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Does an Undervalued Currency Merit Economic Growth? – Evidence from Taiwan

Summary: Whether an undervalued currency is an attainable industrial policy for developing countries' sustained development has recently invoked many discussions. This paper studies the case of Taiwan after first determining the misalignment of Taiwan's currency by estimating the fundamental equilibrium real exchange rate. Three sub-periods for Taiwan's currency exchange rate misalignment are identified: undervaluation in the periods 1981-1986 and 1998-2008 and overvaluation during 1987-1997. Second, we use a vector auto-regression (VAR) model to examine the Granger causality between exchange rate misalignment and GDP, by incorporating export and investment variables. The evidence shows that exchange rate misalignment does Granger cause GDP and it mainly comes from the third sub-period when the Taiwan dollar was undervalued. From past experience and the current economic doldrums of the last resort of global exports - the United States - currency undervaluation is not a validated strategy upon which emerging markets can wishfully impinge.

Key words: Undervaluation, Exchange rate misalignment, Net foreign assets, Terms of trade, Granger causality.

JEL: E58, F32, F34, G15.

The enormous foreign reserve accumulations in emerging market economies (notably in Asia) since the Asian 1997-98 currency crises have instigated much concern about their relationship to global imbalance and the possible adverse influence on global financial stability (Michael P. Dooley, David Folkerts-Landau, and Peter M. Garber 2003; Joshua Aizenman and Jaewoo Lee 2007). Searching for the causes of these anomalous increases in foreign reserves, one of the blaming fingers has pointed toward those governments that have deliberately manipulated their domestic currency in order to promote an export-oriented growth strategy. As Dooley, Folkerts-Landau, and Garber (2003) argued, under the "revived" Bretton Woods system, the peripheral emerging Asian countries use an undervalued currency to enhance exports to the center country (namely, the U.S.) so as to promote their economic growth. Whether export-led growth strategies are viable for developing countries has been widely discussed (Morris Goldstein and Nicholas R. Lardy 2008; Ann E. Harrison and Andres Rodriguez-Clare 2009). Export-led growth targeting is based on the argument that developing countries could benefit from learning-by-doing externalities through exporting (Kenneth J. Arrow 1962; Alwyn Young 1991). However, among the plethora of empirical studies on the causal relationship between exports and economic growth,

hardly any definite conclusion is reached due to using different empirical methodologies, variant sample countries and time periods, and the failure of duly considering missing variables, as argued by Judith A. Giles and Cara L. Williams (2000).

In line with the export-led growth strategy, recent studies have asserted that currency undervaluation is instrumental for economic growth (Eduardo Levy-Yeyati and Federico Sturzenegger 2007; Caroline Freund and Martga D. Pierola 2008; Dani Rodrik 2008). Rodrik (2008) presented that the growth strategy of using an undervalued currency is the second-best policy for developing countries due to their imperfect institutions. Anton Korinek and Luis Serven (2010) proposed that an undervalued currency is akin to lending to foreigners. In as much as the government "outsources" the targeting problem to foreigners, an undervalued currency renders said government to indirectly target the tradable sector (more capital-intensive), which generates large learning-by-investing externalities and boosts aggregate savings and investment. Notwithstanding, Freund and Pierola (2008) indicated that an undervalued currency is beneficial for economic growth due to the beachhead effect for the foreign market share. However, Levy-Yeyati and Sturzenegger (2007) argued that although an undervalued currency appears to induce higher growth, the effect - rather than through import-substitution or export booms - works largely through the deepening of domestic savings and capital accumulation.

While most empirical studies used panel data that include a cross-section sample with different countries and temporal data with different time periods, such as Freund and Pierola (2008) and Rodrik (2008), this paper instead investigates currency undervaluation and its effect on economic growth by focusing on a country-specific case of Taiwan. Although panel data analysis can result in a more general conclusion, an individual country study is able to catch the effect resulting from different political and economic environments that the country specifically faces. We first estimate the fundamental equilibrium exchange rate of Taiwan's currency vis-à-vis the US dollar by employing the cointegration method (Soren Johansen 1988; Johansen and Katarina Juselius 1990). The fundamental real exchange rate is closely related to five macroeconomic economic factors: net foreign assets, productivity differential, government consumption, terms of trade, and trade openness (John Williamson 1983; Peter B. Clark and Ronald MacDonald 1999; IMF 2006a). The misalignment is then determined by calculating the difference between the actual and estimated equilibrium real exchange rates. We find that prior to 1987 the Taiwan dollar indeed was undervalued, and under pressure from the U.S. government, the Taiwan dollar thereafter started to appreciate and remained overvalued until the inception of the 1997-98 Asian currency crises. Since then, the undervalued Taiwan dollar returned and lasted until the sub-prime crisis of the U.S., which reached its height in September 2008 when Lehman Brothers went bankrupt. As the US dollar has begun to depreciate in order to adjust the enduring current account deficit of the past two decades, it will be hard for the Taiwan dollar to remain inexorably low as before.

