which is publicly announced by Bank of Canada. Inflation, π_t is the second variable. Inflation is calculated by percent change over the corresponding period of the previous year. This data is drawn from IFS. The third variables is the interest rate. The interest rate is treasury bills (3 month) which is available in IFS, too. The following variable is domestic credit expansion, d_t. Domestic credit expansion is calculated by author. The definition of the Δd_t is $(h_t D_t - h_{t-1} D_{t-1})/M_{t-1}$ where h_t is the money multiplier. The money multiplier is defined as $h_t = M_t/MB_t$. D_t is the domestic credit expansion at time t. M stands for money supply which is M1B. Also, MB is monetary base. These two variables are drawn from Statistics Canada's key socioeconomic database (CANSIM).

The fifth variable is international reserves, r_t. The data is available from the IFS website. However, it is required to make following calculation in order to use in this analysis. Δr_t is $(h_t R_t - h_{t-1} R_{t-1})/M_{t-1}$. The next variable is exchange rate, e_t. The exchange rate is the foreign currency price in domestic value. As a definition, if the exchange rate increases, then the Canadian dollar depreciates relative to foreign currency (the U.S dollar). Δe_t is the appreciation or depreciation rate.

Finally, the last two variables are inflation, π_t^* and interest rate, i_t^*. The whole sale index was used for the calculation of the foreign inflation. The interest rate is treasury bills (3 month) for the U.S. These variables are drawn from IFS, too.

2.5 Emprical results

The crucial issue is initial values of the SVAR coefficients. To estimate the SVAR, we need to determine the initial values of the coefficients. Since we use the nonlinear estimation, picking up initial values are important. The estimation of the likelihood by using the Gaussian method is like climbing a hill. If the starting point is right, then all the results are good.

Estimated coefficients are given in Table 2.2 According to the estimation,majority of the coefficients are significant. Also, almost all coefficients' signs are correct in terms of theoretical expectations. The estimation also reveals price puzzle in the short term in dynamic Philips curve.

Table 2.1: Estimated Coefficients

Coefficients	Estimated Value	T-value	Coefficients	Estimated Value	T-value
ϕ_{13}	-0.0458	0.0078	ϕ_{16}	0.0866	0.0275
ϕ_{21}	-0.0720	0.0059	ϕ_{23}	0.1155	0.0006
ϕ_{26}	-0.0009	0.0010	ϕ_{29}	0.2919	0.0004
ϕ_{31}	0.0099	0.0113	ϕ_{32}	-0.0012	0.0018
ϕ_{33}	0.0015	0.0009	ϕ_{36}	8.9694	5.9187
ϕ_{38}	1.7670	0.3784	ϕ_{41}	4.7188	1.5189
ϕ_{42}	1.1661	0.2495	ϕ_{43}	0.2615	0.0542
ϕ_{51}	-0.0128	0.0139	ϕ_{52}	-0.0106	0.0033
ϕ_{53}	0.0019	0.0018	ϕ_{54}	4.9008	1.4764
ϕ_{56}	-32.4353	9.8239	ϕ_{57}	0.0108	0.0025
ϕ_{58}	-2.3074	0.8530	ϕ_{61}	0.0016	0.0007
ϕ_{62}	0.0001	0.0001	ϕ_{63}	-0.0003	0.0001
ϕ_{67}	-0.0002	0.0001	ϕ_{68}	0.0213	0.0197

