# FUNDAMENTAL DETERMINANTS OF THE REAL EXCHANGE RATE: A NATREX APPROACH

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# CHAPTER I

## INTRODUCTION

We live in a sophisticated, complex economy, in which there are many mechanisms operating simultaneously. As has been said, "Everything depends on everything else." (Patinkin 1965, p.181) Money does play an integral part in this operation, in which it serves as a medium of exchange, unit of account and store of value. "Money is quite special in its role as a crucial intermediary object that is involved on one side of most transactions that take place in today's market economies." (McCallum 1989, p.3)

As markets become more open, world trade and capital movements among countries have strengthened globalization through various monetary media of exchange; tremendous economic activities are being executed every day with a variety of countries' currencies. Through the different currencies as an intermediary object, a country nowadays can seek rapid economic growth by stimulating more exports to cause wealth reallocation among countries than does a closed economy. In other words, if a country generates a current account surplus (deficit), it is a net lender (borrower) to the rest of the world.

However, fiat money is quite different from other goods; the demand for it is derived demand of other real goods and services, and it is not tied to any real goods, like gold for instance. In addition, only one supplier per country—the central bank—as it produces the monetary base, in association with tremendous demanders exists in the

money market. Currency in circulation is the main liability in the relevant central bank's balance sheet; if the central bank defaults on its debt, then the holders of this currency get nothing at all but pieces of paper. Since the better a country's economy performs, the less possibility the central bank defaults on its debt—the less likely the currency is devaluated without any central bank's interventions, so the investors can prevent their portfolios, or wealth, from shrinking

In the foreign markets, there are lots of currency transactions every day, however, illustrating transactions for goods, which include commodities and financial assets, and services, but not these pieces of paper themselves. Under a floating exchange rate system, volatilities of the nominal exchange rate are a concern. It is analogous to the concern of price stability as well. The drawbacks of large fluctuations of nominal exchange rates are likely taken as the drawbacks of inflation, which are transmitted among countries, because it costs to hold some certain currencies for the business or portfolio purposes if their values are enormously volatile—this is not the support to give up the floating exchange rate, because there are more problems of the fixed exchange rate also.

Kareken and Wallace (1981) developed an overlapping generations model (OLG) to explain the fluctuations of exchange rates due to the indeterminacy of equilibrium exchange rate in the foreign exchange market under a flexible exchange rate with no foreign currency controls for the citizens. The issue here is that fiat money is not tied to any real goods, so we do not exactly know what is the value of on unit fiat money except in terms of other real goods. Moreover, holding different fiat currencies as a store of value is not restricted by all countries, so it makes demand, that is, from the domestic and

foreign countries, for fiat currencies speculative; the unknown proportion of speculative demand from the foreigners causes the indeterminacy of equilibrium exchange rates in a floating exchange rate system, so its nominal values are determined by the criterion of what you think it is.

As a matter of fact, we do observe that strong demand for some particular currencies, i.e. appreciation of these currencies in the foreign market, is the result of holders' rational behavior, whose motives are for transaction, speculation, or precaution. Even if investors hold some foreign currencies in their portfolios by a speculative motive, the reason must be the good performances of relevant economies—or, at least, investors expect the good performances of relevant economies in the future, so they do not make a fetish of holding some foreign currencies—or just holding some foreign currencies for worse and worse economy's performances themselves. In conclusion, if money is to be a store of value, a good economy's performance essentially guarantees solvency for investors.

As explained above, since the derived demand for fiat money comes from all other markets, which are goods and financial markets, the equilibrium exchange rate is supposedly determined by the entire economy instead of the foreign market only. Holding different currencies is a result of investors' rational behavior, and it is highly related to the economy's performance to prevent the holders' wealth from shrinking. As far as it goes, the economy's performance does involve the real demand for currencies, so OLG does not quite fit the case. The hypothesis is: if the economy's performance does involve the demand for money, there are fundamental determinants, which dominate the economy; they essentially determine equilibrium exchange rates—or lead on the trend of

the equilibrium real exchange rates. Since the short run factors disturb the foreign exchange market, they do not last long nevertheless; they move the nominal exchange rate away from the trend transitorily.

If all the markets jointly determine all the real and nominal terms, it is a general equilibrium model. In a general equilibrium model, every real economic variable is related to the others, and all the real variables jointly determine the resource allocations for the internal part and external part of a country—or the world markets[1]. It is hard to believe that there are no fundamental determinants that influence the real exchange rate if all the real economic variables are related to each other, and the real demand for money is a derived real demand for goods and services. Basically, money is neutral; it does not mean it plays no role in a general equilibrium model. In Patinkin's framework, a general equilibrium approach, money does play an important role in the transmission of while the economy is adjusting from a disequilibrium to a new equilibrium. The real exchange rate is determined by the real sectors, which are the goods and bond markets under the neutrality of money (this is explained in the later content).

Although speculative, short-run, factors disturb the foreign exchange market, they do not last long nevertheless; they move the nominal exchange rate away from the equilibrium transitorily. Again, in a general equilibrium system, reaching equilibria for real economic variables may take a long time till the reallocations of all resources are complete; all the real exogenous and endogenous variables are the fundamental determinants of the economy, thereby driving the equilibrium trajectory of the entire economy. Considerable work, therefore, examining the great fluctuations of nominal or

[1] The idea is applied from Patinkin (1965) under a static case. Patinkin's model is used to interpret how markets interact simultaneously to determine the real and nominal variables in the later content.

real exchange rates has been done after the international monetary system moved to a flexible exchange rate in the early 1970s.

Many models have been developed to identify the determinants of either the nominal or real exchange rate; most models revolved around the purchasing power parity framework, with monetary models to ensure a necessary relationship among the nominal prices and exchange rate. From the empirical work, the purchasing power parity is not convincing. Most models are country and time specific. Basically, most economies are evolving, so the model applied to test the hypothesis, at least, should capture the continuous evolution of economies, and how these exogenous and endogenous variables respond to each other to produce a equilibrium relationship in the long run, which drives the economy all the time.

One of these models, called the NATREX approach constructed by Jerome L. Stein, Polly Reynolds Allen, and Associates (1995), offers a potentially more satisfactory theoretical foundation and consistent empirical results by a different way. The NATREX means NATural Real Exchange Rate. The NATREX is built on a general equilibrium concept that stresses the fundamental real terms such as the savings rate and productivity on the trend of the real exchange rate in the economy; it reflects the dynamic interactions among individual decisions and economies. Basically, the NATREX is a variable, which carries only medium and long run information that drives the trend behavior of the real exchange rate. Any short run disturbances deviating the real exchange rate from the trend disappear after a while, so there should be some fundamental determinants of the economy to sustain real exchange rate movement in the long run.

The purpose of this study is to employ the NATREX approach to verify the fundamental determinants of the real exchange rates. For this study, the examination involves testing the Taiwan-US and Canada-US cases. One is a growing small and the other is a developed medium economy, each highly related to the US economy, but under different international monetary systems. There are different levels of openness in their financial markets. Different economy sizes relative to the trade partners bring some features to the dynamic structural models, such as exogenous or endogenous terms of trade and real domestic interest rate to make the NATREX respond to different fundamental determinants of the different sizes in each country. In addition, the state of the economic development might be another factor responsible for some particular and interesting empirical results as well.

Taiwan's foreign exchange market is influenced by its central bank, so its nominal exchange rate has been just allowed to float within a 2.25 percent point range from the weighted average rates on all interbank currency exchange transactions since 1982 and the main foreign currency pegged is the US dollar. Its financial market is highly regulated, so the capital movements are restrained internationally. Taiwan has a close trade relationship with the US. Moreover, it is a growing economy. Especially, it has had a relatively remarkable performance in its economic growth in the past years. There might be some interesting findings in this case.

Canada is a medium open economy, and also closely related to the US markets. It shares a wide border with the US, so their goods and financial markets are highly integrated. In 1970, under the consideration of independence of monetary policy, Canada has employed a flexible exchange rate system. Since it has an open financial market and

a close trade relationship with the US, we can do some analyses in contrast with the small economy—Taiwan with a different international monetary system and highly regulated financial market.

Correspondingly, we do not focus on the actual exchange rates that embody short, medium and long run information—and even do not focus on seeking the equilibrium real exchange rate that carries just only long run information. The feature of an economy is dynamic, so we are looking for a dynamic—long run—relationship among endogenous and exogenous variables in an economy; this is why we call this type of real exchange rate as NATREX instead of the actual or equilibrium real exchange rate. Technically, we need to extract, by appropriate econometric techniques, the medium and long run information from the observations, which carry the short, medium and long run information.

This study consists of four parts: the first part is the introduction, the second part summarizes the previous studies related to this topic, the third part is theoretical model, which is applied in this research work, the fourth part is the pretests, data and pretest results, the following five and six parts are the empirical discussions of the evidences from Taiwan and Canada's cases and the last one is the conclusion for this work.

# CHAPTER II

## LITERATURE REVIEW

Many theories and empirical studies have been developed in an attempt to understand the exchange rate mechanism. During the Bretton Woods period, 1947-1971, the international monetary system functioned under a fixed nominal exchange rate associated with a varying real exchange rate. In 1963, Robert Mundell[2] applied an $IS-LM$ type model to an open economy to analyze the effects of policy implementations under fixed and flexible exchange rate systems. This was before flexible exchange rates came into operation.

From Mundell's standpoint, the nominal exchange rate is highly related to the real exchange rate and trade flows under a sticky price assumption, one of the main characteristics of $IS-LM$ models, so the nominal exchange rate could become a tool to achieve the external balance, and the aggregate demand policies were to keep the internal balance. A variety of cases were conceptually discussed in Mundell's model, but we can see the real, or nominal, exchange rate indirectly determined in the goods market or assets market instead the demand and supply for fiat money in the foreign market.

[2] Refer Robert A. Mundell (1968, pp. 219).

Generally, this kind of traditional flow theory shows the determinants of exchange rate from the definition of the balance of payments. We can apply one typical $IS-LM$ open economy model to illustrate the main idea of this approach. The economy consists of the goods market, money market and foreign goods and service market. The real exchange rate is merely determined in the current account.

$$IS:\ Y = A(Y,i) + B(Y,Y^*,{}^{NP'}\!/_{P})$$
$$LM:\ \frac{\overline{M}}{P} = M_d(Y,i)$$
$$BP:\ BOP = B(Y,Y^*,{}^{NP'}\!/_{P}) + H(i-i^*) = 0$$

Where $A$ is the domestic aggregate demand for goods, $A_Y > 0, A_i < 0$;

$B$ stands for the current account status, $B_Y < 0, B_{Y^*} > 0,\ B_{(\frac{NP'}{P})} > 0$;

$H$ stands for the capital flows, $H_{(i-i')} > 0$;

$M_d$ is the money demand $M_Y > 0$ and $\mathrm{M}_i < 0$;

$Y$ is the domestic income;

$Y^*$ is the foreign income;

$i$ is the domestic interest rate, $i'$ is the foreign interest rate, and $(i-i')$ is the interest rate differences;

$BOP$ is the balance of payment;

$N$ is the nominal exchange rate of one unit foreign currency in terms of domestic currencies;

$P$ is the domestic deflator and $P'$ is the foreign deflator;

${}^{NP'}\!/_{P}$ is the real exchange rate (the price of foreign goods in terms of domestic goods).

Given a fixed price level and an exogenous foreign price, any terms here are real terms. It can be observed that the balance of payments basically determines exchange rates. Under this model, given an initial current account equilibrium, an increase in Y stimulates import demand, thereby raising the price of the foreign currency—depreciating the nominal (real) exchange rate, here taken as a current account deficit associated capital inflows. At the time of Mundell's work, the financial markets were still not well integrated, so the exchange rate was likely dominated by the current account flows. The proximate determinants of the exchange rate were income and interest rate differentials. The exchange rates are simply determined by the external sector of an open economy; basically, it is a partial equilibrium analysis, and we do not see resources reallocate among different sectors.

Most cases were discussed in detail and with more policies concerned, but we could not see any discussions concerning the fundamental determinants of the exchange rate. Any policy effects on exchange rates were derivatives but not any analysis concerning the exchange market directly. Moreover, most cases discussed fit merely a small open economy. Even in 1970s, Rudiger Dornbush dominated the development of open economy macroeconomics, which was basically built on the Mundell's framework, but differently with a flexible price assumption.

The Bretton Woods system, of fixed exchange rates, collapsed in 1971, because the system ignored the differences of economic development among countries and the difficulties in maintaining both internal and external balances in such a system. Since then, the global economy moved to a flexible exchange rate system. With the gradual

integration of financial markets and free capital movements, capital flows become a more important factor influencing the exchange rates.

Beginning in the late 1970s, the expansion of international capital flows has enhanced the influence from the asset market—the exchange rate has to adjust instantaneously to equilibrate the demand and supply for assets. These kinds of asset models stressed imperfect capital mobility, resulting from different levels of risk premia among assets. Pentti Kouri (1976) developed a portfolio balance model that took money and the foreign bond as assets. This paper analyzed, "by way of a dynamic model, the role of monetary asset equilibrium and expectations in the determination of the exchange rate in the short run, and the role of the process of asset accumulation in the determination of the time path from monetary to long run equilibrium" (p.280). Any initial appreciation (depreciation) accompanying a current account deficit (surplus) gives rise to adjustments in the stock of domestic and foreign assets by depreciating (appreciating) the exchange rate to eliminate the current deficit (surplus) in the long run. This model, which allows a current account surplus existing associated with a deficit in the capital account to maintain the balance of payment in equilibrium, differs from the traditional trade flow theory, that current account keeps in equilibrium, no deficit or surplus, eventually.

In 1976, William Branson[3] constructed another asset model by adding one more asset—a foreign bond—in contrast to Kouri's model. He obtained almost the same results. An instantaneous adjustment mechanism in asset stocks determines the nominal exchange rate, given a temporary surplus in the current account to an expected

[3] The discussion of Branson's model is based on Grauwe (1989)

appreciation in the financial market in the future to push the balance of payment back to equilibrium.

This approach takes the determinants of the nominal exchange rate as interest rate differentials and relative asset supplies. Empirically, it is easily observed that markets do not adjust as the portfolio balance model analyzes; the current account deficit sometimes is associated with an depreciation, but sometimes associated with a appreciation to swell the current account deficit more, like the US dollar. The portfolio balance model seems not to be a convincing theory.

During 1980s, the monetary approach became popular. It analyzed the variability of flexible exchange rates through the money demand and supply functions. The main factors influencing money demand were the interest rate and income level; the money supply was exogenous. The typical determinants that influenced the exchange rate were not only interest rates and income levels, but inflation. This approach was built on the framework that the money market decides the equilibrium exchange rate by the demand and supply functions under a variety of assumptions such as purchasing power parity, which claims a stationary real exchange rate over time with covered or uncovered interest rate differentials. The slight distinctions among models were the price flexibility (Frenkel, 1977), price rigidity (overshooting model) (Dornbush, 1976), and real interest rate differentials (Frankel, 1979). Frenkel (1977) examined the determinants of the nominal exchange rate with the sample period covering the German hyperinflation. The nominal exchange rate was significantly influenced by the money supply and price expectation, but the sample was extracted under the economy history background instead

of being built on a strong theoretical base. This significant empirical result might be the result of hyperinflation—a monetary expansion—at that time.

Dornbush (1976) developed a theoretical model with price rigidity assumed for a small open economy under a floating exchange rate; it drew out the different adjustment speeds—of exchange rate and nominal price—in the money market and goods market to make money expansion stimulate the real output in the short run. Basically, the author used money demand, money supply and the goods demand functions to solve for the nominal exchange rate, which adjusts instantaneously, and price level, which adjusts sluggishly. The long run nominal equilibrium exchange rate was a function of monetary variable and real variables, real income and interest rate. This idea was not tested by an empirical work.

From Frankel (1979), the spot exchange rate was determined by the money demand and supply functions and the real interest rate differential parity. It thus was a function of domestic and foreign money supplies, domestic and foreign outputs, domestic and foreign interest rates, and domestic and foreign inflation rates; the money serves as a store of value more than as a medium of exchange. The model considered monetary factors only as exogenous disturbances to the nominal exchange rate. From the empirical results, the author tested alternative hypotheses, which were all monetary point of views.

Also, Frankel (1983) integrated the monetary models with a portfolio-balance model to derive a synthesis asset model associated with uncovered interest rate parity by replacing the imperfect substitutability condition between domestic and foreign bonds. The empirical results did not support the concept after the author corrected for the serial

correction of the regressions—Frankel thought the reason was market intervention by the government.

It seems no matter how sophisticated the monetary models were, none of them was able to explain the large movements of exchange rates empirically, which implies the great variations do not supposedly stem from the shifts of demand or supply for money. Additionally, their ability to forecast the spot rates has been poor. Meese and Rogoff found

> A random walk model performs as well as any estimated model at one to twelve month horizons for the dollar/pound, dollar/mark, dollar/yen and trade weighted dollar exchange rate. The candidate structural models include the flexible-price (Frenkel—Bilson) and sticky-price (Dornbush—Frankel) monetary models, and a sticky-price model which incorporates the current account (Hooper—Morton). The structural models perform poorly despite the fact that we base their forecasts on actual realized values of future explanatory variables. (1983, p. 3)

There are thus doubts that the determinacy of nominal exchange rates is principally dominated by the money demand and supply functions, even though there are still some other arguments about Meese and Rogoff's empirical conclusions. These include the appropriateness of the econometric techniques, which should have been used a multivariate cointegration technique (MacDonald and Taylor, 1994), or stochastic coefficients instead of fixed coefficients to allow the structure coefficients to change over time (Schinasi and Sway, 1989). Generally, the monetary approach ignored shocks other than the monetary shocks.

Why have we paid so much attention to money market and nominal exchange rate around the PPP theory? The major premise is the absolute—or relative—PPP theory existing in the economy, so the indeterminacy of the equilibrium exchange rate is no longer true. The nominal or real exchange rate always converges to the equilibrium values, but the empirical results do not seem support the PPP theory—both nominal and real exchange rates are not stationary through time. From Balassa (1964), the above feature of the absolute purchasing power parity theory for nominal prices and exchange rate only considers a comparative statics proposition, so it is only correct under *ceteris paribus*; the absolute purchasing power parity does not necessarily hold between the nominal prices and exchange rate in dynamic economies for spontaneously continuous changes from fundamental sides. A varying exchange rate causes the same problems, as mentioned previously, like inflation does, so it is necessary to find why the rate fluctuates so much.

First, since we have emphasized the importance of relative price and real terms among countries, we should explain the dynamic concept here. From the traditional Edgeworth box analysis, any changes relative to the trade partners from the production side such as technological progress and a rise of productivity can cause the contract curve to shift to a new equilibrium pattern due to the change of the Edgeworth box, which reflects that the relative price and real terms, may shift over time. International capital movements and trade reallocate resources among countries, thereby causing the economy to reach a new steady state if the economy is growing as a result of exogenous technological progress or endogenous increase of international trades. It can be said that international trade stimulates economic growth. This is a theoretical explanation for not

supporting absolute purchasing power parity; purchasing power parity is barely true when the domestic and foreign economies are in equilibrium without any further disturbances of the exogenous variables.

Another point of argument is related to the partial or general equilibrium analysis. Both monetary and portfolio-balance approaches—even a synthesis asset model—used a partial equilibrium analysis, which might be the reason why the empirical results are so inconsistent with the theories. It is hard to split markets to comprehend the real or nominal variables, because the observed is that all the markets, including domestic and international, simultaneously operate together. We do not agree with the classical dichotomy and neither does the separation between domestic and international markets.

We can use Patinkin's general equilibrium model, for instance, to explain the transmission for an open economy. Commodities, bond (financial) and money markets are included in this general equilibrium model. The following identity expresses the sum of excess demand for each market equals to zero.

$$(F(Y_0, r, \frac{M_0^{"}}{P}, \frac{NP^{'}}{P}) - Y_0) + (B(Y_0, r, r', \frac{M_0^{"}}{P}, \frac{NP^{'}}{P}) + h(\frac{M_0^{"}}{P}))$$
$$+ (L(Y_0, r, \frac{M_0^{"}}{P}) - v(\frac{M_0^{"}}{P})) = 0$$

The first term stands for the excess demand in the goods market, the second term stands for the excess demand in the bond market, and the last term is the excess demand in the money market. The symbols here might be different from the symbols used in the later content. $Y_0$ is the gross real national output, which is produced under a fixed capital stock and some certain technology level. $M_0^{"}$ is the money base and $v$ stands for the money multiplier. $\frac{NP^{'}}{P}$ is denoted as same as the real exchange rate in the NATREX

approach, $,r$ is denoted as the domestic real interest rate and $r'$ is the foreign real interest rate. The entire system simultaneously decides the real interest rate, including domestic and foreign, the real balance (wealth), and the real exchange rate that is defined as it is in the following. According to the Walras' Law, the sum of the total excess demand from three markets equals zero, so if excess demand occurs in any one market, thereby existing excess supply in some other markets as well; the entire system continues to adjust till no excess demand or supply in any markets. Regardless to the same results—neutrality of money—the nominal and real terms are simultaneously determined by the entire system, so we are not able to skip it to solve the system; without money market, the nominal terms in the system could not be solved.

Hence, for this model, an equilibrium real exchange rate indicates the composite price indices also achieve equilibrium other than just the relative price between the nontradable and tradable goods or the terms of trade. We could get the equilibrium real exchange rate under either a floating or fixed exchange rate market under an exogenous money supply or endogenous money supply, because all the domestic and foreign markets interact to determine the equilibrium real variable and money market determine the nominal terms. Money is neutral here, but it does play an important role in the transition to bring the economy back to equilibrium from disequilibirum. That is what we say everything depends on everything else.

We can get some features about reality from Patinkin's model; the system is solved under an assumption of a fixed capital intensity and some certain technology level, thereby creating a situation in which if capital intensity continuously changes through international trade or through technology progress from time to time. This definitely

causes continuously endogenous adjustments of the economy. Any comparative statics analysis assumes the exogenous variable remaining constant during the whole sample period, and it is truly necessary the empirical techniques should represent the features of variables' evolutions.

Sebastian Edwards (1989) developed an intertemporal general equilibrium model of a small open developing economy with capital controls, and analyzed how real exchange rates respond to a series of disturbances in two periods. In the model, the equilibrium real exchange rate is a function of exogenous changes in the terms of trade, exchange controls, government expenditures, technology progress and tariff; the actual real exchange rate is a function of nominal and real terms. All nominal and real factors drive the actual exchange rate away from the equilibrium real exchange rate in the short run, but in the long run, deviations are corrected gradually—the equilibrium exchange rate only responds to the real variables in the long run. However, there are still some drawbacks in this approach; in theory, it just fits a small open economy with a capital control that is taken as an exogenous variable, so we cannot trace the movements of the important endogenous variable, capital flows, among countries for reallocating the resources and initiating all other endogenous adjustments while a spontaneous changes of fundamental determinants occur.

Moreover, we cannot see how various sizes of economies, with different stages of in development, operate to reach equilibrium when some fundamental determinants evolve through time. Empirically, Edwards employed the definition of the real exchange rate as the relative price of the domestic nontradable relative to foreign tradable goods, which barely fits a small economy associated with exogenous terms of trade. It did not

fit a large open economy case. From the empirical results, the fundamental determinants, which are defined as terms of trade, tariffs, technological progress and so on, are not surprisingly significant in influencing the real exchange rate that is assumed by Edwards, because this model did capture the essence of a general equilibrium model.

However, in 1994, Macdonald developed a monetary model of the exchange rate, considering long run relationships and short run dynamics, which took time series into account. He did a unit root and cointegration tests to make sure there is a casual relationship rather than a spurious one among macroeconomic variables through time. The question is still which market determines the equilibrium exchange rate or the entire system of the economy does—where decides the equilibrium exchange rate.

The above models do capture the real fundamental determinants from a general equilibrium concept from Edwards's model and the economy dynamics from the Macdonald's model, which we have addressed previously. Understandably, a more satisfactory theory along with more appropriate econometric techniques are critically essential to expose the determinants that decide the exchange rates in the foreign market in the long run, or medium run at least, so we need a better approach that combines these two features in the model.

Stein, Allen, and associates (1995) have brought up the term of NATural Real Exchange Rate (NATREX), which stands for a medium-run, equilibrium exchange rate, as identified by Ragnar Nurkse (1945)[4]—which combines a general equilibrium concept to a dynamic economy. The NATREX approach focuses on the long run concept and

[4] According to Nurkse(1945, p. 5), the equilibrium rate of exchange is a long run, 5—10 years, concept. The period must be long enough to eliminate cyclical fluctuations, so it could keeps the balance of payments in equilibrium.

does not distinguish between permanent and temporary shocks, so any monetary policy intervention could result in the adjustment of other nominal variables to ensure the economy reaching the equilibrium. Money is neutral here. In contrast to the Patinkin framework, the NATREX approach is quite similar to it; the goods and financial markets determine the real variable, but the entire system still needs the money market to determine the nominal terms to reach equilibrium. The difference between these two is the NATREX approach uses lots of econometrics to test the theory, so it is more empirical than theoretical. According to the definition,

> The NATREX (or NATural Real Exchange Rate) is the *equilibrium real exchange rate that clears the balance of payment in the absence of cyclical factors, speculative capital flows, and movements in international reserves...* We focus on the *real* exchange rate for two reasons. First, the real, rather than the nominal, rate determines basic economic decisions about consumption, growth, and resource allocation. Second, a moving inter-cyclical equilibrium, neutral with respect to money, can be expressed wholly in real terms, making the equilibrium *real* exchange rate independent of the nominal exchange-rate regime. (1995, p.6)

> The NATREX is a *moving* equilibrium real exchange rate, responding to continual changes in exogenous and endogenous real fundamentals. (Allen 1995, p.1)

And, the NATREX is derived under rationalization.