To investigate whether an undervalued currency merits economic growth, we use the Granger causality test. Eschewing the spurious causality inference due to missing variables and the often uncertain integrated order of the variables, we incorporate two more variables, investment and exports, and establish a VAR model. Using the Modified Wald (MWald) test, as suggested by Hiro Y. Toda and Taku Ya-

mamoda (1995) and Juan J. Dolado and Helmut Lütkepohl (1996), we find evidence of a causal relationship going from the exchange rate misalignment to *GDP*, which is particularly eminent in the third sub-period when the Taiwan dollar was undervalued.

The rest of this paper is organized as follows. Section 1 briefly explains Taiwan's external position from balance of payment accounting, accompanied by the evolution of the Taiwan dollar exchange rate vis-à-vis the US dollar. Section 2 derives the fundamental equilibrium exchange rate based on five macroeconomic determinants and shows our empirical methodology and the empirical results of the Taiwan dollar's misalignment in terms of the US dollar. Section 3 investigates the causal relationship between exchange rate misalignment and economic growth by using a four-variable augmented VAR model. Section 4 concludes.

1. Exchange Rate, Balance of Payment Accounting, and Foreign Reserve Accumulation

The excessive foreign reserve accumulation in emerging Asian countries has instigated a debate on whether the social cost is too high, as argued by Rodrik (2006) and Olivier Jeanne (2007), and/or a possible deterrence for the adjustment of a global imbalance, as offered by Maurice Obstfeld and Kenneth Rogoff (2005) and Barry J. Eichengreen and Yung Chul Park (2006). Reserve accumulation for emerging countries could result from either self-insurance, stemming from preventing a recurrence of currency crises or a by-product due to exchange rate intervention in order to promote export-led growth strategies (Dooley, Folkerts-Landau, and Garber 2003). It is difficult to disentangle whether the precautionary motive or mercantilism is the cause of the excessive amassing of reserves in emerging market countries (Jeanne and Romain Rancière 2006; Aizenman and Lee 2007; Cheng-Lang Yang and Ho-Don Yan 2011).

One of the manifestations of deliberate currency intervention is demonstrated in foreign reserve accumulation. Focusing on the exchange rate and the behavior of balance of payment accounting, we briefly observe Taiwan's case. Column (6) of Table 1 shows Taiwan's holdings of foreign reserves (*FR*) from 1981 to 2008, which increased sharply from 1981 to 1986, remained stable until 2001, and then started rising steeply. This sharply growing pattern is consistent with what IMF (2003) observed after the 1997-98 Asian currency crises, whereby Asian emerging market countries began to accumulate enormous foreign reserves. Being excluded from IMF membership, it is understandable that Taiwan's government cautiously holds extra reserves so as to prevent any sudden political and economic tumult. Where are those foreign reserves from? An expedient way is to examine the balance of payment (*BOP*) accounting, which indicates the balance of payments is an identity and is the sum of the current account (*CA*), the capital account (*KA*), the financial account (*FA*), and errors and omissions (*ERR*). The balance of payments is a flow and indicates increasing (decreasing) foreign reserves when it is positive (negative). The increase in foreign reserves, or *BOP*, stems mainly from the surplus of international goods (*CA*) and asset transaction (*FA*).

As witnessed from Table 1, although there is a sporadic negative ratio of the financial account (we add in *ERR* here) to *GDP* (*FAG*) as shown in column (4),

which indicates that capital outflows reduce the accumulation of foreign reserves, Taiwan's foreign reserve accumulation mainly results from a persistent current account surplus. The ratio of the current account (we add in *KA* here) to gross domestic product (denoted as *CAG* in Table 1) remains inexorably positive during the period 1981-2008, although the magnitude differs. Based on two major events - one in 1986 when capital controls were broadly dismantled and Taiwan's currency was forced to appreciate under the pressure of the U.S., and the other when the Asian currency crises erupted in 1997 - we observe the change in Taiwan's foreign reserves that simultaneously mirrors the evolution of the exchange rate in three sub-periods: 1981-1986, 1987-1997, and 1998-2008.