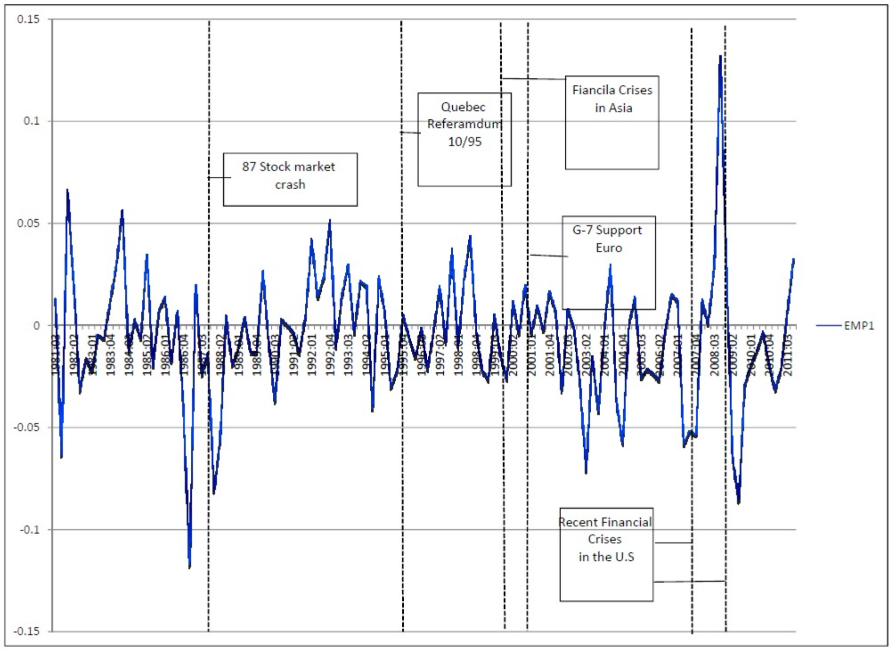
To select initial values is important because the estimation is non-linear. different initial values causes the explosion of the coefficients. This explosion may be from initial values because some initial values causes chaos in the dynamical system.

Now that we estimated the coefficients, we can calculate the elasticity of the change of the exchange rate with respect to the change of the international reserve. $\eta = -0.1068$, which is really low according to benchmark case. Furthermore, the elasticity of the interest rate with respect to the exchange rate is calculated as 0.1413.

The calculated value of the EMP index is given in Table 2.2. In some periods of table 2.2, the index is negative and other periods are positive. The maximum value of the index was .131 in last quarter of 2008. The minimum value of the index was -.117 in early 1987. The mean of the index was -.005. Seventy quarters are calculated is negative which means the pressure forced to the Canadian dollar to appreciate. Maximum appreciation pressures to the Canadian Dollar are the first quarter of 1987, the third quarter of 2009, the first quarter of 1988, the second quarter of 1993 and 2009. There are negative pressure on the Canadian Dollar during the 2000s but, all pressure is flimsy.

Furthermore, fifty two quarters are estimated positive and large. In other words, in these periods, there are speculative attacks to the Canadian Dollars. Especially, from 1986 to 1988 where

Figure 2.1: EMP_1

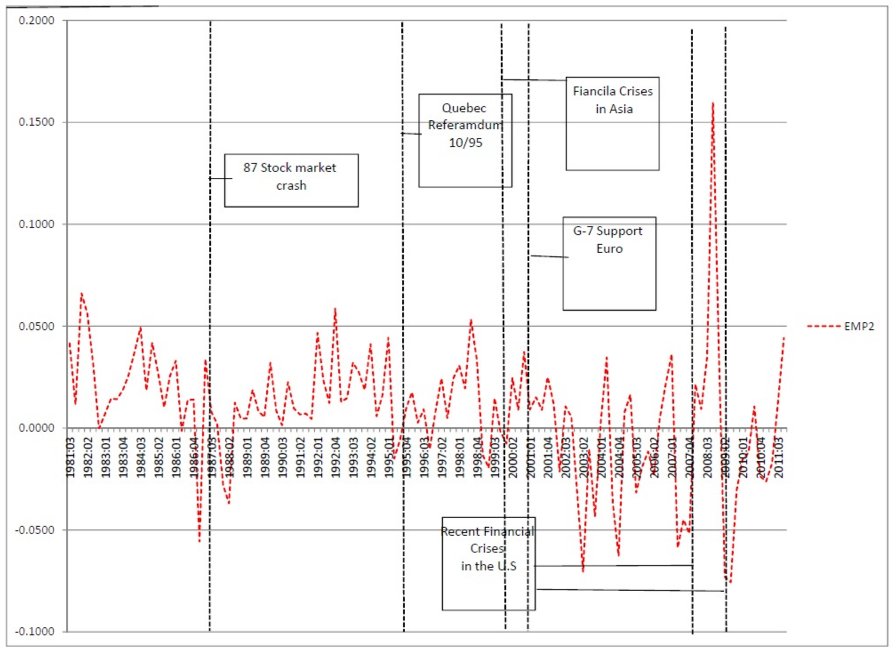


there are more high speculative attacks on Canadian Dollars. After 2000, there are some quarters that shows speculative attacks but there are relatively less than late 1980s.