> A family of consistent general equilibrium models—of rational, optimizing behaviour, determining medium-run equilibrium real exchange rates—forms the core of the NATREX approach. (Allen 1995, p.2)

More intuitively, in a general equilibrium model, although all the markets simultaneously determine the real and nominal endogenous variables, some endogenous variables respond to the spontaneous disturbances from the fundamental determinants of the economy first, and the rest real variables subsequently respond to the exogenous and endogenous adjustments later till the economy reaches a new equilibrium. It is necessary to assume the dynamic stability conditions for the endogenous precursors, some real variables, so the economy is guaranteed to approach a new equilibrium.

In the NATREX approach, capital intensity and foreign debt are the endogenous precursors. They respond to evolutions of fundamental determinants such as a rise of savings rate and productivity, and they induce the subsequent endogenous adjustments of the relative price and real exchange rate until the economy reaches a new equilibrium. Consequently, for the economy to reach a new equilibrium due to the spontaneous changes from the fundamental determinants, it is necessary to set up the dynamic stability conditions for the capital intensity and foreign debt, which prevent the economy from diverging.

When we derive an optimal control path for capital intensity, some information such as the production function, values of the initial and last capital intensities, and time plots are necessary; otherwise, it is not feasible. In the NATREX approach, we just need the information such as the relative ratio of marginal productivity of capital, that is, a proxy of investment returns, and investment discount rate to decide whether the investment is worth proceeding, so the speed of capital accelerations depends on it.

This approach has been investigated in a variety of real situations, like a large open economy (the US case), a small open economy (the Australia case) and a monetary union

(the German and France case), and the empirical results significantly support the hypotheses—first, that the fundamental determinants dominantly influence the real exchange rate; second, the fundamental determinants and the real exchange rate are cointegrated to present a stable long run relationship; third, the NATREX is not stationary over time.

Although the present study comprises most of different international monetary systems, there are still some particular cases worthy of testing and verifying. Taiwan and Canada both have a close trade relationship with the US, but have different exchange rate systems, a pegged exchange rate and flexible exchange rate. Canada shares a long border with the US, so their goods and financial markets are highly integrated. But Taiwan does not have an integrated financial market with the US. Moreover, Taiwan is a growing economy, which does not quite fit the initial assumption in the NATREX approach, and Canada is a developed country. Some particular and interesting empirical results are expected in these two economies; it is true that if the NATREX is convincing, the empirical results should appear the features causing from different economies. We do not even expect that all the dependent variables respond to the independent variables similarly in every case owing to the characteristics of each economy. This is another point of view to verify the theory. Particularly, few empirical studies, with a general equilibrium base, related to these two countries have not been seen yet.

For an instance, Amano and Nordens' (1995) study, the volatilities of the Canadian-US real exchange rate (relative to the US dollar), this is linked to the terms of trade and the influence of the monetary policy. Accordingly, Canada is a net exporter of natural resources, but a net importer of manufacturing products; the authors, therefore, split the

terms of trade into the price of exported energy and the price of non-energy commodities instead of using the overall terms of trade. The reason for not using overall terms of trade was because they were not empirically significant. Moreover, they employed C$/US$ over Consumer Price Indices as the Canada's bilateral real exchange rate with the US; it causes the same problem—using CPI instead of composite price in defining of the real exchange rate. In this paper, terms of trade captured the adjustment in the commodity market, and the short run interest rate differential exposed the influences of the monetary policy.

The real exchange rate consists of three parts (as explained in chapter III)—the terms of trade, and domestic and foreign relative prices. It would not be surprising that the terms of trade are cointegrated with the real exchange rate. The real interest rate differential that is a transmission of endogenous adjustments in the economy may also result in the real exchange rate to adjust. More discussion explaining the importance of terms of trade and real interest rate differential is in the next chapter.

Wu (1996) did an empirical study relating to the real exchange rate of Taiwan-US. This paper applied the Balassa (1964) view: that productivity is a main factor influencing the real exchange rate. The author found there is no purchasing power parity in Taiwan, so he decomposed the real exchange rate—deflated the nominal exchange rate by a composite price index—as the relative prices between the nontradable and tradable goods and terms of trade, an exogenous variable for Taiwan. A unit root test and cointegration test proceeded in this research. The author used the wholesale price indices as proxies of tradable goods prices and consumer price indices as proxies of nontradable goods prices

for both countries. The empirical results support the view that the productivity differential does have influence the real exchange rate.

The empirical productivity data of the nontradable goods in Taiwan's case merely represent the service sector, defined as the nontradable goods sector; the service sector, notwithstanding, is a part of the nontradable goods sector, but still cannot encompass the entire nontradable goods sector. Although he found that higher productivity growth in the nontradable goods sector than in tradable sector in Taiwan's case depreciates the real exchange rate, this empirical result are not convincing due to the data used.

In another point of view, that a surge of productivity influences in the economic growth, Ito, Isard, and Symansky (1997) tested the relationship between economic growth and real exchange rates with an overview of the Balassa-Samuelson hypothesis, which claims rapid economic growth is associated with a real appreciation of real exchange rates due to the productivities differential between the tradable goods sector and nontradable goods sector. They used APEC countries as samples to test the hypothesis. The hypothesis is statistically prominent in some sample countries, Japan, Korea and Taiwan whose resources is relatively less than other countries. These countries followed a similar economic development pattern—the industrial structure transferred from agriculture-oriented goods to light industrial exports and then to heavy industrial exports. Through the evolutions of their industrial structure, the values added of their exports stimulate the rapid economic growth due to the more productivity progress in the tradable goods sector than in the nontradable goods sector, thereby rising the relative prices between the nontradable and tradable goods. Their findings were

consistent with the theory; however, stimulating exports reflect the changes of domestic savings and investment, which are not observed in their work.

The significant empirical results were not surprising, but there are not enough discussions involving how these countries stimulated great exports—these are the real fundamental changes from the economy. Another shortcoming is econometric techniques applied—just simple correlations between variables were tested, so it is obviously insufficient.

The main reason we apply the NATREX approach here is because it is a general equilibrium analysis, but also because it uses time series analysis, which captures evolutions of exogenous and endogenous variables of the economy through time. Correspondingly, neither the actual exchange rate, which carries all short, medium and long run information—nor the equilibrium real exchange rate, which carries just only long run information—has been discussed much in this paper due to the dynamics characteristic of an economy itself. Not only is it not possible to unearth the equilibrium real exchange rate, it is also not feasible to explain the actual deviations of exchange rates. The feature of an economy is evolving, so we are looking for a long run equilibrium relationship instead of long run equilibrium values among endogenous and exogenous variables in an economy. Technically, we need to extract the medium and long run information from the observations, which carry the short, medium and long run information, by using econometrics. These are the reasons we employ the NATREX approach.

# CHAPTER III

## THEORETICAL MODEL

The NATREX is built on a general equilibrium model. It seeks to capture the interactions among all the markets such as the goods market, financial market, and money market. In the goods market, inputs, outputs, and production technology are critical factors in determining the goods supply curve. Demand for goods consists of the private consumption, government consumption, investment and current account surplus (or deficit). Each part of the demand for goods represents the ongoing optimization of the consumer's behavior, government expenditure, investor's behaviors, international trade and capital flows in every market. In the financial market, the borrowers and lenders' behavior jointly decides the demand and supply curves of loans. Money plays several roles in the economy as a medium of exchange, a medium of account, and a store of value. The demand for money comes from the public, but the money supply comes only from the central bank. From a general equilibrium theory and the evidences of the empirical work, money is neutral in the economy; money plays merely to decide the nominal terms. All the specific features related to every single behavior—and related to different markets—are discussed in the later context.

The feature of a general equilibrium that has been discussed already, Patinkin's model as example, is that all the markets operate to solve simultaneous solutions of the relative prices for inputs and goods, capital intensity in the production function, real

interest rate, real exchange rate and nominal prices. When any real disturbances from the supply or demand sides affect the marginal conditions, it leads the entire system to a new equilibrium. No discussion here concerns the nominal disturbances, an increase of money supply for instance, as the money stock is unrelated to the real terms—like real output. None of markets should be assumed remaining still for the convenience of analyzing any exogenous effect or the determination of any single real variable, because of a lot of interactions and dependences among all the markets, including the domestic country and foreign counties.

In an open economy, the domestic goods supply and import demand constitute the aggregate supply; the aggregate demand similarly stems from the domestic and foreign goods demand. In the two-trade partners case, the entire system determines all the real terms in the two economies; therefore the sizes of the economies matter in determining the equilibrium. Reaching equilibrium is more complex and time-consuming if the domestic country has more and more trade partners with spillover effects everywhere. Trade happens because the relative prices of the tradable goods are different among the countries, and with the trade, the relative prices adjust toward equality. The relative prices are the fundamental determinants of the aggregate supply and demand; they are the criteria to allocate the resources among the real sectors of the domestic country—and even among the different countries. Basically, international trade—of goods, service and capital—involves external as well as internal markets.

Consequently, the whole work here tries to employ a general equilibrium model to expound the internal and external adjustments in an open economy if there is a spontaneous disturbance from the fundamentals of the economy. Adjustments within the

markets are not obvious—we only have after-observations to analyze and trace all the interactions that have taken place in the markets. The NATREX captures the features of a dynamic economy, and it is not necessary to be the equilibrium one due to the dynamics itself. Beside, the NATREX approach ultimately generates different empirical results according to the features that economies have under a variety of circumstances. It can be verified later by both cases we use in this study.

This study does not try to evaluate, estimate or seek the equilibrium real exchange rate of an economy by the NATREX approach, but tries to reveal which fundamental determinants drive the medium or long run trend of the real exchange rate under a equilibrium long run relationship among endogenous and exogenous variables, ignoring the short run factors. We start with the theory part of this approach by introducing the equations that represent each market; these are combined with each other as a dynamic structural model, and the NATREX derived from the models. The model is employed to understand the cases of Taiwan and Canada as the domestic countries and the US as the foreign country.

## III.1 Definitions of the Variables and Features of the Behavioral Functions

### III.1.1 Defining the Real Exchange Rate

The actual real exchange rate carries the short run, medium run and long run information, but it is the only one that we can use to trace the interactions among all the markets. Therefore it is against the purpose of this paper, just needing the information of the medium run and long run. Any short run disturbances disappear soon, and they are random terms, so they are not the main forces that drive the real exchange rate. To extract the

information of the medium and long run from the observations of all the variables for the purpose of deriving the NATREX, econometric techniques are required. Both the relationship between the actual real exchange rate and the NATREX and the econometric techniques that are employed to estimate the equations in this study are explained below.

The actual real exchange rate, $R$, is the price of foreign goods in terms of domestic goods:

$$R = NP' / P \tag{1}$$

$N$ is the nominal exchange rate, i.e., one unit of the foreign currency in terms of domestic currencies, which for example is one US dollar in terms of Canadian dollars. $P$ is the GNP deflator, a composite price, for domestic country Canada for instance and $P'$ is the GNP deflator for the foreign country, the US.

In equation (1), it seems, for a general equilibrium model, that adjustments in the price levels would be due to the adjustments in the goods and financial markets. For the further considerations, the nominal exchange rate is observed from the markets, but the price deflators, either the domestic or foreign, are composed of the weighted domestic (or foreign) prices—the exportable price level and importable price level. The domestic price level is definitely endogenous, and the foreign price level is definitely exogenous for the domestic countries. That the exportable and importable prices are exogenous or endogenous depends on the size of the economy. If it is a large economy, the country can affect both the exportable or importable price levels, called endogenous terms of trade; if it is a small economy, it cannot affect either the exportable and importable price levels, called exogenous terms of trade. We are concerned, because it is necessary to find the main sources of adjustments of the economy to achieve a general equilibrium, and see how they respond to the evolutions of the other endogenous and exogenous variables.

In conclusion, for a large economy, disequilibrium adjustments come from the domestic relative price level and the terms of trade, but for a small economy, the disequilibrium depends on the adjustment of the domestic price level in terms of the adjustment of the relative price between the nontradable and tradable goods. The mathematical expression is represented as the following section.

$P$ and $P'$ could be decomposed as

$$P = P_n^{\alpha} P_2^{\beta} P_1^{(1-\alpha-\beta)} \tag{2}$$

$$P' = (P_n')^{\alpha'} (P_1')^{\beta'} (P_2')^{(1-\alpha'-\beta')} \tag{3}$$

$\alpha$ and $\alpha'$ are the weights of the nontradable goods for the domestic and foreign countries in their GNP deflators; $\beta$ and $\beta'$ are the weights of the importable goods of the domestic and foreign countries in their GNP deflators. $P_1$ is the exportable price of good 1 and $P_2$ is the importable price of good 2 of the domestic country. $P_1'$ is the importable price of good 1 price $P_2'$ is the exportable price of good 2 of the foreign country. Then the real exchange rate can be rewritten in logarithms from equation (1) to equation (4) by the alternative expressions of the exportable and importable goods prices of the foreign goods in forms of the domestic currency and nominal exchange rate as $P_1' = P_1 / N$ and $P_2' = P_2 / N$.

$$R = \frac{(\frac{P_n'}{P_2'})^{\alpha'} (\frac{P_1'}{P_2'})^{\beta'} N P_2'}{(\frac{P_n}{P_1})^{\alpha} (\frac{P_2}{P_1})^{\beta} P_1} = \frac{(\frac{P_n'}{P_2'})^{\alpha'} (\frac{P_1}{P_2})^{\beta'} (\frac{P_1}{P_2})^{-1}}{(\frac{P_n}{P_1})^{\alpha} (\frac{P_1}{P_2})^{-\beta}}$$

$$\log R = -\alpha \log(P_n - P_1) + \alpha' \log(P_n' - P_2') - (1 - \beta - \beta') \log(P_1 - P_2) \tag{4}$$

Since $P_1^{'} = P_1 / N$ and $P_2^{'} = P_2 / N$, $\log(P_1 - P_2)$ also could be expressed as $\log(P_1 - NP_2^{'})$, which is the logarithmic form of the terms of trade $(T)$, $P_1/P_2$. The domestic relative price ratio is defined as $R_n = P_n / P_1$—the ratio between the nontradable and tradable goods of the domestic country—and the foreign relative price ratio is defined as $R_n^{'} = P_n^{'} / P_2^{'}$. Thus, equation (4) becomes

$$\log R = -\alpha \log R_n + \alpha^{'} \log R_n^{'} - (1 - \beta - \beta^{'}) \log T \qquad (5)$$

The actual real exchange rate is therefore composed of three parts—the relative price ratios of domestic and foreign countries, $R_n, R_n^{'}$, and $T$ in equation (5). Using the logarithm form is a more tractable way to express elements of the actual real exchange rate, and recognize which parts are exogenous and which are endogenous for the domestic country. The first term, $R_n$, the relative price between the domestic nontradable and tradable goods, is an endogenous part in the actual real exchange rate for any sizes of economies except a small economy, it only can reach the equilibrium by adjusting the relative price between the nontradable and tradable goods under the perfect elasticity of world goods supply for exports and demand for imports. $R_n'$, the foreign relative price, is definitely exogenous for any sizes of economies. $T$, terms of trade—the relative price of exportable and importable goods—are exogenous parts for a small economy, but are endogenous for a medium and large economies.

The only endogenous effect, the relative price for a small economy, can be observed from equation (5), given exogenous terms of trade and foreign relative price. So, in a small economy case, the hypothesis is to test whether the real exchange rate and relative price, the only endogenous parts in the composition of the real exchange rate,

respond to the evolutions of the fundamental determinants. Due to endogeniety of terms of trade, we can take advantage of it to recognize the effect such as a rise of the productivity either from the nontradable goods sector or from the tradable goods sector from our empirical results by investigating the sign of the relative price where the rise of productivity occurs. From the empirical sign of the explanatory variables in the regression of the relative price, we can trace more details of the reallocation of resources between the nontradable and tradable goods sectors, as there is only one endogenous part in the real exchange rate.

For a large or medium economy, both the terms of trade and relative prices are endogenous, so if there is a rise of productivity, we trace the endogenous effects on the adjustments of the relative price and terms of trade from the observations. The reason is the effect comes from the reallocation of the resources between the nontradable and tradable goods sectors, and the effect, from the endogenous effect of terms of trade, comes from the influences of the relative price of exportable and importable goods. In other words, the effect from the endogenous terms of trade depends on the elasticity of the world goods supply for exports and demand for imports, so it seems no way we can recognize whether a rise in productivity comes from the nontradable goods sector or from the tradable goods sector in a medium economy from observations—two endogenous effects are generating here.

Broadly speaking, in the case of Taiwan, the foreign relative price and terms of trade, $R_n^*$ and $T$, are exogenous. One thus can merely derive the relative price, $R_n$, by an indirect way from equation (5), $R_n = 1/RT$. Hence, $T$ is exogenous, the factors that influence the real exchange rate also influence $R_n$. In other words, $R_n$ is the only

endogenous part in the decomposition of the real exchange rate. We can see the necessity of decomposition of the real exchange rate later when we do comparative statics analysis in different cases, a medium economy with endogenous terms of trade and a small economy with exogenous terms of trade.

The main difference between small and large economies is whether the terms of trade are endogenous. In the Canada's case, there are two endogenous parts in the real exchange rate; both of them adjust when the economy is in disequilibrium. Two endogenous effects generate here, and thus the decompositions of the real exchange rate show the necessary attentions to the some specific variables in our research work. The next step is to introduce the functions in all markets.

### III.1.2 Features of the Behavioral Functions

All the behavioral equations are derived from the consumer and producer's optima; maximum utility under the budget constraint and profit under some certain production technology. There are a goods market and a financial market (capital market) in our model, but no money market. The reasons we have discussed a few previously in chapter II.

In reality, the neutrality of money is not a purely theoretical assumption. Recent work (McCandless and Weber, 1995 and Rolnick and Weber, 1997) finds money is neutral[5]. The main finding from their research is that money growth is not highly correlated with the real output but highly correlated with inflation, the changes of the

[5] McCandless and Weber (1995) found: (1) Growth rates of the money supply and the general price level are highly correlated for all three money definitions, for the full sample of countries, and for both subsamples. (2) The growth rates of money and real output are not corrected, except for a subsample of countries in the OECD, where these growth rates are positively correlated. (3) The rate of inflation and the growth rate of real output are essentially uncorrelated.

nominal price level under the fiat standard. The only function of the money market is to determine the nominal values in this general equilibrium system; this research work accordingly focuses on the real terms and excludes the money market.

The goods market, financial market and international trade are considered in the study. The market clearing equations are essential to the model; all market adjustments originate from the excess demand and supply somewhere, so there are no further adjustments of the real terms when the excess demand or supply is eliminated. The discussion starts from the supply side of goods market, including the supply function and its features. It then moves to the demand side of goods market, which is related to the consumer's behavior, the consumption and saving functions. After that, the equations in the financial market and balance of payment are explained.

First, we discuss the features of the supply function. If the production function is homogeneous of any degree, all the marginal equilibrium conditions for a general equilibrium model are functions of capital intensity, $k$, but in different forms. Let $Y(L,K) = X$ be the aggregate production function that is homogeneous degree of $\rho$, where $L$, $K$ and $X$ are labor, total capital and total output. We can transform $Y(L,K)$ as a function of the capital intensity, $k$, by the following procedure.

$$
\begin{aligned}
&Y(L,K) = X \\
&Y(\lambda L, \lambda K) = \lambda^{\rho} X \\
&\text{if } \lambda = \frac{1}{L}, \text{ then} \\
&X = L^{\rho} Y(1, \frac{K}{L}) = L^{\rho} y(k) \\
&Y(L,K) = L^{\rho} y(k) \qquad (6) \\
&\text{where } MP_L = L^{\rho} \frac{\partial y(k)}{\partial L} + \rho L^{\rho-1} y(k) \\
&MP_K = L^{\rho} \frac{\partial y(k)}{\partial K}
\end{aligned}
$$

From equation (6), the marginal productivities of the labor and capital are functions of capital intensity, $k$. For a general equilibrium model, all the marginal conditions determine the equilibrium values of the real endogenous variables in the economy. Similarly the relative prices of goods and marginal utility (MU) are related. Consequently, any influences of $k$ move the economy to a new equilibrium by all the complex adjustments through all the marginal conditions from all the markets. Conclusively, the whole theory of this approach is centered by the change of the capital intensity per capita of an open economy. The theory is complex due to the interrelationships among foreign trade partners—with the capital movements among countries.

Basically, technological progress, borrowing from foreign countries and the growth of population affect the capital intensity, denoted as $k$, in an open economy. Technological progress increases capital intensity. Borrowing from the outside of the economy to finance consumption or investment has different effects on capital intensity: for consumption, it decreases the capital intensity in the future, because the payment of the debt and interest reduce the wealth of the economy in the future, and for investment,

it increases the future capital intensity by the net returns of the investment after paying off the debt and interest to the foreign country.

This is like the consumer's intertemporal decisions of borrowing over different periods to finance either investment or consumption to optimize his utility under a endowment constraint. Such kind of consumer's intertemporal decisions can be extended to an intertemporal decision of a country. As a rational assumption, more investments do enhance capital intensity, that is, wealth, of an economy; in other words, it reaches a higher social utility level. Whether the consumer can reach a higher utility level, more wealth, depends on the purposes of borrowing. Borrowing from the foreign country to finance current consumption is actually borrowing from future consumption, so the utility level is worse by paying off the debt and interests compared to the utility level without any borrowing. Borrowing to finance the investment actually expects the positive returns from the investment after paying off the debt and interests to reach a higher utility level, wealthier. The resources of investment either from the borrowing from the foreign countries or from less consumption, more savings, usually can stimulate a wealthier economy—change the total endowments of an economy. A wealthier economy, the purchasing power of the domestic currency is more valued relative to the foreign, so the real exchange rate appreciates.

This concept is applied to our study, but we do not assume the country is a debtor or creditor; the country could turn out a debtor from a creditor and vice versa by more investment. The only assumption is the foreign debt will never exceed the total wealth of a country.

Borrowing from the foreign country usually is the capital movement internationally, because usually, labor does not move among countries. In a static economy, the effect of natural growth of population depends on whether it comes from immigrants or the natural growth of the resident population: immigrants usually enhance capital intensity, but natural growth of trends to reduce population reduces the capital intensity of the economy. The above conclusions are discussed in chapter III.2.2.

In conclusion, all the discussions are centered on the capital intensity and the foreign debt, which represents the evolutions of the country wealth.

For its goods market clearing condition is equation (7)

$$y(k;Z) = C(k,F,r;Z) + (dk/dt + nk) + CA(R,k,F,k';Z) \qquad (7)$$

In equation (7), $y(k;Z)$ is the aggregate supply function per capita with all the features we have mentioned already. $F, r$ and $Z$ are the foreign debt per capita, real domestic interest rate and fundamental determinants of the economy. $Z$ is the set of all the fundamental determinants of an economy, which we have mentioned, such as technological progress, borrowing from the foreign countries and more or less savings. They evolve the capital intensity, $k$, thus the real output changes. $C(k,F,r;Z)$ is the aggregate consumption per capita, and $(dk/dt + nk)$ is aggregate investment per capita (more discussions later), and $n$ is the net population growth rate. $CA(R,k,F,k';Z)$ is the current account per capita, and $k'$ is the foreign debt per capita. All these terms will be explained more later on. $k$ and $F$ are in the behavioral functions, because this study tries to capture the evolutions of the most essential endogenous variables operating in a dynamic economy.

The consumption function is derived from the consumer optimization, so it is a function of net wealth and social preference discount rate. Any influences that make wealth decrease cause the less consumption. If wealth, denoted as $k$, increases, consumption rises; if foreign debt, denoted as $F$, increases, consumption declines because of more saving, which is needed to pay off the future debt and interests, but the influence of the interest rate is ambiguous because of the substitution and income effects—but also depends on whether the consumer originally is a net debtor or creditor. The signs of $k, F,$ and $r$ in the consumption function are taken as the medium or long run effects and so are other functions.

$$C = C(k, F, r, r'; Z) \qquad \text{where } C_k > 0, C_F < 0, C_r = ? \qquad (8)$$

The saving function is the residual of total income less consumption. When capital intensity rises, savings increases because of the wealth effect; when the foreign debt increases, savings also increases because of the debt and interest payment in the future. The effect of interest rate in the saving function is ambiguous due to the income and substitution effects for a debtor or a creditor, which is the same reason as the consumption function

$$\begin{aligned} S &= y(k;u) - rF - C(k, F, r, r'; u) \\ &= S(k, F, r, r'; u) \qquad \text{where } S_k > 0, S_F > 0, S_r = ?. \end{aligned} \qquad (9)$$

$$S = I + CA \qquad (9')$$

From the identity, $Y = C + I + G + X - M$, derive the equation $(9')$. Given a rise of savings, it could be used for domestic investment and foreign investment, or foreign lending; given constant savings, a country could finance its investment by borrowing from the foreign country in an open economy.