During the first sub-period (1981-1986) when capital mobility was restricted, the current account ratio in terms of *GDP* increased enormously from 1984 to 1986, registering 11.4%, 14.6%, and 20.9%, respectively. The ratio of the balance of payments to *GDP* (denoted as *BOPG* in Table 1) went up to 6.5%, 10.3%, and 30%, causing a large increase in foreign reserves (*FR*). At the same time, to avoid any adverse influence on its export industry, Taiwan's central bank practiced a slow appreciation policy through intervention in the foreign exchange market (Shiu-Sheng Chen and Tsong-Min Wu 2008). Foreign reserves rose sharply from US$22.6 billion in 1985 to US$46.3 billion in 1986, as shown in Table 1.

Under pressure from the U.S., in the second sub-period (1987-1997) the exchange rate of the New Taiwan Dollar (NT$) appreciated from US$1 = NT$35.5 in 1986 to NT$28.55 in 1987 as shown in column (7). The expectation of this appreciation attracted foreign capital inflows, which turned *FAG* to a respectively positive 9.0% and 9.7% in 1986 and 1987 as shown in Table 1 and reinforced the accumulation of foreign reserves. The Taiwan dollar's appreciation sped up and topped out at US$1 = NT$ 25.4 in 1992. The current account balance pared down, although it remained in a surplus. At the same time, economic growth dropped from a height of 10.68% in 1987 down to 5.57% and then maintained around 7% until the next dip in 1998. This partly reflects that Taiwan's economic growth graduated to a high-income country group and that economic growth stabilized.

Until the advent of the 1997-98 Asian currency crises, the Taiwan dollar averaged around 1:27 in terms of the US dollar. The uptrend of *BOPG* tamed out, and *BOPG* turned negative in 1988-1990, 1995, and 1997. The accumulation of foreign reserves dampened and settled to around US$88 billion in 1996. It is worth noting that political tension between the two sides of the Taiwan Strait in 1995-96, when mainland China launched missiles over the northern waters of Taiwan to deprecate Taiwan's first democratic presidential election, pushed forth sudden capital outflows that caused foreign reserves to plunge. The Asian financial crisis started in 1997 and produced another round of capital outflows and debilitated Taiwan's accumulation of foreign reserves.

In the third sub-period (1998-2008), current account surpluses increased steadily, because of the Taiwan dollar's depreciation after the Asian currency crises. Additionally, large foreign capital inflows contributed to *BOPG*'s rise, at 11.2% in 2002 and 11.9% in 2003 as shown in Table 1. Accompanying the increase of *BOPG*, foreign reserves grew to US$161 billion in 2002 and to US$206 billion in 2003. According to IMF (2006b), global foreign reserves jumped from US$1.2 trillion in 1995

to more than US$4 trillion in 2005. Partly due to the precautionary motive to prevent the devastating effect from currency crises, and partly because of an export-driven growth strategy, the uptrend in Taiwan's foreign reserve holdings is similar to Asian emerging market countries that hoarded substantial foreign reserves after the Asian financial crises in 1997-98. In 2008, as the global financial crisis spread to Taiwan, Taiwan's foreign reserves went further higher to US$291 billion from US$270 billion in 2007.

It is important to note that the accumulation of foreign reserves does not just result from an undervalued currency policy. Equal importance is given to the precautionary motive that is for preventing any sudden stop and the ensuing contractionary devaluation (Guillermo A. Calvo 1998; Jeffrey Frankel 2005; Michael M. Hutchison and Ilan Noy 2006). A growing trend of reserve holdings in Taiwan appears during 1981-2008, particularly since 2001, and the precautionary motive seems unable to explain such a trend. By estimating Taiwan's optimal reserve holdings, Yang and Yan (2011) also found that since 2001, the strategy of an undervalued currency to facilitate export-led economic growth plays a dominant role in reserve accumulation. If an undervalued currency contributes to enormous foreign reserve accumulation, then the key issue is to determine whether a currency is undervalued. In the following, we show that during the sample period of 1981-2008, the Taiwan dollar experienced three periods that are mixed with both undervalued and overvalued currencies.

2. Fundamental Equilibrium Exchange Rate and Misalignment

To determine whether a currency is undervalued, we first need to determine what the equilibrium exchange rate is. Instead of using theories of exchange rate determination, such as those methods based on the purchasing power parity or monetary approach, we estimate the fundamental equilibrium real exchange rate (FEER), which is determined by fundamental macroeconomic factors, as suggested by Sebastian Edwards (1989), Clark and MacDonald (1999), and IMF (2006a), among others.