The Figure 2.1 shows us the EMP index over time which is weighted by the estimated value of μ_5. Some of the important points are signed by vertical lines. The first vertical line shows the stock market crashed in late 1987. Just before the stock market crash the index drop dramatically from 0.005 to -0.1.

In late 1995, the Quebec referendum affected the EMP index, too and it dropped sharply two times. Furthermore, the EMP index captured the Asian financial crises during 1998 and 1999. Moreover, we can clearly see a peak and a huge decrease in the index just before the recent financial recession in the U.S. Since the Canadian economy is tied too close to the U.S. economy, what happens in the U.S. economy directly affects the Canadian Economy. So,the EMP index shows significant changes and high fluctuation recent periods relative to the other periods. On the other hand, the index does not determine the Bank of Canadian's intervention to support the Euro. In September 2000, the Bank of Canada intervened in the exchange rate market with G-7 Countries.

Figure 2.2: EMP_2



The new index for the EMP is created by adding interest rate differential with a weight (Figure 2.2). The new weight for the interest rate like the weight for change of international reserve is derived from structural coefficients. Now, the new index has less range but it performs much better than than traditional index. The index was calculated for only five quarters positive, which shows speculative attacks on Canadian Dollars. Also, the interest rate absorbs some pressure due to the fact that the old index was large positive in six more times quarters. Interestingly, the largest positive value was calculated in the forth quarter of 2008; however, the old index failed to capture this. Furthermore, the index was able to show speculative attacks late 1986 and early 1987. The index was negative in the forty three quarters, which show that there was a pressure to appreciate Canadian Dollar. Again, it is clearly observed that these negative pressures were small because of adding interest rate. The largest values were observed in the first quarter of 1982, the last quarter of 2004, the second quarter of 2003, and the second quarter of 2009.

Furthermore, there are two peaks and drops dramatically and rise sharply again before the stock market crash in 1987. The index makes three peaks again in late 1995. The index shows significant fluctuation just before recent financial crises in 2007, and second recession in late 2009. Moreover, the index performs fairly well in the Asian crisis. There exits two peaks just before Asian crises.

Table 2.2: Exchange Market Pressure Index (EMP_1)