The investment function is derived from the applied optimal control theoroy, the feedback control (dynamic programming) intertemporal optimization of Infante and Stein (1973). Capital intensity is capital stock over effective labor, $k = K/L$. If we take total differential of $K$ and divided by $L$, we can get the following equation.

$$\frac{dK}{L} = dk + k\frac{dL}{L}$$

$$I = \frac{\frac{dK}{dt}}{L} = \frac{dk}{dt} + k\frac{\frac{dL}{dt}}{L} = \frac{dk}{dt} + nk \tag{10}$$

$nk$ is an adjustment factor, because the concept here is real investment per effective worker. The investment is a function of the marginal productivity of capital and the real interest rate. It is similar to the Tobin $q$-ratio, in which $q = f'(k;u)/r$ and if $q > 1$, it means the expected returns will exceed the investment cost—investment will increase till the marginal productivities of $k$ equals $r$; if $q = 1$, it means the expected returns will be equal to the investment cost—investment will stay the same; $q < 1$, it means the expected returns will not exceed the investment cost—investment will decrease until the marginal productivities of $k$ equals $r$.

$$I = I(q) + nk = I(k, r; u) \qquad \text{where } q = \frac{f'(k;u)}{r}; I_k < 0; I_r < 0. \tag{11}$$

Basically, we do not need any information related to the initial status, like production function, capital stock and the target capital stock, compared to the investment function derived from the optimal control, which is derived from the Infante and Stein's (1973) paper and called perfect foresight.

The balance on goods and services is a typical function of exports and of imports.

$$
\begin{aligned}
CA &= \text{exports - imports} \\
&= X(R, k'+F; Z) - M(R, k-F; Z) \\
&= CA(R, k, F, k'; Z) \qquad (12)
\end{aligned}
$$

where $\mathrm{CA}_R > 0, \mathrm{CA}_k < 0, \mathrm{CA}_F < 0, \mathrm{CA}_{k'} > 0.$

Exports are usually a typical function of real exchange rate, foreign wealth and fundamental determinants—and so are imports as a function of real exchange rate and net domestic wealth. It is understandable how the real exchange rate and wealth operate in the export and import functions here as they do in the Keynesain model. For instance, if the savings rate surges, then import demand shrinks in the medium run, but in the long run, net wealth will increases—and import demand will increase, too.

In an open economy, a country can stimulate the economic growth by international trade to reallocate the wealth among countries. A current account surplus means that a country, a net foreign lender, exports its current consumption and imports its future consumption; a current account deficit means that a country, a net foreign borrower, imports its current consumption and exports its future consumption. When a country, a net foreign lender, gets paid off the debt, the economy becomes wealthier; when a country, a net foreign borrower, pays off its debt, the economy becomes poorer. Apparently, we can take a negative sign of the current account as a proxy of the foreign debt status in the study.

The debt flow function comes from the flow of the debt stock, D, and is defined as

$$F = \frac{D}{L}$$

$$\frac{dD}{L} = dF + F\frac{dL}{L}$$

$$\frac{\frac{dD}{dt}}{L} = \frac{dF}{dt} + F\frac{\frac{dL}{dt}}{L} = \frac{dF}{dt} + nF$$

since $I - S + CA = 0$,

and $CA + \frac{dF}{dt} + nF = \text{Balance of Payments} = 0$, so

$$\frac{\frac{dD}{dt}}{L} = \frac{dF}{dt} + nF = I - S = -CA = L(k, F, r; Z) \qquad \text{where } L_k < 0; L_f < 0; L_r < 0 \qquad (13)$$

$CA$ is the current account surplus, $X - M$. Equation (13) is the debt function, which is the same function as the current account with opposite signs of the variables. The sum of balance of payments is always equal to zero. A current account surplus implies a rise of foreign credit; a current account deficit implies an increase of foreign debt. From a model stability assumption, the foreign debt cannot explode, because the total debt could never exceed the total wealth of an economy. Any borrowing must be paid by future savings, so a net debtor could possibly turn out a net creditor if the borrowing is to finance the investment.

For a large economy, any real long-term interest rate differential is eliminated shortly by capital flows, because both economies jointly decide the world interest rate; it is just the wealth redistributions by borrowing within two big economies, and borrowing to finance either investment or consumption can not impact the real long-term interest rate. Therefore, there is no real interest rate variable in the debt function. In a small country case, usually, it can borrow as much as it wants with no influences of the real

long-term interest rate, and just have to pay the higher interest rate, due to risk premium. A higher interest rate is necessary to attract capital inflows in a small economy.

All the variables and functions have been discussed, so we combine all these functions to establish models for Taiwan and Canada. From the structural models, we can solve the endogenous variables, which also captures the dynamic relationship with other endogenous variables. After deriving the theoretical solutions, we estimate the regressions of the endogenous variables under the hypothesis that the endogenous variables respond to the evolutions of fundamental determinants. We have to use the estimated parameters of the regressions to do the dynamic forecasting for deriving the NATREX. All the work needs a lot of econometrics skills.

### III.1.3 The NATREX Structural Model

Combining all the behavioral functions to establish the NATREX structural models. Equations (14) and (15) are the goods market clearing conditions for Canada. Canada has influence on the goods market, but no influence on the world interest rate. Canada can jointly determine the real exchange rate and quantity in world goods market, so equations (14) plus (15) is the world goods market clearing condition, no excess demand in world goods market.

Equations (14′) and (15′) are the goods market conditions for Taiwan. They are the clearing equations for the nontradable goods markets. In a small open economy, the tradable goods market is always in equilibrium—the small economy can export and import tradable goods as many as it can, because of the perfect elasticity of the world export supply and world import demand, the exogeneity of the terms of trade. If there is any excess demand in the goods market, it will just reflect in the nontradable goods

market by adjusting the relative price ratio between the nontradable and tradable goods to reach a new steady state. The rest of the world goods market is absent here. $(1-m)I(q)$ is the fraction of the investment by using the domestic goods. Equation (15″) for Taiwan is the current account surplus less the interest payments on the real foreign debt. $mI(q)$ is the fraction of the total investment by using imported goods. This is in a small economy case; we can distinguish the nontradable and tradable goods markets due to the exogenous terms of trade.

Equation (16) defines the real exchange rate for Canada, because there are two endogenous parts in the real exchange rate, which is discussed previously. Equation (16′) is the decomposition of the real exchange rate for Taiwan—and in a small open economy, we also estimate the relative price ratio between the nontradable and exportable goods. But we could not get the relative price ratio directly, we have to use $R_n = 1/(RT)$ to approximate it.

## 1. *The NATREX Structural Model for Canada*

*Goods market:*

$$y(k;e) = C(k,F,\bar{r};Z) + (dk/dt + nk) + CA(R,k,F,k';Z) \qquad (14)$$

$$GDP' = C' + I' - CA(R,k,F,k';Z) \qquad (15)$$

*Real exchange rate:*

$$R = NP'/P = (1/T)^{(1-\beta'-\beta)}(R_n)^{(-a)}(P_n'/P_2')^{\alpha'} \qquad (16)$$

*Investment equation:*

$$dk/dt = I(q) \qquad (17)$$

$$I = I(q) + nk = I(k,r;e)$$

$$I_k < 0, I_r < 0, I_e > 0 > 0 \qquad (18)$$

*Capital inflow:*

$$dF/dt = I - S - nF \qquad (19)$$

*Savings equation:*

$$S = S(k,F;Z) \quad S_F > 0,\ S_k > 0 \qquad (20)$$

*Risk premium:*

$$r = r' + h(F) \qquad h_F > 0 \qquad (21)$$

## 2. *The NATREX Structural Model for Taiwan*

*Goods market clearing = balance in non-tradable goods market:*

$$(I - S) + CA = 0 \tag{14'}$$

$$C_n(R_n, k - F; Z) + (1 - m)I(q) - Q_n(R_n, k; e) = 0 \tag{15'}$$

*Current account:*

$$CA = Q_1(R_n, k; e) - mI(q) - C_2(R_n, k - F; Z) - r'F \tag{15''}$$

*Real exchange rate:*

$$R = NP'/P = (1/T)^{(1-\beta'-\beta)}(R_n)^{(-a)}(P_n'/P_2')^{\alpha'} \tag{16'}$$

*Investment equation:*

$$dk/dt = I(q) \tag{17'}$$

$$I = I(q) + nk = I(k,\ R_n, r, T, e)$$

$$I_k < 0, I_{R_n} < 0, I_r < 0, I_T > 0, I_e > 0 \tag{18'}$$

*Capital inflow:*

$$dF/dt = I - S - nF \tag{19'}$$

*Savings equation:*

$$S = S(k, F; Z) \quad S_F > 0,\ S_k > 0 \tag{20'}$$

*Risk premium:*

$$r = r' + h(F) \qquad h_F > 0 \tag{21'}$$

Where:

$C_n$ = domestic nontradable goods consumption

$C_2$ = foreign tradable goods consumption for the domestic country

$GDP'$ = foreign GDP

$C'$ = foreign consumption

$I'$ = foreign investment;

$Q_n$ = domestic nontradable goods supply;

$Q_1$ = domestic tradable goods supply

$m$ = the fraction of investment goods from imported goods and fraction $(1-m)$ of nontradable goods

$q$ = the ratio of the present value of the stream of returns to an increment of capital relative to its supply price

$n$ = growth of effective labor

$I$ = real investment per worker

$S$ = savings per worker

$r(r')$ = domestic (the US) real long-term interest rate

$h(F,t)$ = the risk premium function

$R$ = actual real exchange rate, the price of foreign goods in terms of domestic goods

$R_n$ = relative price between the nontradable and tradable goods

$P$ = Taiwan (Canada) GNP deflator $P'$ is the US GNP deflator

$k$ = capital per worker (capital intensity)

$F$ = real foreign debt per worker

$Z = (T, s, e, r')$ = fundamental determinants

$T$ = terms of trade

$s$ = the social time preferences (average social propensity to consume)

$e$ = productivity parameter, and $e = (e_n, e_t)$ for nontradable and tradable goods' productivity parameters

The investment functions for Taiwan and Canada, equation (17)[6], (17′) and (18) (18′), capture the Tobin $q$-ratio theory: the capital value of an asset relative to its supply price.

Equations (19) and (19′) are the rates of change of the foreign debt per effective worker derived from the investment less savings and $nF$ or the current account less $nF$. In the NATREX models, savings and investment behaviors are independently decided. Due to the social consumption (private plus government consumption per worker) behavior is a function of the relative price (but not real exchange rate), capital intensity, and foreign debt. From equation (20) and (20′), saving is a residual of income less consumption and empirical evidence found that savings is not a function of relative prices or the real exchange rate[7].

The portfolio balance conditions are equation (21) and (21′). In empirical work, we test whether there is an interest rate differential existing between two countries, like Taiwan-US and Canada-US and if the interest rate differential converges to a certain level. In both cases, the US interest rate represents the world real interest rate; if both economies want to attract capital inflows, they have to pay the risk premium of the borrowing. First, we have to test whether the US interest rate Granger causes the domestic interest rates, and secondly, if it does, does the domestic interest rate converge to the US interest rate or converge to some certain level?

[6] Infante and Stein (1973) derived the investment function: they used a dynamic programming to obtain suboptimal feedback control (SOFC).

[7] The empirical result came from Laursen and Metzler (1950).

From the dynamic structural models, the endogenous variables for Canada's case are the real exchange rate, capital intensity and foreign debt; for Taiwan's case, there is one more endogenous variable, the relative prices. Solving the model results in solutions of all the endogenous variables as reduced forms of all the exogenous variables, which are savings rate, world interest rate and productivity parameter, etc. Any changes in the exogenous variable can affect all the endogenous variables by all the interactions and transformations among the markets.

However, the goal of this research is not seeking the equilibrium value of the real exchange rate, $R^*(Z)$, or estimating every single equation of the structural models, but trying to capture the dynamics of an economy—the peculiarities of the real exchange rate trend are evolving because of the varying fundamental determinants and cointegrated with other endogenous variables in the economy. The main feature of a dynamic economy is the nonstationarity of the fundamental determinants, $Z$. If they are not stationary, then all endogenous variables could not be stationary, either. It is not likely that we can find the equilibrium value of the real exchange rate under the nonstationary $Z$. Therefore, we are more interested in equation (22) than in equation (23), with a dynamic concept, in our research instead of seeking the equilibrium values of the real exchange rate, equation (23).

$$R(k_t, F_t; Z_t) \tag{22}$$

$$R^*(k^*(Z), F^*(Z); Z) = R^*(Z) \tag{23}$$

$Z = (s, e_t, e_n, r')$, which means the set of all the fundamental determinants, and also includes the terms of trade, $T$ for a small country. $R(k_t, F_t; Z_t)$ is the NATREX obtained from the models under a dynamic structure; they are not the long-run equilibrium values,

like equation (23). Although we are not seeking the long run equilibrium, the transmission mechanism in equation (22) is that the spontaneous changes of fundamental determinants occur first. It is necessary that we have to assume the endogenous stability conditions of the investment and foreign debt to make sure the economy is approaching a new equilibrium while the capital intensity and foreign debt evolve. The reason is through the adjustments of the capital intensity and foreign debt, that is, caused by the international trade, resources reallocate among countries. Since they are the endogenous precursors that respond to the changes of fundamental determinants first, we have to assume that the trajectories of these two variables must meet the dynamic stability conditions for guaranteeing that the economy is on the trajectories of approaching the equilibrium. First, marginal productivity of capital is decreasing while the capital stock increases. Secondly, the maximum amount of debt for a country to borrow abroad is its total output, total wealth; the foreign debt cannot borrow without any limitations, so if the foreign debt arises, it is associated with an increase of the future savings, thereby preventing the foreign debt from exploding. This is what we called endogenous stability conditions. Mathematical expressions are ignored here due to the great details in the original NATREX papers.

Two dynamic structural models are built on the behavior functions and market clearing conditions, which have been introduced already. One is for Taiwan, which is a small economy, and the other one is for Canada, which is a medium economy. The main difference relating to the influence each has is in the goods and financial markets. Taiwan has no influence on either markets, but Canada influences the goods market, but not the financial market. Under such circumstances, the endogenous variables in two

cases are different due to economy sizes. The NATREX should be defined first, and some comparative statics analyses are necessary to understand the transmissions in the markets under the NATREX approach.

## III.2 Defining the NATREX and Comparative Statics Analysis

### III.2.1 Defining the NATREX

The NATREX is defined as " the *equilibrium real exchange rate that clears the balance of payments in the absence of cyclical factors, speculative capital flows, and movements in international reserves"* (Stein, Allen and Associates 1995, p.6). This concept comes from Ragnar Nurkse (1945), who defined the equilibrium rate of exchange as a long run—five to ten years—concept; the period must be long enough to eliminate cyclical fluctuations, so it could keep the balance of payments in equilibrium.

> The only satisfactory way of defining the equilibrium rate of exchange is to define it as that rate, which over a certain period of time, keeps the balance of payments in equilibrium...We make long enough to eliminate seasonal fluctuations...to eliminate "cyclical" fluctuations as well...This would give us a period between five and ten years... (Nurkse 1945, p.5)

The assumption is that the economic system, one of simultaneous equations, is always on the trajectory towards the steady state.

The NATREX approach emphasizes the real exchange rate in a long run context without any short run or speculative factors. The NATREX can be explained by the equation (24). The actual real exchange rate that we observe in the market carries a lot of information, including short run, speculative, cyclical and trend factors. We can split the

actual real exchange rate into three elements, which are $[R_t - R(k_t, F_t; Z_t)]$ , $[R(k_t, F_t; Z_t) - R^*(Z_t)]$, and $R^*(Z_t)$ in equation (24):

$$R_t(k_t, F_t; Z_t, u_t) = [R_t(k_t, F_t; Z_t, u_t) - R_t(k_t, F_t; Z_t)] + [R_t(k_t, F_t; Z_t) - R^*(Z_t)] + R^*(Z_t)$$
$$= N_t P_t'/P_t \qquad (24)$$

$u_t$ is the short run disturbances from anywhere in the economy. $R_t(k_t, F_t; Z_t, u_t)$ is the actual real exchange rate, which carries the information from the short run, medium run and long run; it is also the only observation available to extract the medium run or long run information for the NATREX. We see the slight difference is a short run factor in the actual real exchange rate. An increase in $R_t$, either the actual and the NATREX or the equilibrium real exchange rate, means a real devaluation of the home currency, and a decrease means a real appreciation of it. The change for the actual real exchange rate comes from the three elements that comprise in equation (24). $[R_t(k_t, F_t; Z_t, u_t) - R(k_t, F_t; Z_t)]$ is the deviation between the actual real exchange rate and the NATREX—$R(k_t, F_t; Z_t)$. The actual real exchange rate we observe is influenced by both the short run factors and long run factor. So $[R_t(k_t, F_t; Z_t, u_t) - R(k_t, F_t; Z_t)]$ is the short run deviation from the trend, it could be positive and negative. Basically, the actual exchange rate approaches the NATREX whether it is above or below the NATREX. When there is no deviation, the NATREX is the equilibrium real exchange rate.

The second term is $[R(k_t, F_t; Z_t) - R^*(Z_t)]$, which reflects the deviation between the NATREX and steady state value of the real exchange rate, $R^*(Z_t)$. The actual real exchange is always moving toward the NATREX, a moving equilibrium real exchange

rate, and the NATREX is always moving toward the long run equilibrium, $R^*(Z_t)$. It is hard to say whether the NATREX equals $R^*(Z_t)$, because all the fundamental determinants, $Z_t$, are not stationary. The third term, $R^*(Z_t)$, is the equilibrium value of the real exchange rate, which is solved by the general equilibrium model as a function of all the exogenous variables. Is it possible we can find the real equilibrium real exchange rate, $R^*(Z)$? If yes, how long does the steady state last under a dynamic status in internal and external parts of an economy, especially for a growing economy? What if the sample period we use do not cover any information of the equilibrium? Under such circumstances, the necessity of seeking the equilibrium real exchange rate is not the essence of our research work.

The viewpoint here is what is the dynamic relationship among the endogenous and exogenous variables? This kind of equilibrium relationship we are seeking by a time series analysis does not mean the same equilibrium in economics theory. This is why we use the time series analysis to proceed this study, and all the details are explained in the pretests part. As a matter of factor, we are not sure where the NATREX is, because the economy is evolving—we may just capture the observations on the trajectory toward the equilibrium, and the trajectory might be varying by responding the changes from the dynamic fundamental determinants. Besides, we just have the actual real exchange rate, which is also a function of all endogenous and exogenous variables with short run disturbances more.

The actual real exchange rate is not always equal to the NATREX value due to some cyclical, speculative and irregular factors in the short run. The NATREX that has been estimated just carries the medium run or long run information, because we have

dealt with the data by moving average method to dampen the short run factors; we are just interested in which factors affect the trend behavior of the real exchange rate. This is why we see the simulated NATREX slightly differs from the actual real exchange rate; there is just the trend factor and we are just interested in which factors are dragging the trend.

The equilibrium real exchange rate is determined by all the real terms such as the marginal conditions, marginal propensity to consume, technology level and the endowment in the economy. These real terms mainly drive the real exchange rate more than short run disturbances do. It is substantially more interesting and important to know the significant determinants of the real exchange rate in every case, and how do these determinants operate to lead the real exchange rate toward the equilibrium? This is the goal of this research, explaining these questions. In general, the NATREX model fits the data quite well under the empirical test of the model structure stability. We will explain in the following sections. And now we analyze comparative statics of how fundamental determinants affect the real exchange rate.

### III.2.2 Comparative Statics Analysis of Fundamental Determinants

Some comparative statics analyses here explain all the interactions among all the markets; we then can know how a spontaneous change of the fundamental determinants affects the endogenous variables. We use the goods and financial markets to decide the equilibrium values of the real exchange rate, NATREX, and interest rate; when two markets reach equilibrium, it goes without saying the money market reaches equilibrium as well. From the definitions of the NATREX, we know it is not observed easily; we can just observe the actual real exchange rate only, but we can be sure that the actual real

exchange always move toward the NATREX, and the NATREX always moves toward the equilibrium real exchange rate only.

As a result, we cannot recognize which stage of the actual real exchange rate is. The comparative statics are being discussed how the NATREX adjusts from the medium run to the long run equilibrium; we do not discuss short run disturbances here. We are just interested how the NATREX evolves with the capital intensity and foreign debt from the medium run to the long run. For a medium economy, we do not have to distinguish the goods market into the tradable and nontradable goods sectors, because the economy can jointly decide the world goods price; the terms of trade and relative prices, both are endogenous to the real exchange rate, so we can observe the separate adjustments from these tow endogenous variables.

Figure 1 shows how the goods and capital markets determine the equilibrium real exchange rate and how the NATREX adjusts to the equilibrium real exchange rate. The assumption here is to ignore the short run disturbances, so the real exchange rate here is not the actual real exchange rate we observe in the market, but the equilibrium real exchange rate instead. The *IS* curve is the equilibrium path of market clearing conditions, aggregate goods supply equal aggregate goods demand.

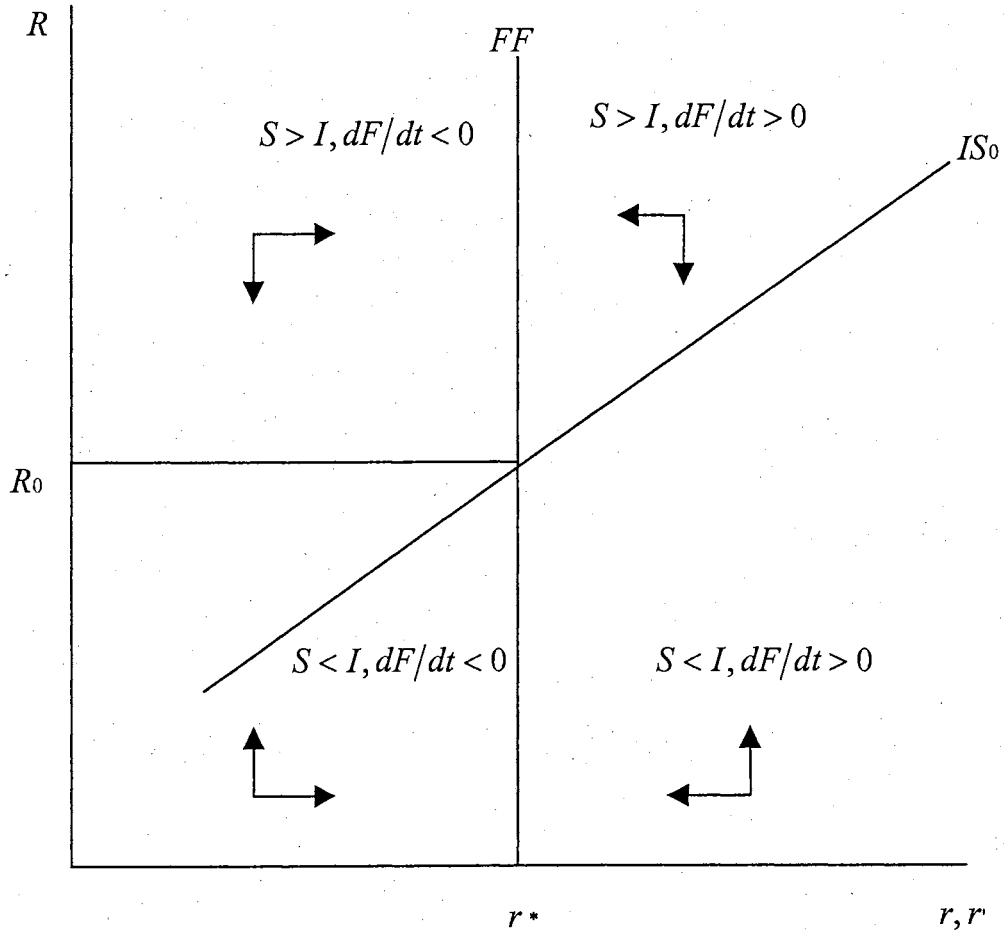


Figure 1. Determination of NATREX and Real Interest Rate

It is positively sloped, because a higher, cheaper, NATREX is associated with a current account surplus, implying an excess demand, $S < I$, in the goods market and capital outflows in the financial market; in order to keep the goods market in equilibrium needs a relatively higher interest rate to eliminate the excess demand in the goods market by reducing investment and stopping the capital outflows. A lower, more expensive, NATREX is associated with a current account deficit, which implies there is excess supply, $S > I$, in the goods market, thus a lower interest rate level is necessary to eliminate the excess supply in the goods markets by stimulating more investment.

The $FF$ curve is the real long-term interest rate that keeps a portfolio balance for the domestic country. Small and medium economies, they are not able to influence the world real interest rate. Hence, the $FF$ curve is vertical; the world real interest rate is also the domestic real interest rate level. The left area of the $FF$ curve, that the current real domestic interest rate is lower than the real world interest rate causes capital outflows till the real domestic interest rate converges to the real world interest rate. An interest rate differential in the medium run causing by the spontaneous changes of the fundamental determinants converges to zero in the long run; the domestic real interest rate converges to the world real interest rate in the long run. Under this assumption, we take world real interest rate as the domestic real interest rate, also as an exogenous variable. In practice, we have to test the convergences of the domestic real interest rate to the world real interest rate.