Date	EMP	Date	EMP	Date	EMP
1981:03	0.0130	1991:04	0.0048	2002:01	0.0072
1981:04	-0.0634	1992:01	0.0427	2002:02	-0.0320
1982:01	0.0665	1992:02	0.0136	2002:03	0.0082
1982:02	0.0209	1992:03	0.0238	2002:04	-0.0009
1982:03	-0.0320	1992:04	0.0516	2003:01	-0.0281
1982:04	-0.0157	1993:01	-0.0106	2003:02	-0.0709
1983:01	-0.0226	1993:02	0.0153	2003:03	-0.0148
1983:02	-0.0046	1993:03	0.0301	2003:04	-0.0422
1983:03	-0.0062	1993:04	-0.0036	2004:01	-0.0015
1983:04	0.0123	1994:01	0.0218	2004:02	0.0297
1984:01	0.0300	1994:02	0.0197	2004:03	-0.0378
1984:02	0.0564	1994:03	-0.0409	2004:04	-0.0580
1984:03	-0.0128	1994:04	0.0239	2005:01	0.0007
1984:04	0.0033	1995:01	0.0066	2005:02	0.0142
1985:01	-0.0060	1995:02	-0.0303	2005:03	-0.0258
1985:02	0.0348	1995:03	-0.0224	2005:04	-0.0212
1985:03	-0.0201	1995:04	0.0053	2006:01	-0.0236
1985:04	0.0078	1996:01	-0.0055	2006:02	-0.0270
1986:01	0.0141	1996:02	-0.0155	2006:03	-0.0019
1986:02	-0.0175	1996:03	-0.0010	2006:04	0.0156
1986:03	0.0073	1996:04	-0.0217	2007:01	0.0122
1986:04	-0.0403	1997:01	-0.0025	2007:02	-0.0585
1987:01	-0.1173	1997:02	0.0194	2007:03	-0.0515
1987:02	0.0199	1997:03	-0.0083	2007:04	-0.0536
1987:03	-0.0242	1997:04	0.0376	2008:01	0.0130
1987:04	-0.0134	1998:01	-0.0111	2008:02	0.0007
1988:01	-0.0811	1998:02	0.0233	2008:03	0.0291
1988:02	-0.0559	1998:03	0.0438	2008:04	0.1318
1988:03	0.0048	1998:04	-0.0029	2009:01	0.0293
1988:04	-0.0196	1999:01	-0.0222	2009:02	-0.0640
1989:01	-0.0110	1999:02	-0.0266	2009:03	-0.0859
1989:02	0.0045	1999:03	0.0054	2009:04	-0.0294
1989:03	-0.0130	1999:04	-0.0149	2010:01	-0.0192
1989:04	-0.0131	2000:01	-0.0263	2010:02	-0.0124
1990:01	0.0269	2000:02	0.0117	2010:03	-0.0028
1990:02	-0.0087	2000:03	-0.0038	2010:04	-0.0191
1990:03	-0.0373	2000:04	0.0201	2011:01	-0.0318
1990:04	0.0032	2001:01	-0.0039	2011:02	-0.0204
1991:01	0.0004	2001:02	0.0098	2011:03	0.0077
1991:02	-0.0028	2001:03	-0.0022	2011:04	0.0327
1991:03	-0.0136	2001:04	0.0168		

Table 2.3: Exchange Market Pressure Index (EMP_2)

Date	EMP	Date	EMP	Date	EMP
1981:03	0.0415	1991:04	0.0045	2002:01	0.0121
1981:04	0.0115	1992:01	0.0467	2002:02	-0.0214
1982:01	0.0661	1992:02	0.0232	2002:03	0.0106
1982:02	0.0562	1992:03	0.0122	2002:04	0.0055
1982:03	0.0309	1992:04	0.0586	2003:01	-0.0320
1982:04	-0.0002	1993:01	0.0127	2003:02	-0.0706
1983:01	0.0070	1993:02	0.0147	2003:03	-0.0104
1983:02	0.0144	1993:03	0.0320	2003:04	-0.0433
1983:03	0.0142	1993:04	0.0273	2004:01	0.0033
1983:04	0.0185	1994:01	0.0187	2004:02	0.0346
1984:01	0.0259	1994:02	0.0412	2004:03	-0.0367
1984:02	0.0374	1994:03	0.0057	2004:04	-0.0628
1984:03	0.0493	1994:04	0.0162	2005:01	0.0076
1984:04	0.0184	1995:01	0.0443	2005:02	0.0163
1985:01	0.0418	1995:02	-0.0150	2005:03	-0.0317
1985:02	0.0265	1995:03	-0.0055	2005:04	-0.0190
1985:03	0.0101	1995:04	0.0096	2006:01	-0.0115
1985:04	0.0255	1996:01	0.0176	2006:02	-0.0231
1986:01	0.0330	1996:02	0.0026	2006:03	0.0050
1986:02	-0.0014	1996:03	0.0092	2006:04	0.0215
1986:03	0.0137	1996:04	-0.0105	2007:01	0.0362
1986:04	0.0139	1997:01	0.0085	2007:02	-0.0588
1987:01	-0.0557	1997:02	0.0243	2007:03	-0.0450
1987:02	0.0338	1997:03	0.0049	2007:04	-0.0518
1987:03	0.0079	1997:04	0.0243	2008:01	0.0216
1987:04	0.0019	1998:01	0.0306	2008:02	0.0092
1988:01	-0.0279	1998:02	0.0194	2008:03	0.0348
1988:02	-0.0370	1998:03	0.0533	2008:04	0.1595
1988:03	0.0124	1998:04	0.0332	2009:01	0.0379
1988:04	0.0046	1999:01	-0.0134	2009:02	-0.0731
1989:01	0.0047	1999:02	-0.0196	2009:03	-0.0757
1989:02	0.0187	1999:03	0.0147	2009:04	-0.0308
1989:03	0.0081	1999:04	-0.0019	2010:01	-0.0156
1989:04	0.0054	2000:01	-0.0077	2010:02	-0.0121
1990:01	0.0320	2000:02	0.0245	2010:03	0.0106
1990:02	0.0085	2000:03	0.0089	2010:04	-0.0238
1990:03	0.0013	2000:04	0.0373	2011:01	-0.0262
1990:04	0.0224	2001:01	0.0090	2011:02	-0.0176
1991:01	0.0095	2001:02	0.0151	2011:03	0.0126
1991:02	0.0066	2001:03	0.0089	2011:04	0.0442
1991:03	0.0071	2001:04	0.0250		