Basically, the NATREX is mostly adjusted by the goods market, and the real domestic interest rate is mostly adjusted by the financial market, but the entire system determine both endogenous variables simultaneously, and we ignore the feedback effects

within the markets. Accordingly to the definition of the real exchange rate, the equilibrium values of the real exchange rate and real interest rate imply the general equilibrium system reaches the steady state. Both cases in this study are not able to influence the world real interest rate, thus the world real interest rate are exogenous.

In figure 2, area 1, $S-I<0$ and $dF/dt>0$, so there are an excess demand, a current account deficit, in the goods market and capital inflows in the financial market. The adjustments in this area are the NATREX to appreciate for eliminating the excess demand in the goods market and the real domestic interest rate to decline to the real world interest rate level for ceasing the capital inflows. In area 2, $S-I<0$ and $dF/dt<0$, so there are an excess demand, a current account deficit, in the goods market and capital outflows in the financial market. The adjustments in this area are the NATREX to appreciate for eliminating the excess demand in the goods market and the real domestic interest rate to surge to the real world interest rate level for ceasing the capital outflows. In area 3, $S-I>0$ and $dF/dt<0$, so there are an excess supply, a current account surplus, in the goods market and capital outflows in the financial market. The adjustments in this area are the NATREX to depreciate for eliminating the excess supply in the goods market and the real domestic interest rate to surge to the real world interest rate level for ceasing the capital outflows. In area 4, $S-I>0$ and $dF/dt>0$, so there are an excess supply, a current account surplus, in the goods market and capital inflows in the financial market. The adjustments in this area are the NATREX to depreciate for eliminating the excess supply in the goods market and the real domestic interest rate to decline to the real world interest rate level for ceasing the capital inflows.

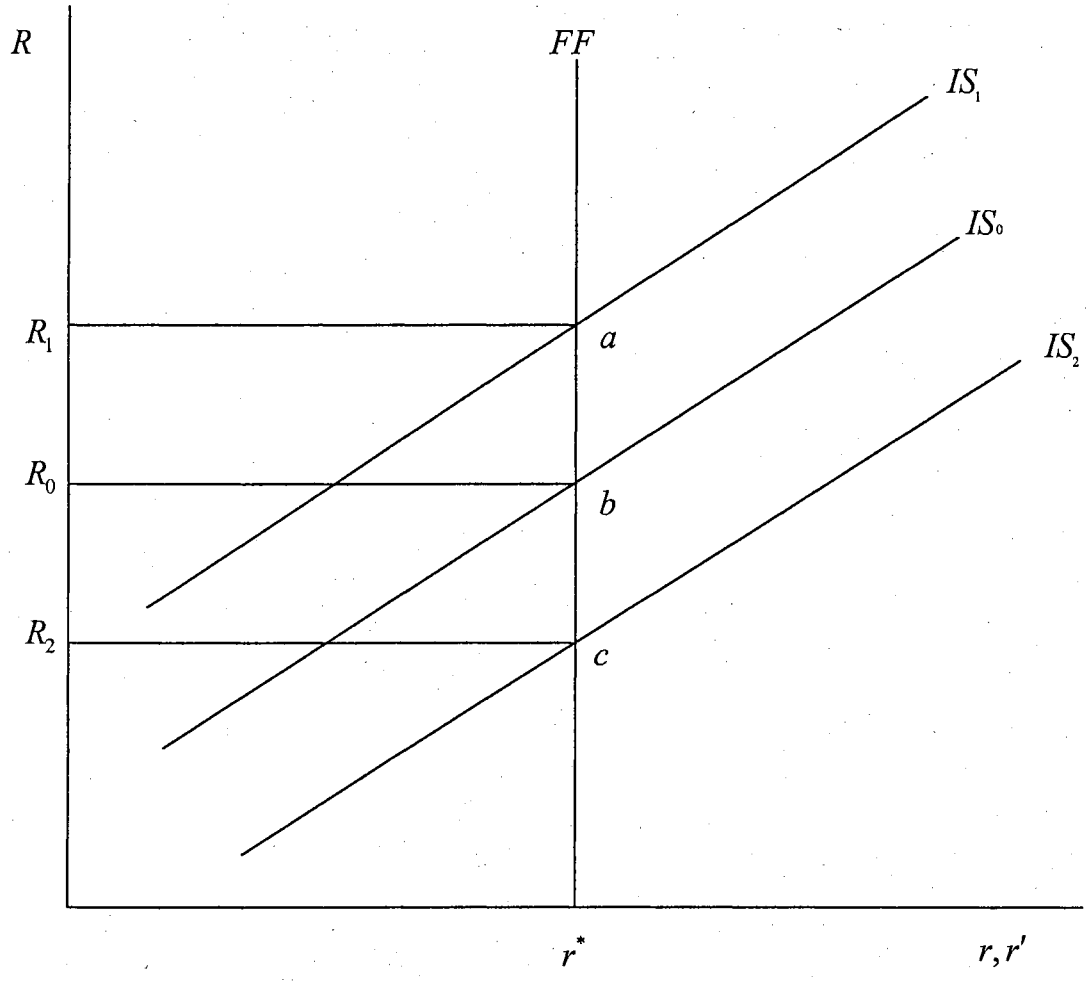


Figure 2. Comparative Statics of NATREX

By figure 2, we can do some comparative statics about how the goods and financial market operates to achieve a new equilibrium, and then how the real exchange rate, capital intensity and foreign debt evolves from the medium run to long run by responding the disturbances of the fundamental determinants. In figure 2, $R_0$ and $r^*$ are the original equilibrium values of the real exchange rate and world real interest rate—and the domestic real interest rate—which are determined by the $IS_0$ and $FF$ curves.

If there is a spontaneous increase in the savings rate, there is excess supply as demand falls relative to aggregate supply; because of less consumption, $IS_0$ shifts to $IS_1$. At the original real exchange rate, $R_0$, interest rate falls and causes capital outflows—and foreign debt decreases—so the real exchange rate depreciates. Capital outflows stop when the real current interest rate converges to the world real interest rate, $r^*$; as it lies below, there is more investment. In the medium run, on the convergences of the real interest rate, domestic investment increases, the foreign debt decreases, the real exchanges rate depreciates, and there is a current surplus.

In the long run, the foreign debt is paid off, so the total wealth of the economy increases by the amount of the foreign interest rate payment. Total wealth increases by the amount of the interest rate payment from the foreign country, so the current wealth level is higher than the original level at $R_0$ and $r^*$. $IS_1$ curve shifts back to $IS_0$, or even to $IS_2$ due to the higher wealth level. In conclusion, the new equilibrium real exchange rate is associated with an appreciation of the real exchange rate, a same interest rate level, more investment and consumption than before. As for the current account, it relies on the reality such as if the domestic country was a net debtor, it could turn out a net creditor, or

still a net debtor with less debt. But From the above analysis, a higher savings rate can stimulate an economy growth rate in the long run.

The NATREX at the beginning for an increase in the savings rate, but appreciate back to the original level or further more in the long run according to the interest rate payment from the foreign country. The comparative statics analysis can be obtained by taking partial derivate of equation (22) with respect to $s$ with an assumption of other fundamental determinants remained constant in the $Z_t$.

$$\frac{dR(k(s),F(s);s)}{ds} = \frac{dR(k(s),F(s);s)}{ds} + \left(\frac{\delta R}{\delta k}\frac{dk}{ds} + \frac{\delta R}{\delta F}\frac{dF}{ds}\right) \qquad (25)$$

$$(+) \qquad (+) \qquad (-)$$

In a general equilibrium model, all the markets in an economy are interrelated; all the markets operate simultaneously to determine the steady state values of the endogenous variables. In the medium run, the economy adjusts its capital intensity, foreign debt, interest rate, real exchange rate, and current account surplus for responding the changes of the fundamental determinants. It keeps adjusting till it achieves a new equilibrium.

A surge of productivity is another resource of spontaneous changes from the fundamental determinants. As a matter of fact, a rise of productivity mixes two effects, that is, an improvement of the input qualities and technological progress, but both effects increase the capital intensity. It is a real shock of the supply side for the goods market. As we have discussed theories, for a medium or large economies, it is not feasible to recognize where the rise of productivity comes from the nontradable goods sector or from the tradable goods sector by the observations; a medium or large economy can reach equilibrium from disequilibrium by adjusting the domestic relative price, which is related

to resources reallocation between the nontradable and tradable goods sectors, and terms of trade, which is related to the world goods supply and demand. All the observations got from the market carry two endogenous effects, so we could not trace where the rise of productivity occurs in the nontradable goods sector or in the tradable goods sector; it is different from the small economy case, which there is just only endogenous part in the real exchange rate, so we can distinguish the effect of the relative price, which allocates resources between the nontradable and tradable goods sectors, from the observations.

There is a slightly different situation from the previous case; we have to discuss this by different sizes of economies. For a medium or large economy, the relative price and terms of trade are both endogenous for the system. We can just discuss net effects from the observations, no any further details of the distinctions between the nontradable and tradable goods sectors. For a medium and large economy, in the medium run, total investment exceeds total saving in association with a higher domestic interest rate to cause capital inflows, so a deficit occurs in the current account, the real exchange appreciates, and foreign debts rise because of capital inflows. It is just like the $IS_0$ shifts to $IS_2$ in figure 2. Capital intensity is increasing, so the investment is declining gradually due to the increasing capital inflows with a decreasing the marginal productivity of capital; the initial deficit in current account is reduced, so as the foreign debt.

In the long run, capital intensity increases—total domestic wealth increases—and foreign debt decreases or even foreign credit increases—there is current account surplus to appreciate the NATREX in the long run, but there are two effects generating here: the lower foreign debt appreciates the real exchange rate, and the higher capital intensity

depreciates the real exchange rate because of more import demand. But if the productivity rises not as much to make the country, initially a foreign debtor, convert into a foreign creditor eventually, there is still a current account deficit; the first effect still depreciate the domestic real exchange rate in the long run. Whether the real exchange rate appreciates in the long run depends on the net effect: $IS_2$ might shift back a few but not to the original level, $IS_0$, or shift further more than $IS_2$ level. If there is a rise of productivity, we take partial derivate of equation (22) with respect to the $e$ under the assumption of other fundamental determinants in the $Z_t$ staying constant. This is equation (26)

$$\frac{\partial R(k(e),F(e);e)}{\partial e} = \frac{dR(k(e),F(e);e)}{de} + \left(\frac{\delta R}{\delta k}\frac{dk}{de} + \frac{\delta R}{\delta F}\frac{dF}{de}\right) \qquad (26)$$

(-) (+) (-)

For the theory, we define Canada as a medium economy, which has influences on the terms of trade in the world goods market, but no influence on the world real interest rate. Amano and Norden (1995) tend to take the terms of trade as an exogenous variable of the Canadian real exchange rate for testing the how the real exchange rate respond to the shocks from the terms of trade. Basically, the authors separate the overall terms of trade into the non-energy terms of trade and energy terms of trade, because Canada is a net exporter of resource-based commodities and a net importer of manufactures. The empirical results: an improvement of non-energy terms of trade, a rise of non-energy commodity price, appreciate the Canadian real exchange rate, but an improvement of energy terms of trade, a rise of energy commodity price, depreciates the Canadian real exchange rate. The results are not both right for a small economy. They did not try the

overall terms of trade, so we cannot conclude the terms of trade is absolutely exogenous in Canada's case—so we can take the terms of trade as an exogenous variable.

The above discussion related to a medium or a large economy with endogenous terms of trade, but if the economy does not have a very big influence on the terms of trade, which implies a rise of productivity does not change the world goods supply that much or even no, we still can do some further analysis about a rise of productivity. Under exogenous terms of trade, the only adjustment factor in the real exchange rate is the relative price between the nontradable and tradable goods, so we can recognize where the rise of productivity occurs in the nontradable or tradable goods sectors.

For a small economy, there is one more adjustment of the relative price of the tradable and tradable goods markets, because the perfect elasticity of the world supply, an exogenous terms of trade. Figure 3 illustrates the adjustment of the relative price for Taiwan's case or for the weak endogenous terms of trade case. The previous discussion about the comparative statics of a rise in the savings rate is a general analysis, but for a small economy, there are some additional adjustments in nontradable and tradable goods markets.

$D_n$ and $Q_n$ are the typical real demand curve and supply curve for the nontradable goods; the supply is a positive function of the relative price, and demand is a negative function of relative price. $R_n$ is the relative price, $R_n = P_n / P_1$. Any disturbances from demand side or supply side affect $R_n$, therefore the supply curve and demand curve shift. $D_n(0)$, $Q_n(0)$ and A point are the original level of the nontradable goods market.

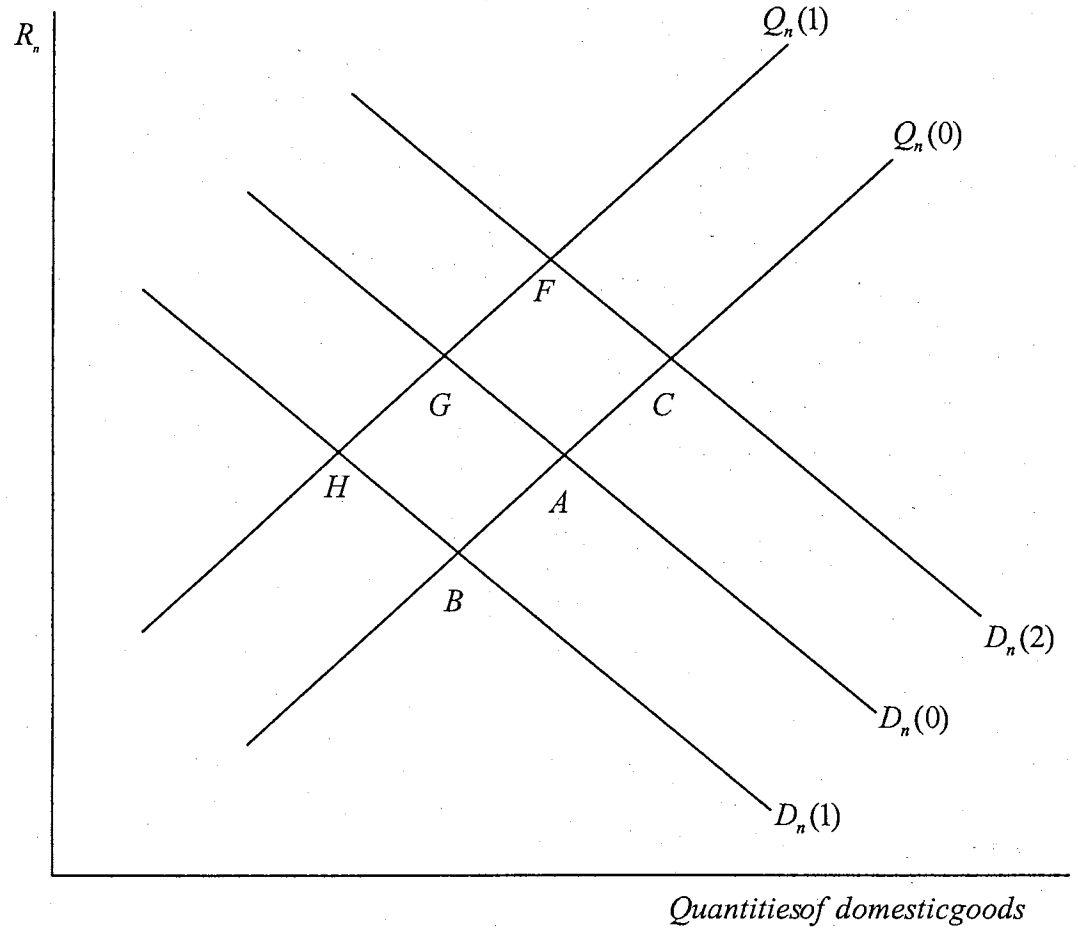


Figure 3. Determination of Relative Price

We derivate the $R_n = 1/RT$ from equation (5) indirectly for a small economy with exogenous terms of trade, $T$. From equation (22) and (23), $R_n$ can be identified as a function of the endogenous capital intensity, foreign debt and all the fundamental determinants as well as equations (27) and (28).

$$R_n(k_t, F_t; Z_t) = \frac{P_n}{P_1} = \frac{1}{TR(k_t, F_t; Z_t)} \tag{27}$$

$$R_n^*(k^*(Z), F^*(Z)) = \frac{P_n^*}{P_1^*} = \frac{1}{TR^*(Z)} \tag{28}$$

A rise in the savings rate reduces the demand for non-tradable goods from $D_n(0)$ to $D_n(1)$ in figure 3. The relative price between the nontradable and tradable goods declines from A to B—and the NATREX depreciates simultaneously—in the medium run. There are associating with a current surplus, capital outflows and a decline of foreign debts. The NATREX depreciation shifts the resources from the nontradable goods sector to the tradable goods sector. In the long run, same conclusion as the previous discussion, capital intensity increases and foreign debt decreases; total wealth increases to stimulate the nontradable goods demand from $D_n(1)$ back to $D_n(0)$ or even to $D_n(2)$. The influence of an increase in capital intensity depends on the characteristics of the non-tradable goods; if they are labor-intensive goods, an increase in capital intensity shifts the supply cure from $Q_n(0)$ to $Q_n(1)$. Under this case, the new supply curve and demand curve determines the new relative price, which is higher in the long run. If they are capital intensive goods, more capital intensity shifts the supply curve oppositely; the net effect of the relative price is ambiguous due to the a surging demand and supply.

Taking first partial derivative of equation (28) with respect to $s$ is the comparative statics result, equation (29). Since we derive $R_n$ by $1/RT$, the signs of $k, F,$ and $Z$ are just inverse of the signs of $k, F,$ and $Z$ in the real exchange rate. There are one direct effect from a rise in the savings rate and two other indirect effects—from a rise in capital intensity and a decline in foreign debt—to relative price.

$$\frac{\partial R_n(k(s),F(s);s)}{\partial s} = \frac{1}{T}\left(\frac{-\dfrac{\partial R(k(s),F(s);s)}{\partial s}}{(R(k(s),F(s);s))^2}\right)$$

$$= \frac{1}{T}\left(\frac{-\left(\dfrac{dR(k(s),F(s);s)}{ds} + \left(\dfrac{\delta R}{\delta k}\dfrac{dk}{ds} + \dfrac{\delta R}{\delta F}\dfrac{dF}{ds}\right)\right)}{(R(k(s),F(s);s))^2}\right) \tag{29}$$

In another case, a rise of productivity, the direct and indirect effects are quite different from the indirect and direct effects in an increase of savings rate. A rise of productivity can occur either in the nontradable goods sector or in the tradable goods sector. If it occurs in the tradable goods sector, the supply of the tradable goods increases because of the higher marginal productivity of capital in the medium run. In the medium run, there is a current deficit and an increase of foreign debt because of more investment to attract capital inflows. But in the long run, the resources will move to the tradable goods sector from the nontradable goods sector due to higher marginal productivity of capital. The supply of tradable goods rises, but the supply of the nontradable goods decrease to cause $R_n$ up. Since the terms of trade are exogenous, more exports make a current surplus and a less foreign debt—total wealth increases, so the demand of the nontradable goods rise. The relative price arises.

$$\frac{dR_n(k(e_t),F(e_t);e_t)}{de_t} = \frac{1}{T}\left(\frac{-\dfrac{\partial R(k(e_t),F(e_t);e_t)}{\partial e_t}}{(R(k(e_t),F(e_t);e_t)^2}\right)$$

$$= \frac{1}{T}\left(\frac{-\left(\dfrac{dR(k(e_t),F(e_t);e_t)}{de_t} + \left(\dfrac{\delta R}{\delta k}\dfrac{dk}{de_t} + \dfrac{\delta R}{\delta F}\dfrac{dF}{de_t}\right)\right)}{(R(k(e_t),F(e_t);e_t)^2}\right) \qquad (30)$$

The direct effect here has no influence, because the terms of trade are exogenous. The indirect effects are similar to the indirect effects in a rise of savings rate case—total capital intensity increases and foreign debt declines in the long run. Generally, the net effect of the change of the fundamental determinants to the relative price depends on the reallocation of the resources within the real sectors, resulted from the unequal marginal productivity capital or labor between the real sectors.

The effects of the changes of the fundamental determinants are quite different in Canada and Taiwan's cases from the empirical results. For a rise of the savings rate, the Canadian real exchange rate tends to appreciate, but the Taiwanese real exchange rate tends to depreciate because of a growing economy. An increase in productivity of the economy depreciates the Canadian real exchange rate, but appreciates the Taiwanese real exchange rate—the relative price goes up, so the productivity increases more in the tradable goods sector. More discussions are in the empirical work.

From the previous discussions, we can find that it is feasible to distinguish the different effects in comparative statics of one situation. The truth is the data we observe in the market, most of the time, carry the messy information from several spontaneous changes of the fundamental determinants, so seeking the long run equilibrium is not

feasibly easy in empirical work—all the endogenous variables are the reduced forms for the exogenous variables. The data just reflect a dynamic structure relationship of the exogenous and endogenous variables, so in empirical work, we need to make do some pretests to ensure all the exogenous and endogenous variables cointegrated with the same order of the time pattern, and then we can estimate the dynamic equations instead of estimating the reduced form of all the exogenous variables.

# CHAPTER IV

# PRETESTS, DATA, AND PRETEST RESULTS

## IV.1 Pretests

As a result of responding to spontaneously continuous changes in exogenous and endogenous real fundamentals, the NATREX is a moving equilibrium real exchange rate. The trajectories to the equilibrium correspondingly vary from time to time. This is why the absolute—or relative—PPP may not represent reality sometimes; it assumes that the mean and variance of the fundamental determinants and real exchange rate are independent of time, which implies no further changes in any of all the fundamental determinants. Thus the NATREX is a dynamic concept that is inconsistent with the PPP theory.

Basically, this essay applies a time series technique to a general equilibrium model for capturing the features of dynamics. A dynamic structural equation approach can remedy the shortcomings of the ordinary least squares (OLS) model, which ignores the behavior of the time series data itself and then has to find other ways to fix the problems. Two common problems of the OLS are autocorrelation and heteroskedasticity in the residuals. Besides, the time series analysis is more attractive than the static structural model due to its flexibility in the specification of the dynamic structure with lag terms in the equation, but it usually ignores the information that could be observed in the static

long run equilibrium. This matches the goal of our research work—we are not looking for a long run equilibrium value. We want to test the variables, with a linkage in a common trend, move toward the long run equilibrium.

The previous chapter developed a complete theoretical model and derived the endogenous variables. The focus of the NATREX approach is the continuously spontaneous evolutions of the fundamental determinants that result in a dynamic long run equilibrium relationship among the endogenous and exogenous variables by allowing short run deviations, which causes to a variety of difficulties in seeking the equilibrium exchange rate. In time series analysis, a long run equilibrium relationship is called a cointegrated relationship. That means all the variables have linkages in their stochastic trends and move dependently. It has quite a different meaning in economic theory. Generally, equilibrium in economic theory means a steady state for all the endogenous and exogenous variables. So, the first thing is whether the endogenous and exogenous variables are nonstationary time series and integrated at order one—after first difference of the data, they are stationary. And the second one is if they are nonstationary, they are cointegrated, called an equilibrium relationship that catches a stable long run relationship among endogenous and exogenous variables by allowing short run deviations from the long run equilibrium relationship.

This chapter deals with empirical matters—pretests and it ensures that the data have the features that have been emphasized in the theory; in the brief, some of the endogenous and exogenous variables are integrated at order one, and cointegrated with independent variables to produce stationary residuals. The Granger causality, unit root and cointegration tests for the time series data are conducted. The problem of using a

time series model is we have to avoid the spurious regressions, which usually have a high $R^2$ and coefficients that are significant, but with no economic meaning. Not only does it require a good theory, but also all the series must meet the features we need in the empirical work. The next step is to derive the basic time series equations that we will estimate, and introduce the pretests.

For Canada, the dependent variables are $R_t(k_t, F_t; Z_t)$, and the ratio of the current account surplus to GNP, denoted as $CURRENT$; for Taiwan, they are $R_t(k_t, F_t; Z_t)$ and relative price, denoted as $R_n(k_t, F_t; Z_t)$. We assume a simple dynamic and structural equation as follows. Both $R_t(k_t, F_t; Z_t)$ and $Z_t$ behave as autogressive processes in the equations due to the hypothesis of unit roots.

From the previous discussion, we have initially general forms of $R_t(k_t, F_t; Z_t)$, and the equilibrium real exchange rate, $R^*(Z)$, as a function of other endogenous and exogenous variables that are linearly cointegrated.

$$\begin{aligned} R_t(k_t F_t; Z_t) &= \alpha + \beta_1 R_{t-1} + (\beta_{21} s_t + \beta_{22} e_{t_t} + \beta_{23} e_{nt} + \beta_{24} r_t' + \beta_{25} T_t) \\ &\quad + (\beta_{31} s_{t-1} + \beta_{32} e_{t_{t-1}} + \beta_{33} e_{n_{t-1}} + \beta_{34} r_{t-1}' + \beta_{35} T_{t-1}) + \varepsilon_t \\ &= \alpha + \beta_1 R_{t-1} + \beta_2 Z_t + \beta_3 Z_{t-1} + \varepsilon_t \end{aligned} \tag{31}$$

Equation (31) is the basic equation that is estimated by the OLS. We subtract $R_{t-1}(k_t, F_t; Z_t, u_t)$ from both sides of it to get an error correction equation that is estimated by NLS.