Chapter 3

Conclusion

Exchange rate is one of most important variables for the economies because it is so volatile, and unexpected changes is happen frequently. Since exchange rate predictability is very difficult , money authorities do not have a chance to guess what exchange rate should be ,therefore they don't how to react or take a position. Since exchange rate can not be correctly predicted, it makes to hard long term plan for firms and governments. Also, unexpected changes in exchange rate may lead to cash strapped in business, which causes many firms and companies to bust. Therefore, money authorities need some kinds of indexes that observe changes in certain macroeconomic variables.

In developed countries, the exchange rate regime had changed from managed float to freely float. After this alteration, developing countries makes similar changes. However, several currency crises have happened after this change in regime. Several studies focus on how to predict currency crises applying different indexes. Furthermore, after the free float exchange rate regime, many researchers have tried to predict the exchange rate.

One of the most important indexes is the EMP index amongst international and macro economists. The EMP index can capture successful and unsuccessful speculative attacks, so it has been highly popular. There exists two type of EMP indexes. GR introduced the model dependent EMP index. They used the monetary approach to balance of payment. They defined it as the summation of international reserve and exchange rate appreciation. Weymark developed the general model, and she used PPP and UIP equations in order to get the weight for international reserve. Now, the weight is elasticity of the change in exchange rate with respect to international reserves.

On the other hand, ERW developed a model independent index, and they set a threshold in order to identify economic and politic crises. They point out that macroeconomic variables that have less power over exchange rate, so the model independent index can be used. However, this approach is not convenient because the threshold is arbitrary. Also, the index does not have any tie with the economic model. Consequently, the model dependent index is employed in this dissertation.

In this dissertation, the SVAR model is used. The contemporaneous matrix is set up by using six equations that explained in the model section of the chapter. This matrix helps to estimate the coefficients simultaneously. Also, this matrix captures the relation between interest rate, domestic credit expansion, international reserves and exchange rate. Furthermore, the SVAR model reveals the agents' expectations.

I use the SVAR approach to estimate the international reserve's contemporaneous effects on the change of exchange rate. This paper is important because it opens ways to estimate full information on both exchange rate estimation and the EMP index. Also, central banks can easily estimate the weight for international reserve and can check whether there is a potential threat for their economy. Moreover, the construction of exchange rate equation is important since it is assumed that the exchange rate is determined by some weight with purchasing power parity, interest rate rule and the fundamental which is represented by the output gap.

The summary of our results follows as. Many coefficients did meet our expectations in terms of sign according to the economic theories. As expected like many SVAR cases, almost 60% of the coefficients are statistically significant. Furthermore, the contemporaneous coefficient matrix is overidentified which is valid according to the F test. On the one hand, we got the partial derivative of Δet with respect to Δrt. Our results seem pretty low compared to the benchmark case(Weymark,1995).