When the economy reaches the steady state, $Z_t = Z_{t-1}$ and $E(DR_t) = 0$, because there are no changes in the fundamental determinants and real exchange rate. Hence it is appropriate to say $R^* = \gamma Z_{t-1} = \gamma Z_t$ when the system is in the steady state.

$$R^*(Z) = \left[\frac{\beta_2 + \beta_3}{1-\beta_1}\right] Z_t = \gamma Z_t = \left[\frac{\beta_2 + \beta_3}{1-\beta_1}\right] Z_{t-1} = \gamma Z_{t-1}$$

From the above relationship, we can derive the error correction equation for the NATREX; since we want to observe how the real exchange rate level responds to fundamental determinants, it is necessary to develop the level status of the real exchange rate like equation (32) and (32′) instead of just the percentage change of the real exchange rate, because we are concerned more about how the levels of the variables respond to each other.

$$\begin{aligned} R_t(k_t, F_t; Z_t) - R^*(Z) &= \beta_1 R_{t-1} + \beta_2 Z_t + \beta_3 Z_{t-1} + \varepsilon_t - \beta_1 R^*(Z) - \beta_2 Z_{t-1} - \beta_3 Z_{t-1} \\ &= \beta_1 (R_{t-1} - R^*) + \beta_2 (Z_t - Z_{t-1}) + \varepsilon_t \end{aligned}$$

$$\begin{aligned} R_t(k_t, F_t; Z_t) &= R^*(Z) + \beta_1 (R_{t-1} - \gamma Z_{t-1}) + \beta_2 (Z_t - Z_{t-1}) + \varepsilon_t \\ &= \gamma Z_t + \beta_1 (R_{t-1} - \gamma Z_{t-1}) + \beta_2 (Z_t - Z_{t-1}) + \varepsilon_t \qquad (32) \\ &\text{or} \\ &= \gamma Z_{t-1} + \beta_1 (R_{t-1} - \gamma Z_{t-1}) + \beta_2 (Z_t - Z_{t-1}) + \varepsilon_t \qquad (32') \end{aligned}$$

The question of whether a medium run relationship asymptotically approaches the long run equilibrium relationship is examined by the Wald tests for the error correction equation (32) or (32′). $\beta_1$ is an adjustment factor of the error correction equations. If $\beta_1$ and $\beta_2$ in equation (32) or (32′) is equal to zero, the independent variables do not Granger cause the dependent variable, which means the deviation from the long run equilibrium relationship is not gradually adjusted; this is a pure VAR model. If the error correction model does not work satisfactorily, the conclusion of no causality is actually sort of strong, because the sample period might be not long enough, and also the economy may be still in the medium run or on varying trajectories for a growing economy.

It is important that the explanatory variables have been chosen, although we have a good theory to derive the equations. In practice, we have to do some pretests to assure the causality among independent and dependent variables and all the features we need in analyzing and estimating time series regressions.

The first pretest is for the theoretical requirement. In the theory, we assume the domestic countries, Taiwan and Canada, have no influence on the world real long-term interest rate, that is, the US real long-term interest rate, so the US real long-term interest rate is taken as an exogenous variable in both cases. In empirical work, we need to test whether the US real long-term interest rate Granger causes the domestic real long-term interest rate, and if so whether the domestic real interests rates converges to the US real long-term interest rate. The Granger causality test is the first pretest here to decide whether the US real interest rate is an exogenous variable in each case.

The second and third pretests are to guarantee that all the variables have the features of time series data we need for the research work. The second pretest is Augmented Dickey-Fuller (ADF) (1979) unit root test. This investigates if a series is stationary through time. In the theory, we have mentioned that all the evolving fundamental determinants make the endogenous variables vary through time, so first we test if the endogenous and exogenous are nonstationary. We expect the time series data to be integrated at order 1, which means if we first difference the data, it represents a stationary process.

It is an important step of ADF tests, because Engle and Granger (1987) show that a linear combination of two or more nonstationary series that are integrated of the same order may produce a stationary process; they are cointegrated. For instance, consumption

is a function of income (wealth), but it does not necessarily mean the time processes of consumption and income (wealth) are stationary, with a constant mean and variance, in the long run. Instead of being stationary, the time processes of consumption and income (wealth) usually have a linkage in trends over time; they generate a causality relationship in the long run by allowing short run deviations from the long run equilibrium relationship, called transitory and permanent consumption.

After the unit root test, we perform the cointegration test to assure these fundamental determinants and endogenous variables are cointegrated together to produce stationary residuals. The method is the Johansen cointegration test. After having done all the pretests, we estimate the main equations, the real exchange rate and relative price. A linear dynamic equation (31), which is estimated by the OLS and the error correction equations (32) or (32′), which are estimated by the NLS.

## IV.2 Data and Pretest Results

The data used for Canada are taken from the *International Financial Statistics* and Canada National Statistics, which is an electronic database[8]. The quarterly data cover the period of 1971:4–1997:4; originally, we employed the data for 1961:1–1997:4, but from the Chow breakpoint test, a model stability test, there is a significant change in the model structure. Most likely, it is the breakdown of the Bretton Woods system of the fixed exchange rates. Due to this, the sample period begins in 1971:4.

In the Taiwan's case, the data come from the National Statistics of Taiwan, which is also an electronic database[9]. The sample interval covers the period 1981:3–1999:4. Since 1982, Taiwan's exchange rate has been just allowed to float within a 2.25 percentage point range from the weighted average rates on all interbank currency exchange transactions and the main foreign currency pegged is the US dollar.

All the definitions of empirical symbols for the variables are stated in table 1. The first pretest, the Granger causality test, deals with the problem of the real long-term interest rates, which are weighted averages of ten and over ten years bond yield that come from the *International Financial Statistics.* The issue is whether the US real long-term interest rate Granger causes the Canadian real long-term interest rate, and whether Canadian real long-term interest rate converges to the US real long-term interest rate. Canada is a medium size economy with no influence on the world interest rate and the US is a large size economy with an absolute influence on the world long-term rate.

[8] http://www.statcan.ca is the web site for the database used in the Canada's case.
[9] http://www.dgbasey.gov.tw is the web site used in the Taiwan's case.

TABLE 1

DEFINITIONS OF VARIABLES

| Variable | Definition |
|---|---|
| $R$ | Real exchange rate; expressed as #home currency/$US |
| $R_n$ | Relative price ratio; $P_n/P_1$ |
| *CURRENT* | The ratio of current account to GNP; $CA/GNP$ |
| *CANGROWTH* | The proxy of the capital intensity and productivity; the real growth rate of Canada by using 12-quarter moving average to eliminate the seasonal, cyclical and any irregular components except the trend component |
| *USGROWTH* | The proxy of the capital intensity and productivity; the real growth rate of the US by using 12-quarter moving average to eliminate the seasonal, cyclical and any irregular components except the trend component |
| *TAGROWTH* | The proxy of the capital intensity and productivity; the real growth rate of Taiwan by using 12-quarter moving average to eliminate the seasonal, cyclical and any irregular components except the trend component |
| *SOCIAL* | The ratio of the real private and government consumption to the real GNP; no difference between private and public consumptions; average propensity to consume and also marginal propensity to consume in the long run; $(C+G)/GNP$ |
| $(1-SOCIAL)$ | Savings rate; $(1-((C+G)/GNP))$ |
| *CANYIELD* | The Canadian real long-term interest rate by using long-term (10 and over 10-year) bond rate minus the percentage change of 12-quarter moving average of CPI |
| *USYIELD* | The US real long-term interest rate by using long term (10 and over 10-year) bond rate minus the percentage change of 12-quarter moving average of CPI |
| *TAYIELD* | The Taiwanese real long-term interest rate by using 7-year bond rate minus the percentage change of 12-quarter moving average of CPI |
| *DINTEREST* | The real long-term interest rate differential between Canada and the US; $(r-r')$ |
| $D(r-r')$ | The first difference of *DINTEREST* |

It is necessary to decide whether the Canadian real long-term interest rate is an endogenous variable in the model—whether the Canadian real long-term interest rate has an influence on the world real long-term interest rate. The US real long-term interest rate Granger causes the Canadian real long-term interest rate, but Canada's rate does not Granger causes the US real long-term interest rates. Then the US real long-term interest rate is an exogenous variable in its model. If the Granger causality runs two ways between these two variables, then the Canadian real long-term interest rate might have some influence on the world real long-term interest rate—so we may take the Canadian real long-term interest rate as an endogenous variable. The reason for the work on the real long-term interest rate is because it is crucial to an economy; it drives private investment and consumption, and also is very important in influencing international capital flows, which cause the wealth allocations among countries.

It is not easy to observe or decide whether the Canadian real long-term interest rate converges to the US real long-term interest rate or to some certain level. First, it usually takes a long time for real interest rates to converge. Secondly, as is shown below it also depends on the sample interval we extract. Third, in a large economy and a small (or medium economy), if the risk premium of the small (or medium) economy varies, this causes a divergence of the interest rate differential between two economies. Basically, the Granger causality between the Canada and US real long-term interest rates must be established, and then a proxy for the influences from the US capital market to the Canada capital market must be identified.

We dampen the seasonal, or speculative factors in the time series data by using 12-quarter moving averages to expose the trend component. This procedure loses

observations; the adjusted sample interval just covers through 1997. From figure 4, on the Canadian and US real long-term interest rates, we can observe the problems we have discussed previously. What we could conclude about whether there is a convergence with a constant risk premium or not between the Canadian and US real interest rates is based on the sample period extracted, and the variations of the risk premium. Actually, from the Augmented Dickey-Fuller (ADF) unit root test, if the sample interval is 1961:3 to 1997:4, there is a convergence with a constant risk premium, about 0.94% (ADF=-4.251076; 1% level=-3.4986), but during 1961–1985, it is about 1.23%. Moreover, if the sample interval is 1971:1–1997:4, there is no constant convergence between the Canada and US real long-term interest rates (ADF=-2.484; 5% level=-2.8887 and 1% level=-2.5811); there might be on the path to the convergence or no convergence at all.

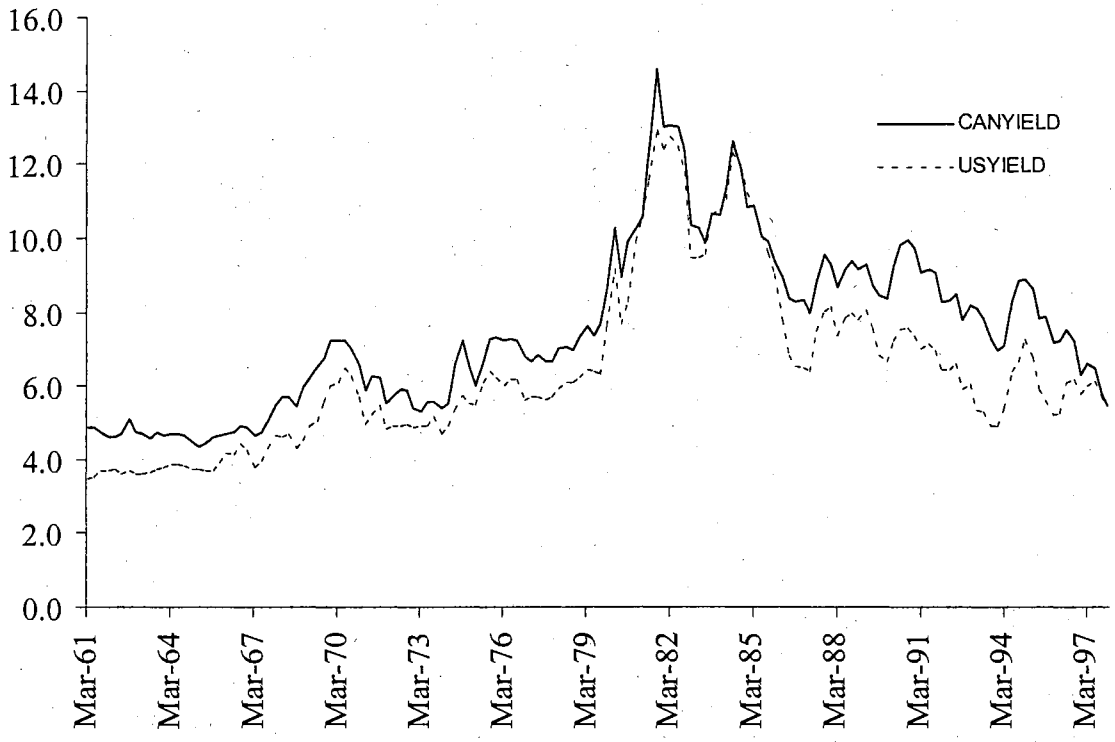


Figure 4 Canada and US Real Long-Term Interest Rates

It is generally believed that Canada and US have a close relationship in the goods and financial markets. Amano and Norden (1995) also conclude that both Canada and the US have more similar monetary policies due to the closely linked business cycles. But the sample interval used in the Canada's case does not establish there is a convergence between the Canada and US real long-term interest rates, so the further work is necessary to find more convincing explanations for this. The Granger causality test between the Canada and US real long-term interest rates indicates that the empirical results are supportive—the US real long-term interest rate does Granger cause the Canadian real long-term interest rate at the 1% significant level nearly, but there is not bi-directional causality. The empirical results are illustrated in table 2.

TABLE 2

GRANGER CAUSALITY TEST FOR CANADA AND US REAL LONG-TERM INTEREST RATES

| Null Hypothesis | Obs | F-Statistic | Probability |
|---|---|---|---|
| *USYIELD* does not Granger cause *CANYIELD* | 103 | 3.08509 | 0.01279 |
| *CANYEILD* does not Granger cause *USYIELD* | | 0.90661 | 0.48037 |
| D$(r-r')$ does not Granger cause *CANYEILD* | 103 | 3.18828 | 0.01064 |
| *USYIELD* does not Granger cause $D(r-r')$ | | 1.39637 | 0.23297 |

*Note*: Sample period, 1961:1–1997:4

The empirical results also establish that the interest rate differential between Canada and the US does cause the Canadian real long-term interest rate, but not vice versa. From this point of view, we believe that the US real long-term interest rate does have an influence on the Canadian real long-term interest rate. The sample period matters in Canada's case. Under the circumstances, the US real long-term interest rate is an exogenous variable in Canada's case.

Because the interest rate differential is not stationary during the sample interval, it might be that the risk premium is varying or that the data series is on the path of convergence to cause the interest rate differential to be nonstationary. The first difference of interest rate differentials to capture the fundamental changes of the economy is one approach. Although the interest rate differential is not stationary, the first difference of the real interest rate differential is stationary.

The situation of the international financial market in Taiwan is quite different from the one in Canada, although Taiwan also has a close trade relationship with the US. Whether the US real long-term interest rate does drive the Taiwanese real long-term interest rate is in doubt, because relative to other Pacific-Rim financial markets of Japan, Hong Kong and Singapore, Taiwan has a more closed and highly regulated financial market; capital movements are restricted internationally.

There is no daily bond market in Taiwan—bonds are auctioned irregularly, so the long-term interest rate data are not continuous in months. There is also a black market in Taiwan due to the private lending and borrowing, not through financial intermediates, so the short run interest rate statistics do not reflect the actual short run interest rate in Taiwan's case.

Phylaktis (1999) found "US rates do not Granger cause rates in Taiwan, but Japanese rates Granger cause rates in Taiwan." The main finding in this paper is the capital markets in the basin countries, like Singapore, Hong Kong, Malaysia, Korea, are highly influenced by Japan and the US. In case of Taiwan, it is only that Japans Granger causes rates in Taiwan and not vice versa. Although Phylaktis used the 90 day treasury rate in his research, from the theory of term structure of interest rate, the long term interest rate is derived from the average of current and future short term interest rate. Even in Taiwan's case, the author used the curb rate of the private financial market to find the actual short-term interest rate. Under this premise, if there is still no causality between short-term interest rates of these two countries, there is no causality between the long-term interest rates of these two countries.

There is another plausible way to test if there is any relationship between the US and Taiwanese real interest rates by using Granger causality test with the available data. It uses the existing, discrete, data and omits the observations in the US series data whenever there are missing data in Taiwan side. The longest long-term bond in Taiwan is a 7-year bond, so we have to use it with monthly data instead of using a 10 or over 10-year bond quarterly rate. The empirical results are illustrated in table 3, and they show that there is no any Granger causality relationship between Taiwan and the US real long-term interest rate—it is consistent with Phylaktis's (1999) finding.

TABLE 3

GRANGER CAUSALITY TEST FOR TAIWAN AND US REAL LONG-TERM INTEREST RATES

| Null Hypothesis | Obs | F-Statistic | Probability |
|---|---|---|---|
| *USYIELD* does not Granger cause *TAYIELD* | 70 | 0.35173 | 0.70505 |
| *TAYEILD* does not Granger cause *USYIELD* | 70 | 0.68070 | 0.50983 |

*Note*: Sample period: 1985:01–1998:11

Generally, the Taiwanese real 7-year interest rate is lower than the US real 7-year interest rate, which is observed in figure 5, but the US are a large economy and Taiwan is a small economy with high regulations in financial market—with limited capital movements internationally; the Taiwanese real interest rate should have been higher than the US real interest rate to attract capital inflows. Because there is an almost $7,500 hundred-tax exemption of the interest rate income for every citizen of Taiwan, the US real interest rate sometimes is higher than the Taiwanese real interest rate. There could be another explanation for this: the US real long-term interest rate has no influences on the Taiwanese real long-term interest rate. It is also shown by the Granger causality test: the US real interest rate does not Granger cause the Taiwanese real long-term interest rate nor does the Taiwanese rate Granger cause the US rate.

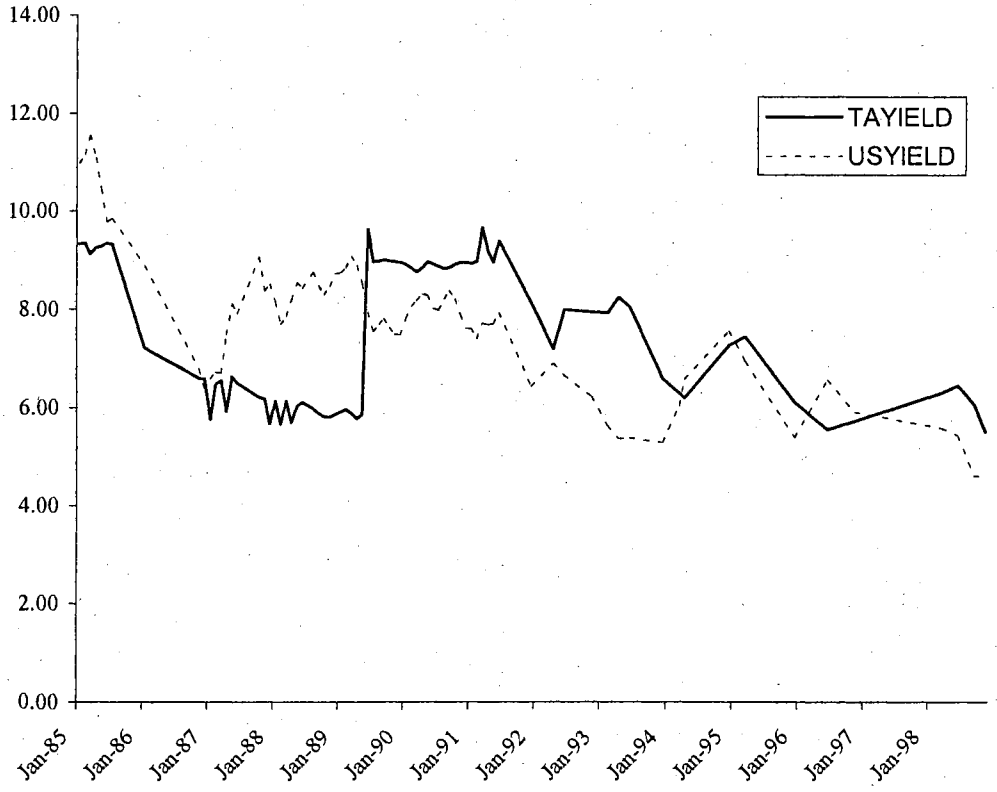


Figure 5. Taiwan and US Real Long-Term Interest Rates

From figure 5, it also could be observed that the patterns of two countries' real long-term interest rates are different as well. There is a significant jump of the Taiwanese real long-term interest rate in the late 1980s and early 1990s, because at that time, Taiwan began deregulating its financial market—there were a lot of capital inflows associated with substantial appreciations of the currency. In fact, Taiwan had accumulated considerable foreign reserves and great savings in the domestic economy at the same time. Taiwan's central bank had an inflation worry, so the central bank implemented a tight monetary policy; this is the reason of the sudden jump of the Taiwanese real 7-year interest rate in early 1990. Besides, the time series should have been smoother if data were continuous, so the jump might not seem too strange.

Having enough evidence supports not using the US real long-term interest rate in Taiwan's case, because this study focuses on the relationship between Taiwan and the US, not the multi-relationship within the US, Japan and Taiwan. We will not discuss all the spillover effects between the international markets and just omit the US real long-term interest rate in Taiwan's case.

The second pretest is the unit root test, which examines whether the endogenous and exogenous variables are stationary time series. If the actual real exchange rate is stationary, $I(0)$, with a constant mean and variance, it is not necessary to do further work—purchasing power parity is true; if they are not, we will try proceed to the final pretest, Johansen cointegration test. Table 4 summarizes the ADF test results for Canada. All the variables denoted as $I(1)$, become stationary when we take first differencing. In the parentheses following the empirical variables, C stands for a constant term and the integer represents AR terms. We focus on whether the data process is stationary, not how

many AR terms in the process, so there is no discussion related to this here. Variables denoted as $I(0)$ means their data are under a stationary process with a constant mean and variance through time.

The ADF test for the endogenous variables, which are the real exchange rate and the ratio of current account to GNP, and exogenous variables in Canada's case are stated in table 4. We test the raw time series data with the null hypothesis that there is a unit root, a nonstationary time series. If the ADF statistic is not significant at 1% (asterisked ***), 5% (asterisked **) or even 10% (asterisked *) levels, then we fail to reject the hypothesis of a unit root of that variable, the interpretation of which is that its mean and variance are evolving through time.

The ADF tests for *CURRENT* and *CANGROWTH* are on the border of significance, so we observed the correlograms, autocorrelation function (ACF) and partial correlation functions (PACF) of these two variables to check carefully whether they are stationary. Since their ACF and PACF decay slowly, the data series are correlated in each period, not independently over periods. They cannot be taken as stationary processes even though the ADF tests are nearly significant stationary processes. The problem of the ADF test is how many lags, AR terms, should be used in testing the stationarity instead of just a simply AR (1). We tested a variety of lag terms by Augmented Dickey-Fuller and Phillips-Perron (PP) tests to decide they are not stationary through time with different lag combinations.

TABLE 4

AUGMENTED DICKEY-FULLER STATISTICS FOR CANADA'S CASE

| Variable | ADF |
|---|---|
| **Nonstationary:** $I(1)$ | |
| $R$ (C, 1) | -0.489 |
| *SOCIAL* (C, 1) | -1.4165 |
| *CANGROWTH* (C, 2) | -2.542 |
| *USYIELD* (C, 1) | -1.439 |
| *CANYIELD* (C, 1) | -1.749 |
| *USYIELD* (C, 1) | -1.871 |
| *DINTEREST* at sample period 1971–1997 (C, 1) | -2.484 |
| *CURRENT* (C, 3) | -2.165 |
| **Stationary:** $I(0)$ | |
| *DINTEREST* at sample period 1961–1997 (C, 0) | -2.979** |
| *DINTEREST* at sample period 1961–1985 (C, 0) | -4.251*** |
| $D(r - r')$, at sample period of 1971–1997(C, 0) | -8.970*** |

*Note*: Adjusted sample period 1971:4–1997:4. In the ADF Statistics (C=Constant, integer=lags). Significant level 1%(***)= -3.4934, 5%(**)=-2.8889, 10%(*)=-2.5812. I(1) means the series is stationary after first differencing. I(0) means the time series is stationary.

Basically, if the lag terms stated one in the ADF tests, we have also tested with different lags terms. Usually, if the lag terms are stated as one, when we extend lag terms, the empirical results fail to reject the unit root hypothesis. Therefore, we just put only lag one in the empirical results to reflect the nonstationarity of the processes; the point here is not the AR terms, thereby not discussing the details of the unit root test. When we first difference all the nonstationary data, the differenced data are stationary, and they are called integrated at order one, $I(1)$. All the variables are highly expected with a unit root and integrated at order one.

From the Engle and Granger (1979) defined more clearly the notion of cointegration. Some $I(1)$ variables, especially macroeconomic ones linearly combine together to produce stationary residuals, which generate a long run equilibrium relationship. In macroeconomics, many variables are interrelated. Although most of the macroeconomics variables are nonstationary individually, they are all in a simultaneous and general equilibrium system with a lot of dependencies—they are drifting with a common trend, roughly the same percentage of variations.

This is why we assume that the variables follow at least an $I(1)$ processes, and that they are cointegrated to give an $I(0)$ process in the long run. The only stationary time series, $I(0)$, is the interest differential between Canada and the US at different sample periods. It is hard to judge whether there is a convergence, because it depends on the sample intervals, the varying risk premiua, transactions cost and interest taxes.

In Canada's case, the sample period covers 1971:4—1997:4, but during this period, the real interest rate differential fails to reject the unit root test, so we take first difference of the interest rate differential at this period; it is stationary. For the reason of the

importance of the real long-term interest rate, we still believe in that there is information from the first difference of the real long-term interest rate differential.

Given that some variables have unit roots—the Johansen cointegration test is only valid when the variables are not stationary—we can do this cointegration test under the null hypothesis of no cointegration between the variables. The results are in tables 5 and 6. The result shows at least one linear combinations of the nonstationary time series of variables are stationary in both cases for $R_t(k_t, F_t; Z_t)$ and $CURRENT$. Basically, the next step is to estimate the linear dynamic equation by the OLS and the error correction equations by the NLS.

The endogenous variables here are $R_t(k_t, F_t; Z_t)$ for table 5 and $CURRENT$ for table 6. From the results of the Johansen cointegration test for $R_t(k_t, F_t; Z_t)$, there is one cointegrating equation at the 1% significance level, so we can estimate the regressions of the real exchange rate for Canada's case in the next section. The model's residuals should be a stationary time series with a zero mean and constant variance, which require a model stability test.

In Canada's case, it can influence the world goods market, but not the financial market, so we are also interested in the activities of the current account surplus, which is a part of adjustment of the domestic and world goods markets. From the Johansen cointegration test of $CURRENT$, the results indicate one cointegrating equation at the 1% significance level, which means that $CURRENT$ and other explanatory variables have linkages to their trends.

TABLE 5

JOHANSEN COINTEGRATION TEST OF $R_t$ FOR CANADA

| Null | Alternative | Statistics | 99% critical value | 95% critical value |
|---|---|---|---|---|
| $r = 0$ | $r \geq 1$ | $112.31^{***}$ | 103.18 | 94.15 |
| $r \leq 1$ | $r \geq 2$ | 66.17 | 76.07 | 68.52 |
| $r \leq 2$ | $r \geq 3$ | 36.34 | 54.46 | 47.21 |
| $r \leq 3$ | $r \geq 4$ | 15.17 | 35.65 | 29.68 |
| $r \leq 4$ | $r \geq 5$ | 6.00 | 20.04 | 15.41 |
| $r \leq 5$ | $r = 6$ | 2.29 | 6.65 | 3.76 |

*Note*: The variables are $R, CANGROWTH, SOCIAL, USYIELD, USGROWTH,$ and $DINTEREST$ (104 observations and maximum lag in VAR=3;.adjusted sample period 1971:4–1997:4).

TABLE 6

JOHANSEN COINTEGRATION TEST OF *CURRENT* FOR CANADA

| Null | Alternative | Statistics | 99% critical value | 95% critical value |
|---|---|---|---|---|
| $r = 0$ | $r \geq 1$ | $92.93^{***}$ | 76.07 | 68.52 |
| $r \leq 1$ | $r \geq 2$ | 37.33 | 54.46 | 47.21 |
| $r \leq 2$ | $r \geq 3$ | 18.24 | 35.65 | 29.68 |
| $r \leq 3$ | $r \geq 4$ | 10.22 | 20.04 | 15.41 |
| $r \leq 4$ | $r = 5$ | 3.14 | 6.65 | 3.76 |

*Note*: The variables are $CURRENT, CANGROWTH, USYIELD, USGROWTH,$ and $SOCIAL$ (104 observations and maximum lag in VAR=3;.adjusted sample period 1971:4–1997:4 )

The results of the ADF test for Taiwan are summarized in table 7. Each of endogenous and exogenous variables is nonstationary, that is, each has with a unit root. The endogenous variables in Taiwan's case are the real exchange rate ($R$) and relative price ($R_n$) and the fundamental determinants are the terms of trade ($T$), social time preferences ($SOCIAL$) and the real growth rate ($TAGROWTH$)—a proxy of the capital intensity and technological progress. After we have taken first difference of all the variables, the time patterns of the variables are statistically stationary, so they are integrated at order one. Table 8 states the summary of the Johansen cointegration test for Taiwan.

We use all the nonstationary variables in table 7 to do the Johansen cointegration test for Taiwan's case. The variables in the cointegrating vector are $R$, $TAGROWTH$, $SOCIAL$ and $T$. The results in table 8 indicate one cointegrating equation at the 1% significant level. We do not do the same test for $R_n$, because it is derived indirectly from $R$—if $R$ is a function of all the fundamental determinants, so is $R_n$. We estimate the linear dynamic and error correction equations by the OLS and NLS. The empirical results of these two for both countries are discussed in the following section.

TABLE 7

AUGMENTED DICKEY-FULLER STATISTICS FOR TAIWAN'S CASE

| Variable | ADF |
|---|---|
| **Nonstationary:** $I(1)$ | |
| $R$ (C, 1) | -1.116 |
| *SOCIAL* (C, 1) | -2.069 |
| *TAGROWTH* (C, 1) | -1.216 |
| $T$ (C, 1) | -1.391 |
| $R_n$ (C, 1) | -0.931 |
| *CURRENT* (C, 1) | -1.481 |
| **Stationary:** $I(0)$ | |
| $D(R)$ (C, 2) | -3.930*** |

*Note*: Adjusted sample period 1982:1–1998:4. In the ADF Statistics (C=Constant, integer=lags). Significant level 1%(***)=-3.5363, 5%(**)=-2.9077, 10%(*)=-2.5911. I(1) means the series is stationary after first differencing. I(0) means the time series is stationary.

TABLE 8

JOHANSEN COINTEGRATION TEST OF $R_t$ FOR TAIWAN

| Null | Alternative | Statistics | 99% critical value | 95% critical value |
|---|---|---|---|---|
| $r = 0$ | $r \geq 1$ | $78.69^{***}$ | 54.46 | 47.21 |
| $r \leq 1$ | $r \geq 2$ | 25.50 | 35.65 | 29.68 |
| $r \leq 2$ | $r \geq 3$ | 8.53 | 20.04 | 15.41 |
| $r \leq 3$ | $r = 4$ | 0.00 | 6.65 | 3.76 |

*Note*: The variables are $R$, $TAGROWTH$, $SOCIAL$ and $T$ (63 observations and maximum lag in VAR=2; adjusted sample period 1982:1–1998:4).

# CHAPTER V

## DYNAMIC ESTIMATES FOR CANADA

An important conclusion is that the endogenous and exogenous variables are coingetrated to produce a long run equilibrium relationship. The next step is to estimate the linear cointegration model and error correction model for Canada and Taiwan. From the regressions, the influences of the fundamental determinants impact on the real exchange rate, current account to the GNP and relative price can be observed in relation to the theory that is developed in chapter III.

The endogenous variables in Canada's case are the real exchange rate, $R_t(k_t, F_t; Z_t, u_t)$ and the ratio of the current account surplus to $GNP$, denoted as $CURRENT$, for which the estimated regressions are based on equation (31) and (32). The $\hat{\beta}_i$ terms in empirical results that are shown in the following tables are the estimates of the $\beta_i$ in equations (31) and (32) or (32′).

Special attention is paid to the estimated parameter of the error term in the error correction model—and the estimated parameter of the lag terms of changes, denoted as $(Z_t - Z_{t-1})$, from the fundamental determinants, because if they are both equal to zero, the dependent variables do not gradually adjust their short run deviations to the long run equilibrium relationship indicated by the Johansen cointegration test. It is just a pure VAR model, and the independent variables do not Granger-cause the dependent ones. If

the error correction model does not work satisfactorily, the conclusion of no causality is too strong, because it might be due to the sample period not being long enough. It also might be that the economy is still along a medium run path for a growing economy owing to varying trajectories.

Using table 9, we interpret the empirical results by the NATREX theory that has been discussed. For a medium or large economy with endogenous terms of trade, it is hard to distinguish the influence of a rise of productivity in the nontradable or tradable goods sector. In the general discussion of a rise of productivity, there are two effects: one is that a rise of productivity raises investment relative to savings and attracts the capital inflows. Associated with it, the foreign debt increases initially owing to the reduced savings relative to investment, but later declines due to the higher savings that comes from the higher GDP and also due to a decreasing speed of capital inflows (the decreasing marginal productivity of capital). So, the domestic country might convert to a net creditor, with a current account surplus, to the foreign country eventually, so the NATREX appreciates if the country generates a current account surplus in the long run.

The other effect is that total higher capital intensity means a wealthier economy, so the increased import demand depreciates the NATREX in the long run. The net effect of a rise of productivity is thus ambiguous due to these two opposite effects. To be more precise about the proxy of productivity, it is a variable that mixes the information of the endogenous capital intensity ($k_t$) and the technological progress that includes the effectiveness of labor and capital technological progress. In the theory, it is easy to distinguish the endogenous variable and exogenous variable, but in practice, the data

usually carry mixed information that includes both the endogenous and exogenous sides—it is hard to be precise to define which one is endogenous or exogenous.

The first empirical result in Canada's case is that a rise of productivity, *CANGROWTH* ($\hat{\beta}_3$) that is nearly significant at the 5% level, depreciates the NATREX. The reason is that the rise of productivity, *CANGROWTH*, is not relatively strong enough to convert Canada—a foreign debtor—into a foreign creditor. So the other effect, a surge of import demand as a result of more wealth, dominates, thereby depreciating the NATREX in the long run. This is what underlies the positive sign of *CANGROWTH*.

TABLE 9

DYNAMIC ESTIMATES OF REAL EXCHANGE RATE $R_t$ FOR CANADA (OLS MODEL)

| Independent Variable | Coeff ($\hat{\beta}_i$). | t-stat | 2-tail sig. |
|---|---|---|---|
| *CONSTANT* ($\hat{\beta}_1$) | -0.2565 | -3.4324 | 0.0009 |
| $R(-1)$ ($\hat{\beta}_2$) | 0.9501 | 41.0319 | 0.0000 |
| *CANGROWTH* ($\hat{\beta}_3$) | 0.0131 | 1.9412 | 0.0551 |
| *SOCIAL* ($\hat{\beta}_4$) | 0.3745 | 3.7961 | 0.0003 |
| *USYIELD*(1) ($\hat{\beta}_5$) | 0.0019 | 1.6780 | 0.0961 |
| $D(r-r')(-1)$ ($\hat{\beta}_6$) | -0.0116 | -1.8448 | 0.0680 |

*Note*: Adjusted sample period 1971: 2–1997: 4, observations 106; Adj $R^2$=0.96; ADF for residuals is UROOT(N, 0)=-8.266 ; Heteroskedasticity test, prob is 0.17.

The significant positive coefficient of the social time preference variable, $SOCIAL\,(\hat{\beta}_4)$, implies a depreciation of the real exchange rate. The coefficient is significant at the 1% level. An increase of the social time preference, a decline of the savings rate, depreciates the NATREX in the long run by reducing capital intensity, wealth, and increasing the foreign debt. Investment and consumption are less than before. The initial adjustment of this can be viewed as $IS_0$ shifting to $IS_2$ in figure 2. It appreciates the NATREX in the medium run. In the medium run, there is a current deficit, capital inflows, but in the long run, $IS_2$ shifts back to $IS_0$, or even to $IS_1$ due to the payment of the foreign debt plus the interest payment causing less total wealth in the long run. This is an argument of whether the current deficit is a burden in the future; borrowing for present consumption reduces the future consumption eventually. As for the current account, it relies on the situation such as if the domestic country was a net creditor, it could become a net debtor, or still a net creditor with less credit with a rise of $SOCIAL$. This is the case of borrowing to finance current consumption reducing the future consumption eventually.

We have used a quarter ahead of $USYIELD\,(1)\,(\hat{\beta}_5)$ that is weakly significant to capture the lead of $CANYIELD$, because of the result of the pretest, which $USYIELD$ Granger causes the $CANYIELD$. In fact, its impact on the Canadian economy is when the US real long-term interest rate surges—the world real long-term interest rate surges—it induces capital outflows from Canada to the US, thereby depreciating the Canadian real exchange rate in the medium run; capital outflows cease in association with a higher interest rate level in the long run. Since the real long-term interest rate substantially dominates the economy, the variation of the world real long-term interest rate reallocates

the resources among countries. Specifically, the resources here mean the capital movements internationally. The investment is a function of the real interest rate and marginal productivity of capital. Since capital moves among countries gradually for higher returns, the decreasing marginal productivity is a critical factor to cease the capital movement—and eliminates the interest rate differential or makes the interest rate differential converge to some certain level, called risk premium for a small or a medium economy.

$D(r-r')$ (-1) $(\hat{\beta}_6)$, which is nearly significant at the 5% level, is the lag one of the first difference of the interest differential between Canada and the US. This is used as a proxy of the changes, $(Z_t - Z_{t-1})$, of the fundamental determinants. As a matter of fact, we should have applied $(CANGROWTH_t - CANGROWTH_{t-1})$ and $(SOCIAL_t - SOCIAL_{t-1})$, which are in the set $Z_t$, instead of applying $D(r-r')$, but neither of the empirical results of these two terms is significant. We do believe that $D(r-r')$ has a conclusive impact on the Canadian economy, though the Canadian real interest rate does not converge to the US real long-term interest rate during the sample period. It may be that the interest rate differential causes the capital flows and they then change the capital intensity of the economy.

Having emphasized that capital movements imply changes of wealth for a country, the different evolutions of capital intensity result in the changes of all the marginal equilibrium conditions, so the economy evolves through time. The interest rate differential causes capital movements between Canada and the US, so we use the first differencing of the real interest rate differential to capture the evolutions of the fundamental determinants. The negative lagged coefficient of $D(r-r')$ indicates a

positive influence on Canada; the higher interest rate differential, risk premium, thus appreciates the Canadian dollar by stimulating capital inflows.

The unit root and heteroskedasticity tests for the model's residuals are done to investigate whether the model's residuals are stationary and have a constant mean and variance, which reflect the model's explanatory ability. The test results in the note to table 9 show the residuals are stationary. This is consistent with that all the variables being nonstationary through time, but their linear combination can produce a stationary process.

A model stability test is necessary. With this purpose, figure 6 graphically illustrates recursive residuals, which are derived from the OLS model in table 9 by using recursive least squares, using ever larger subsets of the sample data. Add one sample period each time to estimate the equations until the whole period has been covered. Every parameter that has been estimated from sub-sample period could proceed a quarter ahead forecast. The recursive residuals are obtained from the forecast errors that are products of the recursive least squares. Figure 6 shows recursive residuals are located within two standard errors around a zero mean, it means the estimated parameters corresponding to the recursive least squares are stable, which implies the model structure has been statistically stable during the sample period.

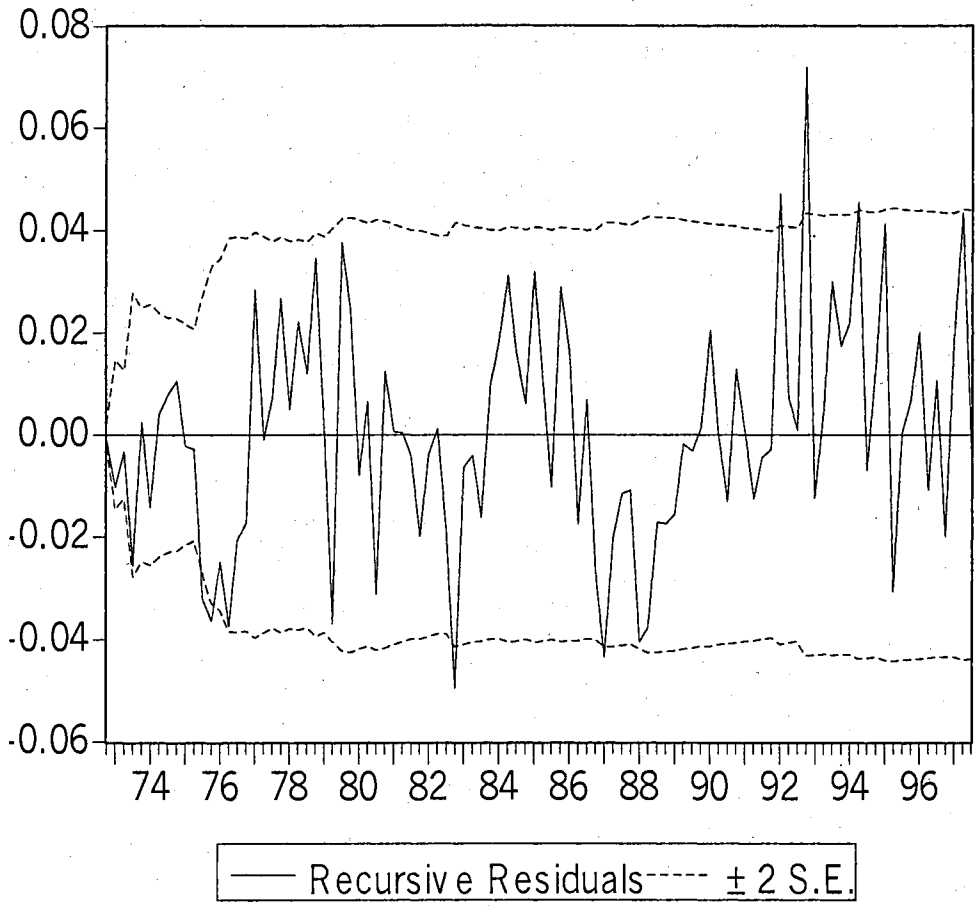


Figure 6. Recursive Residuals of Canadian Real Exchange Rate (OLS Model)

If most of the recursive residuals are located out of the bound, then it implies the instability of the parameters we estimated for the model; the recursive residuals do not have an independent and normal distribution with a zero mean and constant variance; the OLS regression does not explain most of the variations of the dependent variables well, therefore the parameters or the variance are not stable.

The summary of the empirical results of the error correction regression is in table 10. First, it is necessary to examine whether the error term ($\hat{\beta}_5$) is significantly different from zero, in which case the real exchange rate does respond to the evolutions of fundamental determinants. The error correction term is significant at the 1% level and is less than unity at about the 5% level; the real exchange rate does adjust the deviations gradually to the long run equilibrium that is dominated by the fundamental determinants. We also did the Wald test to investigate the hypotheses of whether the error term ($\hat{\beta}_5$) and the proxy of changes of the fundamental determinants $D(r-r')(-1)$ ($\hat{\beta}_6$), which is significant at the 10% level, simultaneously are equal to zero. The Wald test results in the note to table 10 reject them being jointly equal to zero; it supports the proposition that the NATREX does respond to the evolutions of fundamental determinants.

The constant term and *SOCIAL* ($\hat{\beta}_3$) are statistically significant at the 5% level in the error correction model, and *SOCIAL* has a sign consistent with that in the OLS model; when the savings rate declines, the NATREX depreciates in the long run as a result of borrowing to finance the current consumption—future consumption will be less due to the decrease of total wealth.

TABLE 10

DYNAMIC ESTIMATES OF REAL EXCHANGE RATE $R_t$ FOR CANADA (ERROR CORRECTION MODEL)

| Model and Variable | Coeff $(\hat{\beta}_i)$. | t-stat | 2-tail sig. |
|---|---|---|---|
| *CONSTANT* $(\hat{\beta}_1)$ | -0.2335 | -3.0387 | 0.0030 |
| *CANGROWTH* $(\hat{\beta}_2)$ | 0.2446 | 1.5056 | 0.1353 |
| *SOCIAL* $(\hat{\beta}_3)$ | 7.6986 | 2.2023 | 0.0229 |
| *USYIELD*(1) $(\hat{\beta}_4)$ | 0.0469 | 1.4965 | 0.1376 |
| *ERROR TERM* $(\hat{\beta}_5)$ | 0.9558 | 39.7263 | 0.0000 |
| $D(r-r')(-1)$ $(\hat{\beta}_6)$ | -0.0118 | -1.8388 | 0.0680 |

*Note*: Adjusted sample period 1971: 2–1997: 4, observations 106; Adj $R^2$=0.96; ADF for residuals is UROOT(N, 0)=-8.138; Wald test for [ $\hat{\beta}_5 = \hat{\beta}_6 = 0$ ], prob is 0.

The other independent variables—*CANGROWTH* $(\hat{\beta}_2)$ and *USYIELD*(1) $(\hat{\beta}_4)$—are not significant, although they have the same signs as they do in the OLS model. Since we obtained the basic results, deriving the NATREX is the final step in Canada's case. The NATREX just carries the medium and long run information, so we apply the data, which have been dampened by the moving average method, to derive all the values in every period of the NATREX.

Finally, the NATREX of Canada is derived by the dynamic ex ante forecast that uses the OLS model in table 9; this is graphically illustrated in figure 7. The starting point, $NATREX_0$, is the actual real exchange rate value—$R_0(k_t, F_t; Z_t, u_t)$ . After the second period, we apply the predicted $NATREX_1$ to equation (33) to derive $NATREX_2$;

we compute all the $NATREX_t$ with all the predicted values of $NATREX_{t-1}$ except the starting value by using the actual real exchange rate. Using the recursively computed forecast of the lagged values of the NATREX and all the observations of other independent variables derive the series of the NATREX, called the dynamic ex ante forecast.

$$NATREX_t = -0.2565 + 0.9501NATREX_{t-1} + 0.0131CANGROWTH_t + 0.3745SOCIAL_t + 0.0019USYIELD_{t+1} - 0.0116D(r - r')_{t-1} \quad (33)$$

Because we have dampened the seasonal and short run factors from the data, the derived NATREX goes through the series of the actual real exchange rate; there is slight difference between the NATREX and the actual real exchange rate observed in the market due to way we have dealt with them. That is the way we extract the medium and long run information from the actual real exchange rate. The NATREX passes through the actual real exchange rate, because the NATREX just captures the trend, and under the floating exchange rate, there are more fluctuations indeed. The correlation between the forecasts of the NATREX and the actual real exchange rate are approximately 0.7. The estimated residuals from equation (33) are statistically stationary without a unit root.

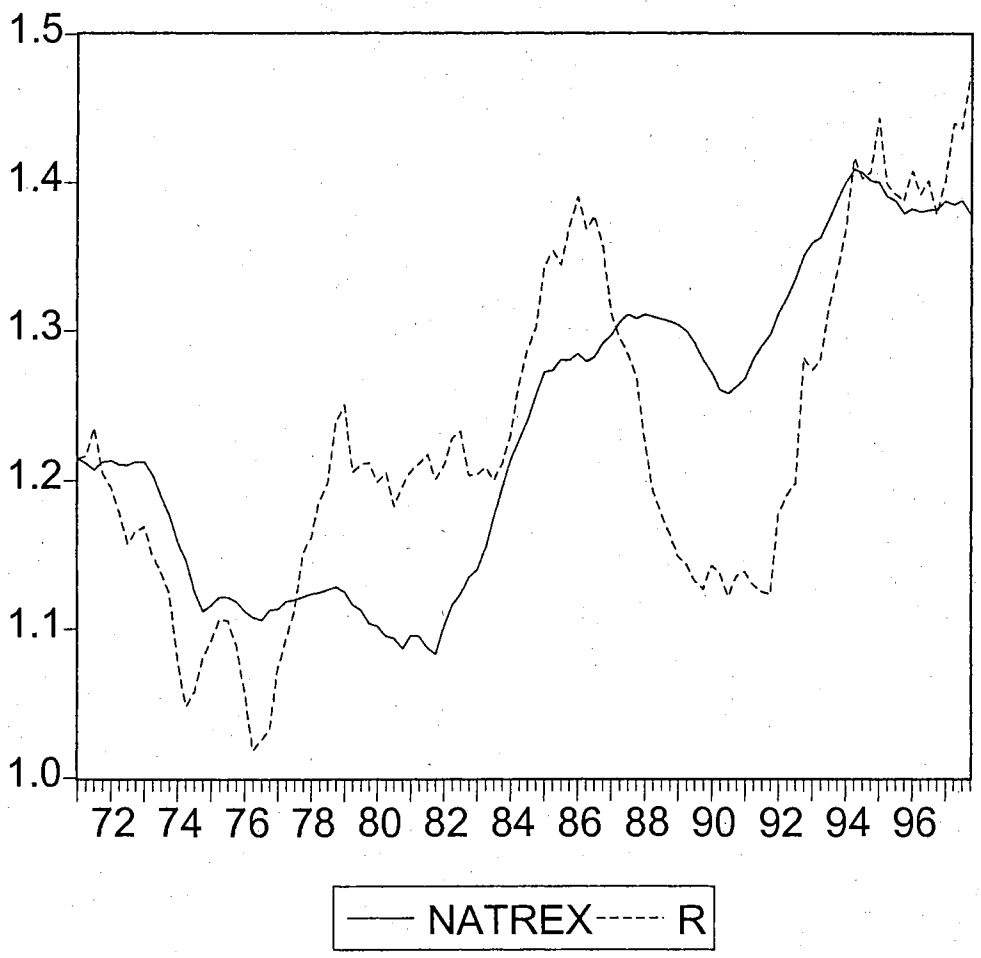


Figure 7 Dynamic Ex ante Forecast of NATREX for Canada

In addition to the real exchange rate, we are also interested in the other endogenous variable, *CURRENT*. The same procedure that is used to estimate the regressions of the real exchange rate is repeated for *CURRENT*. Table 11 is the summary of the empirical results of *CURRENT*. The OLS model does not work very well here; only *USYIELD* ($\hat{\beta}_4$) is significant at the 5% level; $D(r-r')(-1)$ ($\hat{\beta}_6$) is weakly significant. In the real exchange rate model in table 10, one quarter ahead of *USYIELD* has a positive influence if a surging *USYIELD* depreciates the NATREX due to capital outflows from Canada. It is consistent with the empirical results here; a surging *USYIELD* enlarges the *CURRENT*, caused by the depreciation of the NATREX with capital outflows.