Readers can see easily how efficient the index is in Figures 2.1 and 2.2. The EMP index captures almost all important economic crises and political issues. Therefore, central banks can use this index as one of the important crises indicators in order to take some cautions or decrease the effects of potential undesirable effects of crises to economies and firms. Even if this study is just in the Canadian contex, it is easy to apply different countries whose Central banks intervene in the foreign currency market in order to prevent unexpected attacks. Sometimes, these kind of unexpected speculative attacks can impair an economic system, which may cause huge costs to the countries. Consequently, I believe that estimating the EMP index provides an efficient way to guess potential currency and economic crises according to investors' expectations.

Furthermore, this study may open a path way to new research, because Agnostic identification used for the estimation for weight (which has less restriction than the SVAR approach). Also, agnostic identification may be integrated through non-recursive identification in order to achieve the global identification result in the SVAR approach.

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Appendix A

Mathematical Appendix

A.1 Appendix for Chapter 1

A.2 Construction of SVAR

The simple standard SVAR with p-order auto regressive model can be described as

$$A_0 Y_t = A_1 Y_{t-1} + \cdots + A_p Y_{t-p} + \varepsilon_t \tag{A.1}$$

where $\varepsilon_t \sim N(0, \Sigma_\varepsilon)$ and $Y_t = \begin{pmatrix} y_t & \pi_t & i_t & \Delta d_t & \Delta r_t & \Delta e_t & \pi* & i_t* \end{pmatrix}'$

The closed form of the SVAR model is

$$Y_t = B_1 Y_{t-1} + B_2 Y_{t-2} + \cdots + B_p Y_{t-p} + e_t \tag{A.2}$$

where $e_t \sim N(0, \Sigma_e)$

Under the invertibility of the A_0 matrix, the mathematical relation between structural coefficients and closed form coefficients is the following:

$B_1 = A_0^{-1} A_1$, $B_p = A_0^{-1} A_p$, $u_t = A_0^{-1} \varepsilon_t$, $\Sigma_\varepsilon = A_0^{-1} \Sigma_u A_0^{-1\prime}$, and $p = 1, ..., 24$

Equations A.1 and A.2 are the structural and closed form representation of the system. A_0 determines the contemporaneous restriction in our system. The matrix form of the estimation is in Appendix B.

In expectational form in the SVAR, it is required to add one more term into equation A.1, because now the model is included one period ahead expectational variable. If we take expectation at time t and t-1 of the equation A.3, then subtracts t from t-1, we must come to the following equations:

$$A_0 Y_t = A_1 Y_{t-1} + ... + A_p Y_{t-p} + A^* E_t Y_{t+1} + \varepsilon_t \tag{A.3}$$

$$A_0 E_{t-1} Y_t = A_1 Y_{t-1} + \cdots + A_p Y_{t-p} + A^* E_{t-1} Y_{t+1} \tag{A.4}$$

$$A_0 (Y_t - E_{t-1} Y_{t+1}) = A^* (E_t Y_{t+1} - E_{t-1} Y_{t+1}) + \varepsilon_t \tag{A.5}$$

First we should take the closed form equation one period step, and take the expectation time the and t-1 for the equation A.6. Subtract each other we should have equation A.9.

$$Y_{t+1} = B_1 Y_t + B_2 Y_{t-1} + ... + B_p Y_{t-p+1} + e_{t+1} \tag{A.6}$$

$$E_t Y_{t+1} = B_1 Y_t + B_2 Y_{t-1} + ... + B_p Y_{t-p+1} \tag{A.7}$$

$$E_{t-1} Y_{t+1} = B_1 E_{t-1} Y_t + B_2 Y_{t-1} + ... + B_p Y_{t-p+1} \tag{A.8}$$

$$(Y_{t+1} - E_{t-1} Y_{t+1}) = B_1 (Y_t - E_{t-1} Y_t) \tag{A.9}$$

Now, to solve right hang side (RHS) of equation A.9, take the expectation of time t and t-1 of closed form equation A.2 and get equations A.10 and A.11. If equation A.10 is subtracted from equation A.11, then we have equation A.12. Plugs equation A.12 into A.9, then the LHS of equation A.9 is solved. After plug equation A.9 into A.5, we must have equation A.13, so that we can estimate equation A.14 easily.