But the sign of the $D(r-r')(-1)$ is not consistent with the results we have obtained from the real exchange rate regressions. When the interest rate differential widens, the real exchange rate appreciates—capital inflows, but *CURRENT* increases. This is consistent neither with the theory nor the empirical results in the regressions of the real exchange rate.

Basically, the remaining signs of the variables are consistent with the real exchange rate model, although none is significant. For instance, *CANGROWTH* ($\hat{\beta}_3$), which is nearly significant at the 10% level, has a positive influence on *CURRENT*: a rise of productivity depreciates the Canadian real exchange rate, thus stimulates a higher *CURRENT*. A similar situation is for *SOCIAL* ($\hat{\beta}_4$) as well.

TABLE 11

DYNAMIC ESTIMATES OF *CURRENT* FOR CANADA (OLS MODEL)

| Variable | Coeff. ($\hat{\beta}_i$) | t-stat | 2-tail sig. |
|---|---|---|---|
| *CONSTANT* ($\hat{\beta}_1$) | -0.0192 | -1.6700 | 0.0922 |
| *CURRENT*(−1) ($\hat{\beta}_2$) | 0.6124 | 7.8345 | 0.0000 |
| *CANGROWTH* ($\hat{\beta}_3$) | 0.0016 | 1.6569 | 0.1007 |
| *SOCIAL* ($\hat{\beta}_4$) | 0.0160 | 1.2244 | 0.2237 |
| *USYIELD* ($\hat{\beta}_5$) | 0.0004 | 2.2576 | 0.0261 |
| $D(r-r')(-1)$ ($\hat{\beta}_6$) | 0.080 | 1.8138 | 0.0727 |

*Note*: Adjusted sample period 1971: 2–1997: 4, observations 106; Adj $R^2$=0.44; ADF for residuals is UROOT(N, 0)=-10.004 ; Heteroskedasticity test, prob is 0.17.

A unit root and heteroskedasticity test support the hypothesis that model's residuals are stationary. We also test for model stability by using the recursive residuals derived form the OLS model in table 11. This is shown in figure 8. Most points of the recursive residuals are located within two standard errors around the zero mean, so its distribution is normal and statistically independent. So the model is stable during the sample period. The regressions for the *CURRENT* do not work as well as we expected.

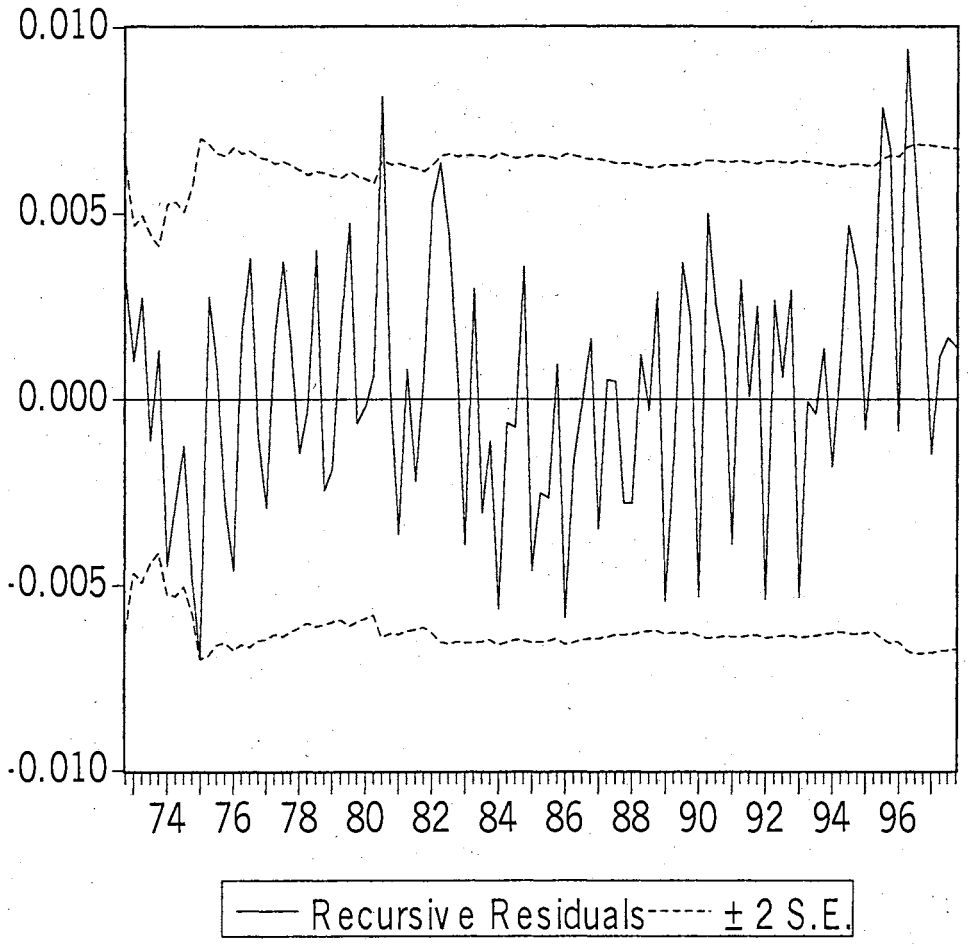


Figure 8 Recursive Residuals of Canadian *CURRENT* (OLS Model)

An error correction model is also estimated, and it is shown in table 12. In it, the coefficient of the error term ($\hat{\beta}_5$) is significant at the 1% level, which supports the view that the deviations from the long run equilibrium gradually adjust period by period; the dependent variable *CURRENT* does respond to the evolutions of the fundamental determinants. The Wald test in the note to table 12 shows that the probability of that the terms error term ($\hat{\beta}_5$) and $D(r-r')$ (-1) ($\hat{\beta}_6$) simultaneously are equal zero is zero.

*USYIELD* ($\hat{\beta}_3$) is not used as one quarter ahead as it is in the real exchange rate model and it is nearly significant at the 5% level. We believe the current account responds first, compared to other variables while *USYIELD* rises. When the US real long-term interest rate rises, the capital outflows occur in the domestic country to depreciate the NATREX and increase the current account surplus, consistent with the empirical result that obtains in the real exchange rate regression; a surging of *USYIELD* depreciates the NATREX, thus it enlarges the current account surplus, *CURRENT*.

*CANGROWTH* ($\hat{\beta}_2$) is significant at the 10% level in the model—this is a mores satisfactory result than in the OLS model—and it has an identical sign as in the OLS framework. $D(r-r')$ ($\hat{\beta}_6$) is also significant at the 10% level, which is consistent with the OLS model of *CURRENT*, but still inconsistent with the real exchange rate models. The *SOCIAL* ($\hat{\beta}_3$) is not significant, but has a positive sign here; *SOCIAL* depreciates the NATREX, so it enhances the current account surplus, *CURRENT*.

TABLE 12

DYNAMIC ESTIMATES OF *CURRENT* FOR CANADA (ERROR CORRECTION MODEL)

| Variable | Coeff. ($\hat{\beta}_i$) | t-stat | 2-tail sig. |
|---|---|---|---|
| *CONSTANT* ($\hat{\beta}_1$) | -0.0473 | -2.0109 | 0.0470 |
| *CANGROWTH* ($\hat{\beta}_2$) | 0.0037 | 1.7548 | 0.0823 |
| *SOCIAL* ($\hat{\beta}_3$) | 0.0407 | 1.4574 | 0.1481 |
| *USYIELD* ($\hat{\beta}_4$) | 0.0008 | 2.1634 | 0.0329 |
| *ERROR TERM* ($\hat{\beta}_5$) | 0.6248 | 7.8611 | 0.0000 |
| $D(r-r')$ (-1) ($\hat{\beta}_6$) | 0.0017 | 1.8057 | 0.0740 |

*Note*: Adjusted sample period 1971: 2–1997: 4, observations 106; Adj $R^2$=0.96; ADF for residuals is UROOT(N, 0)=-10.071 ; Wald test for [ $\hat{\beta}_5 = \hat{\beta}_6 = 0$ ], prob is 0.

# CHAPTER VI

## DYNAMIC ESTIMATES FOR TAIWAN

From the theoretical discussion, the endogenous variables in Taiwan's case are the real exchange rate, $R_t(k_t, F_t; Z_t)$ and the relative price, $R_n(k_t, F_t; Z_t)$, between the non-tradable and tradable goods, which have been derived previously from the decomposition of the real exchange rate. For a typical small economy, the importable demand and exportable supply functions are perfect elastic for a small economy; one that exports or imports as many goods as it wants. So the terms of trade are exogenous; there is just one endogenous factor (the relative price between the nontradable and tradable goods) dominating the real exchange rate. The nontradable goods market is always in equilibrium through the adjustment of the relative price between the nontradable and tradable goods.

The exogenous variables in this case are the Taiwanese real growth rate, denoted as *TAGROWTH*—as a proxy of the endogenous capital intensity and exogenous technological progress—social time preferences, denoted as *SOCIAL*, and terms of trade, denoted as $T$. The data are, as the case of the Canadian data, smoothened by the moving average method to mitigate the short run and seasonal factors. As we have concluded in chapter IV, the Taiwanese real long-term interest rate is not driven by the US real long-term interest rate but by the Japanese real long-term interest rate indeed; there is no interest rate variable in the Taiwan-US case due to lack of Granger causality between

these two countries' real long-term interest rates. Besides, Taiwan's financial market is highly regulated, the degree of capital integration with other countries is low; the influences on the domestic interest rate from the large economies are limited.

The variables that we employ to represent the changes of the lag terms of the changes, $(Z_t - Z_{t-1})$, of the fundamental determinants, in equation (31) and (32′), are $(TAGROWTH_t - TAGROWTH_{t-1})$, $(SOCIAL_t - SOCIAL_{t-1})$ and $(T_t - T_{t-1})$. Only $(TAGROWTH_t - TAGROWTH_{t-1})$ is statistically significant in both the OLS and error correction models. Therefore, $(SOCIAL_t - SOCIAL_{t-1})$ and $(T_t - T_{t-1})$ are not incorporated in the models in this case.

The empirical results of the OLS model are illustrated in table 13. *TAGROWTH* $(\hat{\beta}_3)$ is significant at the 1% level. Its highly significant negative sign during the sample period indicates that the relatively strong real growth appreciates the NATREX, which is a result consistent with the theory. The reason might be that the accumulated real growth of Taiwan is a relatively remarkable performance of the economy, so this country has accumulated lots of wealth. From the OECD report (1995), the annual growth rate of Taiwan from 1950–1992 is around 12%, which is derived by the real income per capita during 1950–1992 at constant price level, and at the same sample period, the US annual growth rate is around 0.5%. This empirical result is identical to Ito, Isard, and Symansky's (1997) finding, which rapid real economic growth appreciates the real exchange rate.

TABLE 13

DYNAMIC ESTIMATES OF REAL EXCHANGE RATE $R_t$ FOR TAIWAN (OLS MODEL)

| Variable | Coeff. ($\hat{\beta}_i$) | t-stat | 2-tail sig. |
|---|---|---|---|
| *CONSTANT* ($\hat{\beta}_1$) | 14.3938 | 4.1467 | 0.0001 |
| $R(-1)$ ($\hat{\beta}_2$) | 1.0217 | 28.3822 | 0.0000 |
| *TAGROWTH* ($\hat{\beta}_3$) | -293.57 | -6.4377 | 0.0000 |
| $T$ ($\hat{\beta}_4$) | -0.5148 | -0.2281 | 0.8203 |
| *SOCIAL* ($\hat{\beta}_5$) | -13.1492 | -5.1689 | 0.0000 |
| ($TAGROWTH_t - TAGROWTH_{t-1}$ ($\hat{\beta}_6$) | 223.63 | 1.7949 | 0.0778 |

*Note*: adjusted sample period 1982: 2–1998:2, observations 65; Adj $R^2$=0.96; ADF for residuals is UROOT(N, 0)=-5.657 ; Heteroskedasticity test, prob is 0.742.

*SOCIAL* ($\hat{\beta}_5$) is significant at the 1% level. It appreciates the NATREX while rising. In fact, the phenomenon is increasing the consumption and appreciating the real exchange rate at the same time, because Taiwan still has a current surplus and the economy is growing, which results from the relatively higher savings rate than the US one: the speed of accumulating wealth is still faster than the speed of accumulating debt and expanding consumption. The sign of *SOCIAL* is not consistent with the theory, which is a very interesting result. After having observed the raw time series of savings rates, this may not be a very surprising result: in 1986, Taiwanese savings rate reached the peak of 55%, which is calculated by $\frac{C+G}{Y}$, and even now, it is around 45%, which

is still relatively higher to the US savings rate, around 30%. Borrowing to finance investment stimulates the economy growth enormously. This supports the argument that the evolution of spontaneously continuous changes from the fundamental determinants impacts the economy; exogenous variables evolve through time, so the endogenous variables correspondingly evolve through time also.

Moreover, from the examination of *CURRENT* time series, foreign debt, we can observe Taiwan is a net creditor during the sample period, even tracing to 1976. The *CURRENT* time series during the sample interval was rising, reaching a peak and then decreasing, but Taiwan is still a net creditor to the rest of the world, especially relative to the US. The current account is still in a surplus, so the real exchange rate is still on the trajectories to appreciate due to the spontaneous changes from a savings rate that is declining. This is why the *SOCIAL* has a negative sign. The sample period used here just captures the information from the medium run of a growing economy.

The theoretical discussion of a higher savings rate was that it depreciates the real exchange rate in the medium run, but in the long run, the returns of investment accumulate to increase the wealth of the economy; thus the real exchange rate appreciates in the long run as well. Although we do not have a consistent result, the negative sign of *SOCIAL*, consistent with the theory, this is a very good example to demonstrate the importance of a higher savings rate for an growing economy to catch up with developed countries: Taiwan had experienced the depreciation of the currency, more foreign debt, less consumption when the savings rate increased in the early 1960s, but we can see there is more consumption, no foreign debt, more wealth nowadays.

The proxy of changes from the fundamental determinants, $(TAGROWTH_t - TAGROWTH_{t-1})(\hat{\beta}_6)$, depreciates the Taiwanese real exchange rate in this case. *TAGROWTH* appreciates the real exchange rate with a decreasing speed though the effect borders on insignificance; the speed of accumulating capital intensity is slowing down due to the effect from $(TAGROWTH_t - TAGROWTH_{t-1})(\hat{\beta}_6)$ and the speed of accumulating foreign debt is increasing to gradually eliminate the current account surplus, foreign credit. The terms of trade $T$ $(\hat{\beta}_4)$ are not statistically significant, and with a positive sign; a rise of exogenous terms of trade appreciates the real exchange rate.

An ADF test for the residuals from the real exchange rate OLS model shows the their process is stationary. The results of a heteroskedasticity test indicates that the residuals have a constant variance, which meets the classical assumption of the OLS model. Figure 9 is the graph of the model stability test for the OLS model. We use the same procedure as we do in Canada's case. The recursive residuals are located within two standard errors around a zero mean—within confidence interval; the parameters we estimated seem stable to produce random residuals with a zero mean and constant variance, so the model is statistically stable.

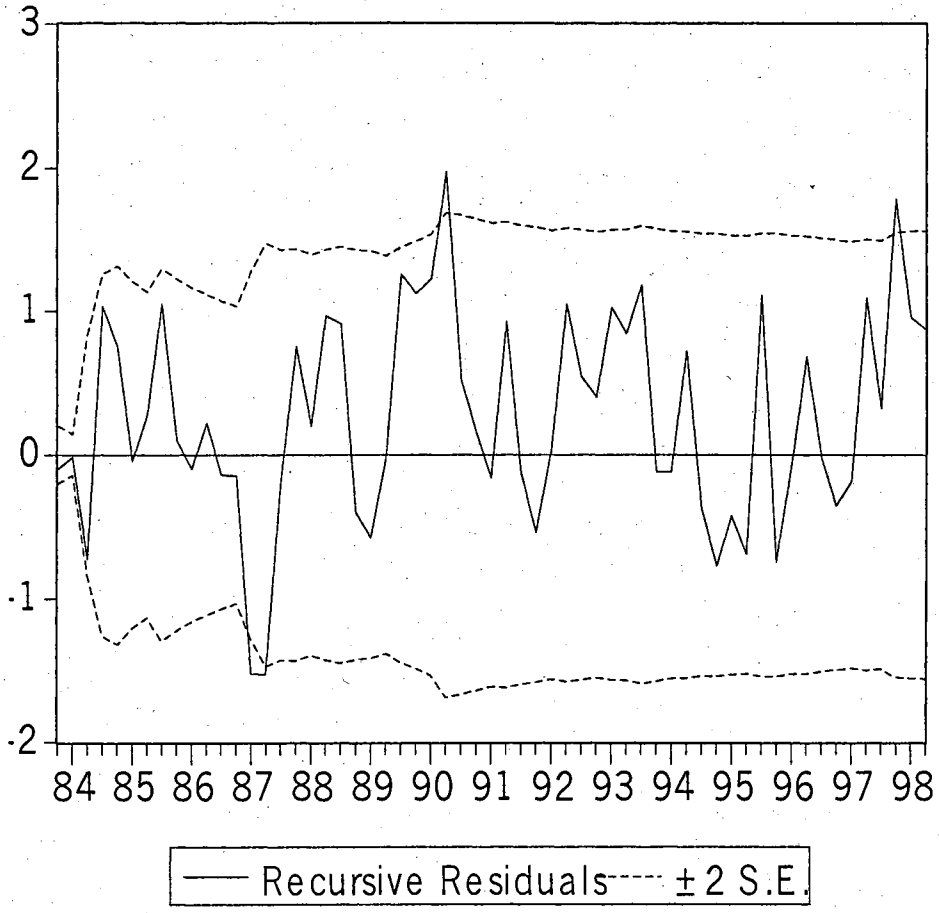


Figure 9. Recursive Residuals of Taiwanese Real Exchange Rate (OLS model)

We also estimate the error correction model that is shown in table 14, but the empirical results are not very satisfactory for the real exchange rate—the error correction term is significantly different from zero at the 1% level and the proxy of the changes from the fundamental determinants is not significantly different from zero. Both the adjustment factor ($\hat{\beta}_5$) and ($TAGROWTH_t - TAGROWTH_{t-1}$) ($\hat{\beta}_6$) could not be zero in cointegrating regressions—if both equal to zero, this means the dependent variables do not respond to the change of the fundamental determinants; the explanatory variables do not Granger cause the independent variable. The Wald test result of $\hat{\beta}_5 = \hat{\beta}_6 = 0$ is significant at the 1% level, which supports the hypothesis that the real exchange rate adjusts gradually toward the long run equilibrium relationship.

Other independent variables have identical signs as in the OLS model, but only the constant term ($\hat{\beta}_1$) and $SOCIAL$ ($\hat{\beta}_4$) are significant at the 1% level, so $SOCIAL$ ($\hat{\beta}_4$) has a consistent result compared to the OLS model. We doubt the error correction model works as well in Taiwan's case, because that economy is still growing rapidly, so that the economy's adjustments to the long run equilibrium are not empirically obvious owing to the varying trajectories.

TABLE 14

DYNAMIC ESTIMATES OF REAL EXCHANGE RATE $R_t$ FOR TAIWAN (ERROR CORRECTION MODEL)

| Variable | Coeff. ($\hat{\beta}_i$) | t-stat | 2-tail sig. |
|---|---|---|---|
| *CONSTANT* ($\hat{\beta}_1$) | 2.6844 | 2.7116 | 0.0088 |
| *TAGROWTH* ($\hat{\beta}_2$) | 3178.1680 | -0.6872 | 0.4947 |
| *T* ($\hat{\beta}_3$) | -3.7769 | -0.6880 | 0.4942 |
| *SOCIAL* ($\hat{\beta}_4$) | -7.7173 | -5.0552 | 0.0000 |
| *ERROR TERM* ($\hat{\beta}_5$) | 0.9728 | 21.4944 | 0.0000 |
| ($TAGROWTH_t - TAGROWTH_{t-1}$) ($\hat{\beta}_6$) | 3189.6950 | 0.6989 | 0.4873 |

*Note*: adjusted sample period 1982: 2–1998:2, observations 65; Adj $R^2$=0.96; ADF for residuals is UROOT(N, 0)=-6.740 ; Wald test for [ $\hat{\beta}_5 = \hat{\beta}_6 = 0$ ], prob is 0.

We derive the NATREX of Taiwan by the dynamic ex ante forecasts that uses the model shown in table 13, which is graphically illustrated in figure 10. The starting point, $NATREX_0$, is the actual real exchange rate value, $R_0(k_t, F_t; Z_t, u_t)$ as we do in Canada's case. After the second period, we apply the predicted $NATREX_1$ to equation (34) to derive $NATREX_2$, using the recursively computed forecast with the lagged values of the NATREX and all the observations of other independent variables to derive the series of the NATREX, called the dynamic ex ante forecast. The NATREX in Taiwan's case seems fit the model quite well, because the correlation between the NATREX and actual exchange rate is 0.95.

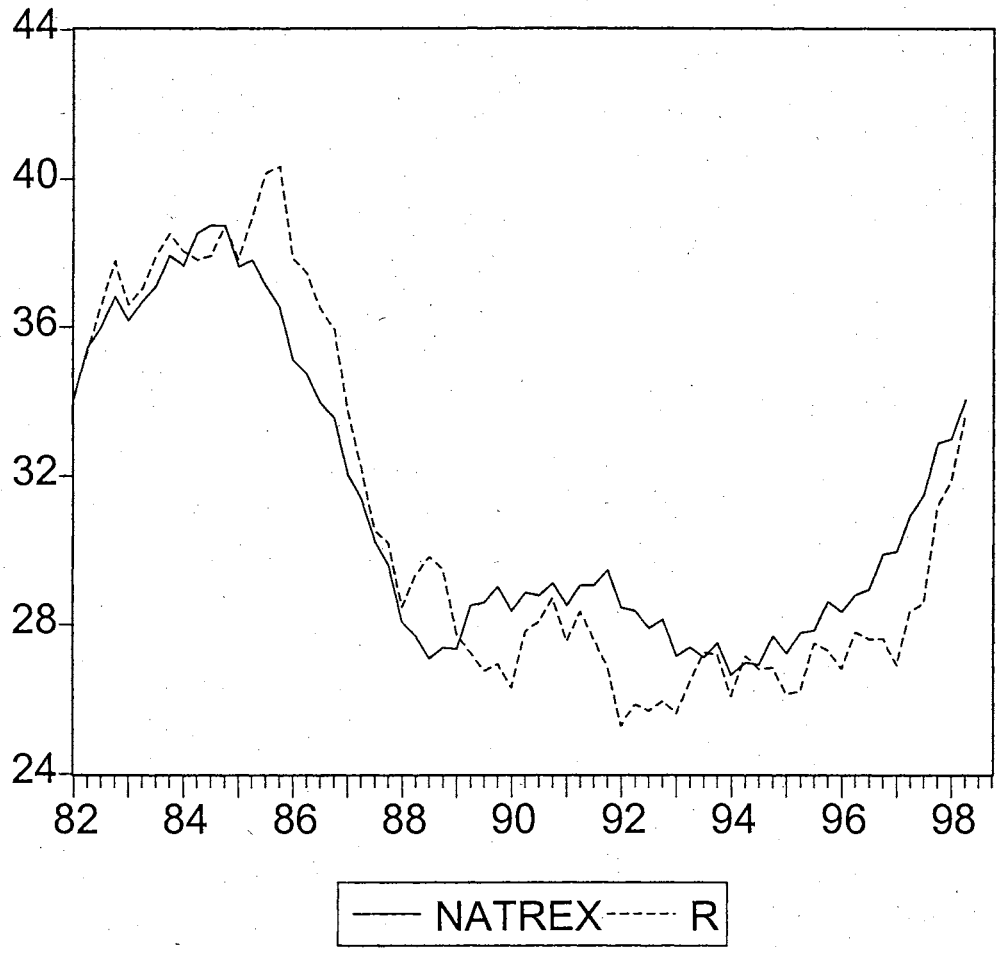


Figure 10. Dynamic Ex ante Forecast of NATREX for Taiwan (OLS Model)

$$NATREX_t = 14.3938 + 1.0217 NATREX_{t-1} - 2.9357 TAGROWTH_t - 0.5148 T$$
$$- 13.1492 SOCIAL_t + 2.2363 (TAGROWTH_t - TAGROWTH_{t-1}) \quad (34)$$

Another important endogenous variable in this case is the relative price ratio between the non-tradable and tradable goods. It plays a very important role in determining the real exchange for a small economy—the decomposition of real exchange rate shows that the terms of trade are exogenous for a small economy, so the economy essentially depends on the adjustments of the relative prices to reach a new equilibrium. The linear dynamic regression of the relative price shows the results consistent with the linear dynamic regression of the real exchange rate. Since $R_n(k_t, F_t; Z_t) = 1/RT$, all the signs of coefficients supposedly are opposite the signs of the regressions of the real exchange rate.

The empirical results of the OLS model are summarized in table 15. The constant term ($\hat{\beta}_1$), *TAGROWTH* ($\hat{\beta}_3$), and *SOCIAL* ($\hat{\beta}_4$) are statistically significant at the 1% and have the opposite signs compared to the relative price OLS model. The proxy, $(TAGROWTH_t - TAGROWTH_{t-1})$ ($\hat{\beta}_5$), of the changes of fundamental determinants is nearly significant at the 5% level also. There are no terms of trade ($T$) in the regressions, because it is not significant; its marginal contribution to explain the independent variable is too small.