$$E_tY_t = E_tB_1Y_{t-1} + E_tB_2Y_{t-2} + \cdots + E_tB_pY_{t-p} + e_t \tag{A.10}$$

$$E_{t-1}Y_t = B_1E_{t-1}Y_{t-1} + E_{t-1}B_2Y_{t-1} + \ldots + B_pY_{t-p+1} \tag{A.11}$$

$$Y_t - E_{t-1}Y_t = e_t \tag{A.12}$$

$$A_0e_t = A^*B_1e_t + \varepsilon_t \tag{A.13}$$

$$(A_0 - A^*B_1)e_t = \varepsilon_t \tag{A.14}$$

where B_1 is the first lags coefficients' matrix of the closed form estimation.

Following matrix is shown contemporaneous restriction in estimation.

$$\begin{pmatrix} 1 & 0 & -\phi_{13} & 0 & 0 & -\phi_{16} & 0 & 0 \\ -\phi_{21} & (1-\phi_{26}) & -\phi_{23} & 0 & 0 & \phi_{26} & \phi_{26} & 0 \\ -\phi_{31} & -\phi_{32} & -\phi_{33} & 1 & 1 & -\phi_{36} & 0 & -\phi_{38} \\ -\phi_{41} & -\phi_{42} & -\phi_{43} & 1 & 0 & 0 & 0 & 0 \\ -\phi_{51} & -\phi_{52} & -\phi_{53} & -\phi_{54} & 1 & -\phi_{56} & -\phi_{57} & -\phi_{58} \\ -\phi_{61} & -\phi_{62} & -\phi_{63} & 0 & 0 & 1 & \phi_{67} & \phi_{63} \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & -\phi_{78} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} y_t \\ P_t \\ i_t \\ \Delta d_t \\ \Delta r_t \\ \Delta e_t \\ p_t^* \\ i_t^* \end{pmatrix} = A_1Y_{t-1} + A_2Y_{t-2} +$$

$$\ldots + A_pY_{t-p} + A^*E_t[Y_{t+1|t}] + u_t$$

$$A^* = \begin{pmatrix} 0 & -\phi_{13} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \phi_{29} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \phi_{59} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}, B_1 = \begin{pmatrix} b_{111} & b_{112} & b_{113} & b_{114} & b_{115} & b_{116} & b_{117} & b_{118} \\ b_{121} & b_{122} & b_{123} & b_{124} & b_{125} & b_{126} & b_{127} & b_{128} \\ b_{131} & b_{132} & b_{133} & b_{134} & b_{135} & b_{136} & b_{137} & b_{138} \\ b_{141} & b_{142} & b_{143} & b_{144} & b_{145} & b_{146} & b_{147} & b_{148} \\ b_{151} & b_{152} & b_{153} & b_{154} & b_{155} & b_{156} & b_{157} & b_{158} \\ b_{161} & b_{162} & b_{163} & b_{164} & b_{165} & b_{166} & b_{167} & b_{168} \\ b_{171} & b_{172} & b_{173} & b_{174} & b_{175} & b_{176} & b_{177} & b_{178} \\ b_{181} & b_{182} & b_{183} & b_{184} & b_{185} & b_{186} & b_{187} & b_{188} \end{pmatrix}$$

Therefore;

$$A^* \times B_1 = \begin{pmatrix} -\phi_{13}b_{121} & -\phi_{13}b_{122} & -\phi_{13}b_{123} & -\phi_{13}b_{124} & -\phi_{13}b_{125} & -\phi_{13}b_{126} & -\phi_{13}b_{127} & -\phi_{13}b_{128} \\ \phi_{29}b_{121} & \phi_{29}b_{122} & \phi_{29}b_{123} & \phi_{29}b_{124} & \phi_{29}b_{125} & \phi_{29}b_{126} & \phi_{29}b_{127} & \phi_{29}b_{128} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \phi_{59}b_{161} & \phi_{59}b_{162} & \phi_{59}b_{163} & \phi_{59}b_{164} & \phi_{59}b_{165} & \phi_{59}b_{166} & \phi_{59}b_{167} & -\phi_{59}b_{168} \\ b_{161} & b_{162} & b_{163} & b_{164} & b_{165} & b_{166} & b_{167} & b_{168} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$A - A^* \times B_1 =$$

$$\begin{pmatrix} (1+\phi_{13}b_{121}) & \phi_{13}b_{122} & (-\phi_{13}+\phi_{13}b_{123}) & \phi_{13}b_{124} & \phi_{13}b_{125} & (-\phi_{16}+\phi_{13}b_{126}) & \phi_{13}b_{127} & \phi_{13}b_{128} \\ (-\phi_{21}-\phi_{29}b_{121}) & [(1-\phi_{26})-\phi_{29}b_{122}] & (-\phi_{23}-\phi_{29}b_{123}) & -\phi_{29}b_{124} & -\phi_{29}b_{125} & (\phi_{26}-\phi_{29}b_{126}) & (\phi_{26}-\phi_{29}b_{127}) & -\phi_{29}b_{128} \\ -\phi_{31} & -\phi_{32} & -\phi_{33} & 1 & 1 & -\phi_{36} & 0 & -\phi_{38} \\ -\phi_{41} & -\phi_{42} & -\phi_{43} & 1 & 0 & 0 & 0 & 0 \\ -(\phi_{51}+\phi_{59}b_{161}) & -(\phi_{52}+\phi_{59}b_{162}) & -(\phi_{53}+\phi_{59}b_{163}) & -(\phi_{54}+\phi_{59}b_{164}) & (1-\phi_{59}b_{165}) & -(\phi_{56}+\phi_{59}b_{166}) & -(\phi_{57}+\phi_{59}b_{167}) & -(\phi_{58}+\phi_{59}b_{168}) \\ -(\phi_{61}+b_{161}) & -(\phi_{62}+b_{162}) & -(\phi_{43}+b_{163}) & -b_{164} & -b_{165} & (1-b_{166}) & (\phi_{67}-b_{167}) & (\phi_{63}-b_{168}) \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -\phi_{78} & 1 \end{pmatrix}$$

where; $\Sigma_e = (A_0 - A^* \times B_1)^{-1} \Sigma_\varepsilon ((A_0 - A^* \times B_1)^{-1})'$

The equation is above gives us cross equations restriction matrix.

$$\begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} & \sigma_{14} & \sigma_{15} & \sigma_{16} & \sigma_{17} & \sigma_{18} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} & \sigma_{24} & \sigma_{25} & \sigma_{26} & \sigma_{27} & \sigma_{28} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} & \sigma_{34} & \sigma_{35} & \sigma_{36} & \sigma_{37} & \sigma_{38} \\ \sigma_{41} & \sigma_{42} & \sigma_{43} & \sigma_{44} & \sigma_{45} & \sigma_{46} & \sigma_{47} & \sigma_{48} \\ \sigma_{51} & \sigma_{52} & \sigma_{53} & \sigma_{54} & \sigma_{55} & \sigma_{56} & \sigma_{57} & \sigma_{58} \\ \sigma_{61} & \sigma_{62} & \sigma_{63} & \sigma_{64} & \sigma_{65} & \sigma_{66} & \sigma_{67} & \sigma_{68} \\ \sigma_{71} & \sigma_{72} & \sigma_{73} & \sigma_{74} & \sigma_{75} & \sigma_{76} & \sigma_{77} & \sigma_{78} \\ \sigma_{81} & \sigma_{82} & \sigma_{83} & \sigma_{84} & \sigma_{85} & \sigma_{86} & \sigma_{87} & \sigma_{88} \end{pmatrix} = (A_0 - A^* \times B1)^{-1} \begin{pmatrix} \varepsilon_y^2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \varepsilon_\pi^2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \varepsilon_i^2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \varepsilon_d^2 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \varepsilon_r^2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \varepsilon_e & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \varepsilon_\pi *^2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \varepsilon_i *^2 \end{pmatrix}$$

$((A_0 - A^* \times B1)^{-1})$