When the real exchange rate appreciates because of an increase of the real growth (*TAGROWTH*) or a decline of the social time preference (*SOCIAL*), the capital intensity increases, foreign debt declines and total wealth increases in the long run. Appreciation effects switch partly import demand to domestic demand to drive the relative price ratio $P_n/P_1$ up.

TABLE 15

DYNAMIC ESTIMATES OF RELATIVE PRICE $R_n$ FOR TAIWAN (OLS MODEL)

| Variable | Coeff. ($\hat{\beta}_i$) | t-stat | 2-tail sig. |
|---|---|---|---|
| *CONSTANT* ($\hat{\beta}_1$) | -0.01659 | -4.4084 | 0.0000 |
| $R_n(-1)$ ($\hat{\beta}_2$) | 1.0408 | 20.8323 | 0.0000 |
| *TAGROWTH* ($\hat{\beta}_3$) | 0.3019 | 4.7951 | 0.0000 |
| *SOCIAL* ($\hat{\beta}_4$) | 0.0136 | 3.9600 | 0.0002 |
| ($TAGROWTH_t - TAGROWTH_{t-1}$) ($\hat{\beta}_5$) | -0.3278 | -1.9646 | 0.0541 |

*Note*: Adjusted sample period 1982: 2–1998:2, observations 65; Adj $R^2$=0.96; ADF for residuals is UROOT(N, 0)=-6.845 ; Heteroskedasticity test, prob is 0.0.427.

*TAGROWTH* ($\hat{\beta}_3$) that is significant at the 1% level has a positive sign here. For a small economy, if the real economic growth appreciates the real exchange rate and increases the relative price between the nontradable and tradable goods, the productivity increases more in the tradable goods sector than it does in the nontradable goods sector by the Balassa-Samuelson hypothesis, which is also the finding of Ito, Isard and Symansky (1997). If productivity of the tradable goods sector surges, the resources are switched from the nontradable goods sector to tradable goods sector and increase the supply of exports for a small economy. The terms of trade are exogenous, so the country can sell as many goods as it wants without influencing the tradable goods prices. Greater exports appreciate the real exchange rate with a rise of $R_n$ under exogenous terms of

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trade, and on other hand, the decrease of the supply of non-tradable goods pushes the relative price ratio, $R_n$, going up.

The positive sign of $SOCIAL$ $(\hat{\beta}_4)$, which is significant at the 1% level, is consistent with the regressions of the real exchange rate either. We have explained why a rise of $SOCIAL$ causes an appreciation of the real exchange rate, more consumption, a reduced rate of accumulating capital intensity and total wealth of the economy, because the economy is still growing and is on varying trajectories. So more consumption and appreciation of the real exchange rate push $P_n/P_1$ up. The proxy of the change of the fundamental determinants, $(TAGROWTH_t - TAGROWTH_{t-1})$ $(\hat{\beta}_5)$, has a negative sign with a 5% significant level, which is consistent with the result in the regressions of the real exchange rate.

The terms of trade are not significantly different from zero in the real exchange rate and relative price ratio. Usually, if the terms of trade, $T$, improve under a given $R_n$, it means that $P_n/P_2 = TR_n$ rises. Initially, this reduces the demand for the nontradable goods because of a relative higher price to the tradable goods. On the other side, a improved terms of trade stimulates the investment demand by Tobin's $q$, so there are two demand effects with two opposite effects thus causing an ambiguous net effect to the aggregate demand for the nontradable goods. The terms of trade thus can have a positive or negative sign with respect to the relative price between the nontradable and tradable goods both. The discussion empirically depends on how the terms of trade affect the real exchange rate and relative prices. Because they are not statistically significant in this case, as a consequence, they need not be discussed any further.

The same procedure for testing model stability and residuals by the unit root and heteroskedasticity tests is applied to assure us that the empirical results are reasonable and convincing enough. Figure 11, the recursive residuals, graphically illustrate the model stability with all the residuals within two standard deviation around a zero mean.

The error correction model that is shown in table 16 works well, too, and the empirical results are consistent with the OLS regression. All the interpretations of the error correction model related to the empirical work are similar to the interpretations for the OLS model. One more thing is that the error term $(\hat{\beta}_3)$ and $(TAGROWTH_t - TAGROWTH_{t-1})$ $(\hat{\beta}_4)$ have passed the Wald test, which are not equal to zero jointly with a 1% level. The dynamic ex ante forecast, denoted as $R_{nf(t)}$ has been derived on a base of the OLS model in table 15 and it has a good explanatory power. Figure 12 is the graph of the results that are produced by equation (35).

$$R_{nf(t)} = -0.01659 + 1.0408R_{nf(t-1)} - 0.3019TAGROWTH_t + 0.0136SOCIAL_t - 0.3278(TAGROWTH_t - TAGROWTH_{t-1}) \quad (35)$$

Finally, Taiwan's economic development pattern, which is policy-oriented, is from agriculture-oriented goods to light industrial exports and then to heavy industrial exports. Through the evolutions of its industrial structure, the values added of their exports stimulate the rapid economic growth due to the more technological progress in the tradable goods sector, thereby raising the relative price between the nontradable and tradable goods. A higher savings rate and great technological progresses have been resulted in the economy accumulating wealth over the past 40 years.

TABLE 16

DYNAMIC ESTIMATES OF RELATIVE PRICE $R_n$ FOR TAIWAN (ERROR CORRECTION MODEL)

| Variable | Coeff. ($\hat{\beta}_i$) | t-stat | 2-tail sig. |
|---|---|---|---|
| *TAGROWTH* ($\hat{\beta}_1$) | 1.4385 | 8.1046 | 0.0000 |
| *SOCIAL* ($\hat{\beta}_2$) | 0.0082 | 3.9970 | 0.0002 |
| *ERROR TERM* ($\hat{\beta}_3$) | 0.9550 | 51.4128 | 0.0000 |
| ($TAGROWTH_t - TAGROWTH_{t-1}$) ($\hat{\beta}_4$) | -1.5453 | -6.5289 | 0.0000 |

*Note*: Adjusted sample period 1982: 2–1998:2, observations 65; Adj $R^2$=0.96; ADF for residuals is UROOT(N, 0)=-6.845 ; Wald test for [ $\hat{\beta}_3 = \hat{\beta}_4 = 0$ ], prob is 0.

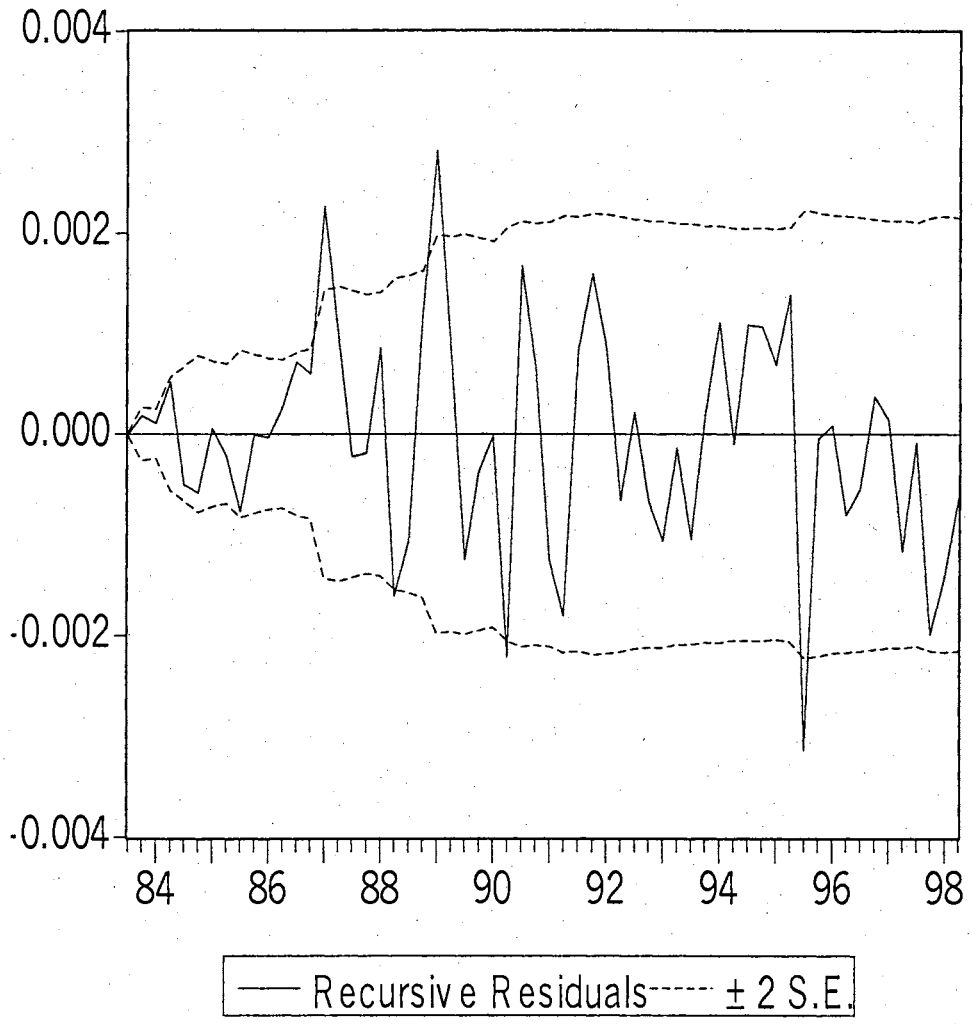


Figure 11. Recursive Residuals of Taiwanese Relative Price (OLS Model)

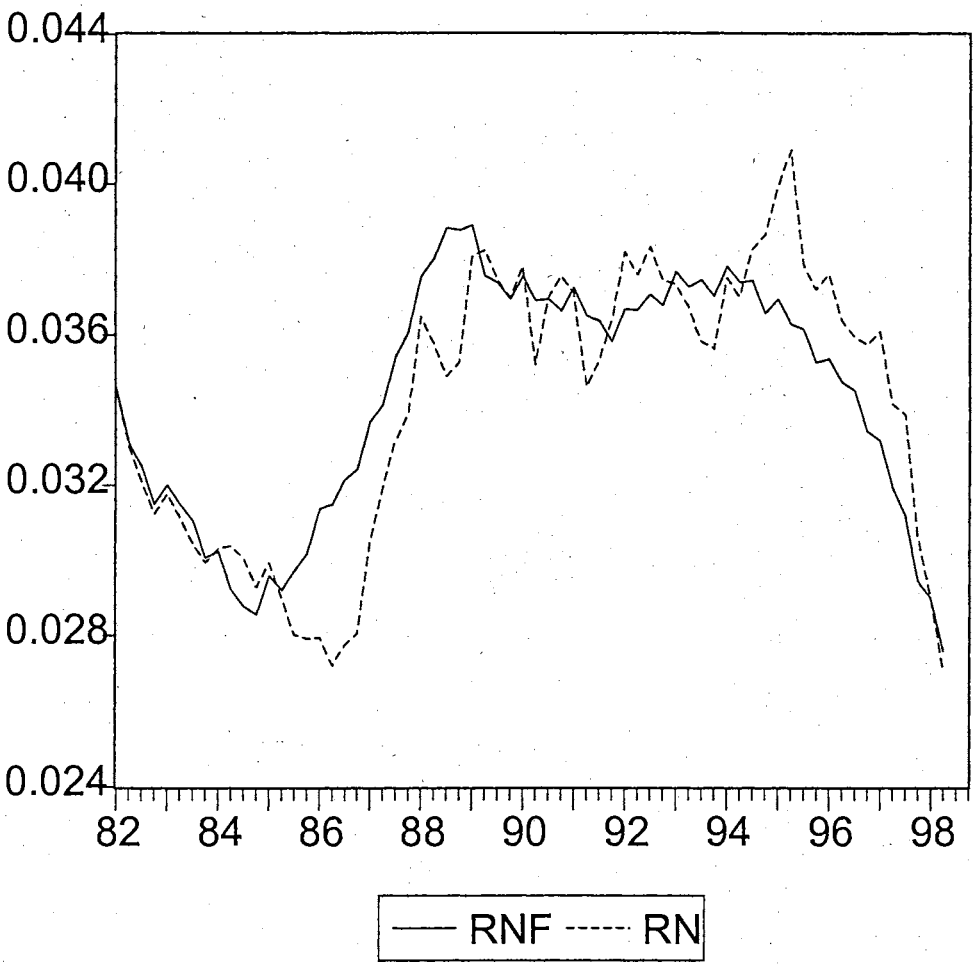


Figure 12. Dynamic Ex ante Forecast of Taiwanese Relative Price (OLS Model)

# CHAPTER VII

# CONCLUSION

A country can seek rapid economic growth by stimulating more exports and capital movements internationally than does a closed economy through a crucial intermediary object, fiat money. Great concerns have been raised about the volatilities of the exchange rates, including the argument of indeterminacy of the exchange rate in the foreign market. We do observe that economic performance involves the real demand for money, so the hypothesis is that there are fundamental determinants of equilibrium exchange rates resulting that causes trends in quilibrium real exchange rates.

This study employs the NATREX approach to verify the fundamental determinants of the real exchange rates. The NATREX means NATural Real Exchange Rate, and it is a moving equilibrium exchange rate responding to continual changes in exogenous real fundamentals—the savings rate and productivity for instance—and endogenous real fundamentals, which are the capital intensity and foreign debt. It is built on a general equilibrium concept that stresses the fundamental real terms such as the savings rate and productivity on the trend of the real exchange rate in an open economy. The NATREX reflects the dynamic interactions among individual decisions and different economies. It also stresses the real terms determine the basic economic decisions such as resource allocations but not the nominal terms.

Basically, the NATREX is a variable, which carries only medium and long run information that drives the trend behavior of the real exchange rate. We do not seek the equilibrium real exchange rate, because it is not possible to unearth the equilibrium real exchange rate due to the continuous changes of the fundamental determinants. We are not interested in explaining the actual deviation of exchange rate either—any short run disturbances deviating the real exchange rate from the trend disappear after a while, so there should be some fundamental determinants of the economy to sustain real exchange rate movements in the long run and this is the reason we apply the NATREX approach to our work.

For this study, the examination involves testing Taiwan-US and Canada-US cases; one is a growing small economy and the other is a developed medium economy, each highly related to the US economy, but under different international monetary systems and also under different levels of openness in their financial markets. Different economy sizes relative to foreign countries bring some features to the dynamic structural models, such as exogenous or endogenous terms of trade and real domestic interest rates to make the NATREX respond to different fundamental determinants in each country. In addition, the state of economic development might be another factor responsible for some particular and interesting empirical results.

Time series analysis is used to implement the whole research work. Three pretests are done first, the Granger causality, unit root and cointegration tests. After the pretests, an OLS and an error correction model are estimated in each case for both countries. We derive the NATREX for both countries by the dynamic ex ante forecast that uses the OLS models for each case. We dampen the seasonal and short run factors from the data, so the

derived NATREX goes through the series of the actual real exchange rate. There is slight difference between the NATREX and the actual real exchange rate observed in the market due to the way we have dealt with them. That is the way we extract the medium and long run information from the actual real exchange rate. The NATREX passes through the actual real exchange rate, because the NATREX just captures the trend, and under the floating exchange rate, there are more fluctuations indeed.

The main findings from the empirical results in Canada's case are as follows. When productivity, *CANGROWTH* , rises, the NATREX depreciates due to the wealth effect that dominates. It is difficult to distinguish the rise of productivity occurring in the nontradable goods sector or the tradable goods sector, because of doubts about the exogeneity of the terms of trade.

When the Canadian savings rate declines—*SOCIAL* surges—the NATREX depreciates due to the effect of borrowing to finance current consumption. The US real long-term interest rate weakly influences the Canadian economy. Generally, from the empirical results of the error correction component model, the NATREX does respond to the fundamental determinants; it does adjust the short run deviations gradually to the long run equilibrium relationship.

In Taiwan's case, the OLS model and error correction models for the real exchange rate and relative price strongly support the theory. When productivity, *TAGROWTH*, rises in the tradable goods sector, the relative price rises under the exogenous terms of trade and appreciates the NATREX; when the Taiwanese savings rate decreases, *SOCIAL* arises, it pushes the relative price up and appreciates the NATREX. The savings rate generates a very different effect in Taiwan's case.

From the theory, a rise of the savings rate appreciates the NATREX in the long run under a developed economy assumption, but for a growing economy, a decline in the savings rate still appreciates the NATREX due to the large current account surplus and the accumulating wealth. The savings rate is still relatively higher than other trade partners and the rising consumption is on the path to eliminate the current account surplus. Actually, this is a very good example of an emerging economy with a high savings rate catching up with developed countries. The exogenous terms of trade are not significant either in the regressions of the real exchange rate or in the regressions of the relative price

Taiwan's economic development pattern is from agriculture-oriented goods to light industrial exports and then to heavy industrial exports. Through the evolutions of its industrial structure, the values added of their exports stimulate the economic growth due to the higher productivity progress in the tradable goods sectors than in the nontradable goods sectors, thereby raising the relative prices between the nontradable and tradable goods sectors. A higher savings rate and high technological progress have helped Taiwan accumulating wealth over the past 40 years.

The fundamental determinants, which are the savings rate, productivity, and real long-term interest rate, do dominate the trend of the real exchange rate in the long run from our empirical evidences. That the correlations between the NATREX and the actual exchange rate is 0.70 in Canada case, and it is 0.95 in Taiwan's case fully support the NATREX fit the model quite well. The real fundamentals do sustain real exchange rate movements in the long run.

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# APPENDIXES

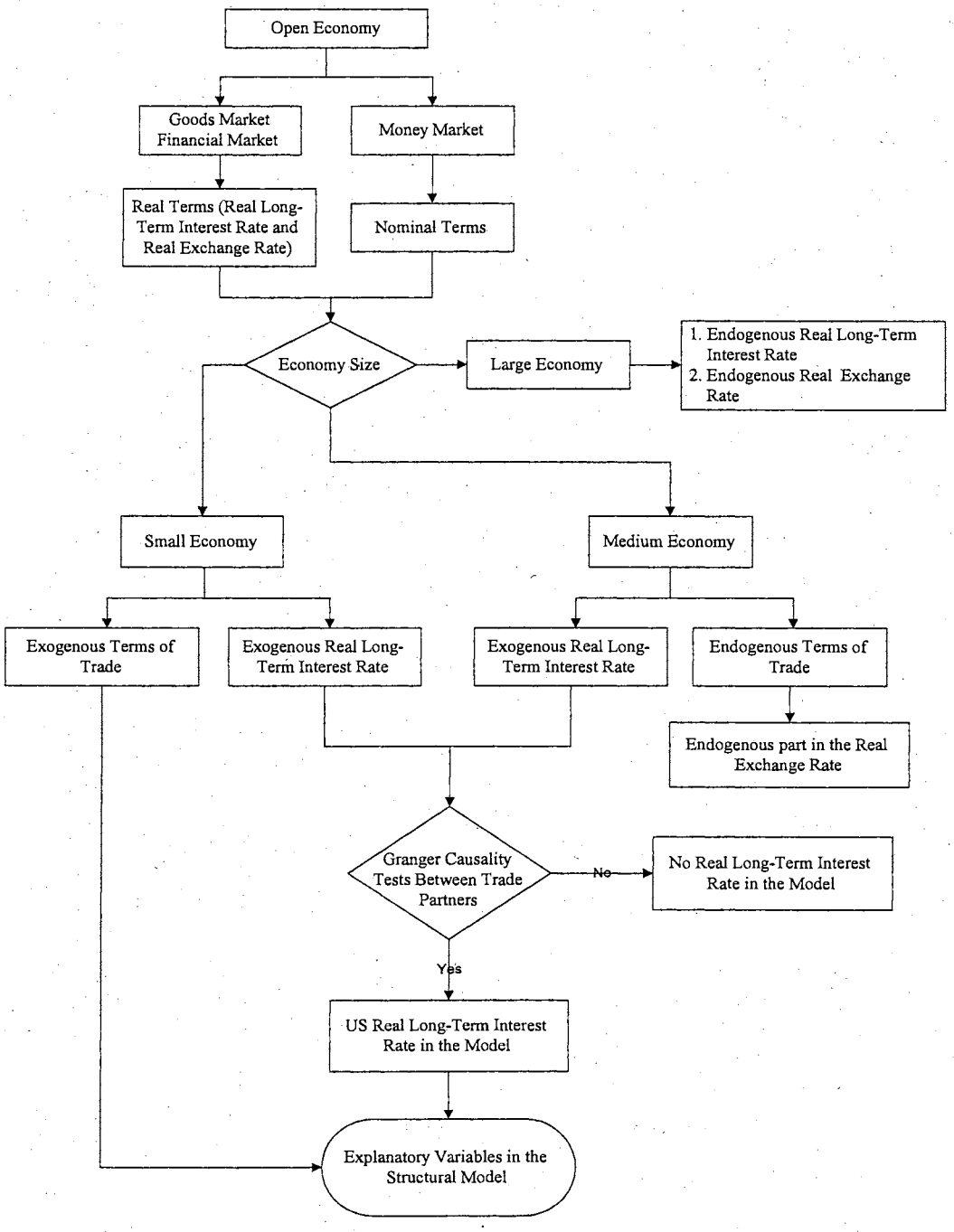


Figure A.1. Determination of the Exogeneity for Real Long-Term Interest Rate

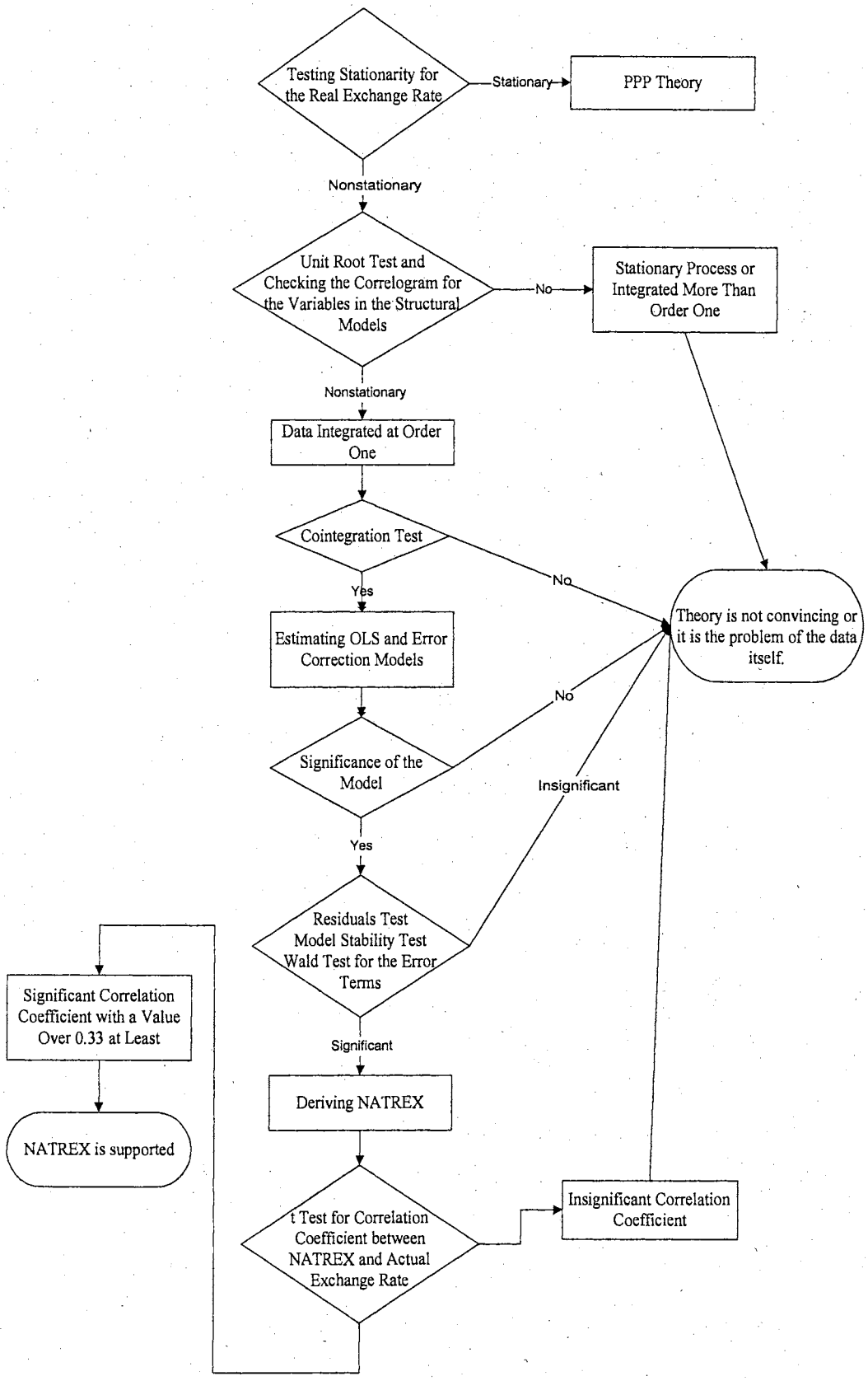


Figure A.2 Flowchart for Empirical Work

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