2.1 Determinants of the Fundamental Equilibrium Exchange Rate

We first define the real exchange rate as follows:

$$q_t = s_t - p_t + p_t^* , \tag{1}$$

where q_t is real exchange rate, and s_t, p_t, and p_t^* represent the corresponding nominal exchange rate (US dollar in terms of NT dollar), domestic price level, and foreign price level. All four variables are in log form. Factors that determine the fundamental equilibrium real exchange rate are represented by Z_{1t}. As a result, equation (1) can be expressed as:

$$q_t = \beta_1' Z_{1t} + \varepsilon_t . \tag{2}$$

Here, β_1' is a coefficient vector, and ε_t is a random error term.

Following Clark and MacDonald (1999), we define total misalignment (tm) as:

$$tm_t = q_t - \beta_1' \overline{Z}_{1t} \tag{3}$$

where $\overline{Z}_{1t}$ denotes the medium-term sustainable fundamentals. The total misalignment therefore can be expressed as:

$$tm_t = \left[\beta_1'\left(Z_{1t} - \overline{Z}_{1t}\right)\right] + \varepsilon_t . \tag{4}$$

where $\left[\beta_1'\left(Z_{1t} - \overline{Z}_{1t}\right)\right]$ measures the deviation of the current exchange rate away from the economic fundamentals. In general, the total misalignment can be divided into two parts. One is from the random errors, and the other is the misalignment of the exchange rate.

In practice and as aforementioned, the real exchange rate (q_t) is defined as the foreign price (U.S.) multiplied by the nominal exchange rate and divided by the domestic (Taiwan) price level. The price levels of U.S. and Taiwan are represented by *CPI*. The economic fundamentals consist of the five variables that are often discussed (Hamid Faruqee 1995; Clark and MacDonald 1999; IMF 2006a). In the following, we introduce the relationship between the real fundamental equilibrium exchange rate and five determinant variables.

Net foreign assets (nfa_t): Net foreign assets are defined as the difference between foreign assets held by domestic residents and foreign investors' holdings of domestic assets. For debtor countries, currency depreciation is one of the ways to decrease net external debts. On the contrary, creditor countries are capable of appreciating their currency (IMF 2006a). However, for a net debtor country, it is possible that a short-term increase in capital inflow leads to currency appreciation, as often occurs in transition economies (Robert M. Burges, Stefania Fabrizio, and Yuan Xiao 2003; Omar AIShehabi and Shuang Ding 2008). On the other hand, a country under export-led growth, such as an emerging Asian country, might follow an undervalued currency growth strategy, which could cause net foreign assets to have a positive relationship with currency depreciation. Due to unavailable quarterly data of net foreign assets in terms of *GDP*, following Plamen Iossifov and Elena Loukoianova (2007), and Luca A. Ricci, Gian Maria Milesi-Ferretti, and Lee (2008), we use the accumulated current account (*CA*) instead. We use net foreign assets in 1980 as the base (annual data adapted from Philip Lane and Milesse-Ferreti 2007) and sequentially add up the current account balance of each quarter to obtain the time series of net foreign assets from 1981Q1 to 2008Q2.

Productivity differential (tnt_t): According to the Balassa-Samuelson effect (Béla Balassa 1964; Paul A. Samuelson 1964), when the productivity of tradable sectors is greater than that of non-tradable sectors, the average price level will be higher as the price level of non-tradable increases. This is because higher wages in tradable sectors spill over to non-tradable sectors and put upward pressure on wages, resulting in a higher relative price for non-tradables. Accordingly, the domestic currency appreciates in real terms (Farugee 1995). We use the ratio of per capita *GDP* of Taiwan

relative to the U.S. to proxy the productivity difference (Alexander *Chudik and* Joannes *Mongardini* 2007; AIShehabi and Ding 2008).

Government consumption (cg_t): Increasing government consumption pushes the price of non-tradable goods to go up and renders real exchange rate appreciation (Jóse De Gregorio, Alberto Giovannini, and Holger C. Wolf 1994; Ricci, Milesi-Ferretti, and Lee 2008). However, if the sources of government consumption are from taxing the private sector, then to some extent, it could cause the real exchange rate to depreciate (AIShehabi and Ding 2008). We use government consumption in terms of *GDP* relative to the U.S. to capture the effect of government consumption on the real exchange rate.

Terms of trade (tot_t): The terms of trade represents the ratio of the export price index (*XPI*) and import price index (*MPI*). An improvement in terms of trade generates an income or wealth effect, which increases domestic demand and may cause currency appreciation (IMF 2006a). However, if the substitution effect dominates the income effect, then it is possible to cause real currency depreciation.

Trade openness ($open_t$): We use *exports* plus *imports* in terms of *GDP* to proxy for trade openness. Trade protection leads to higher domestic prices and a greater appreciated real exchange rate. A shift in a country's trade policy towards greater liberalization leads to an increase in demand for tradable goods. The real exchange rate will depreciate in order to shift the demand from non-tradable to tradable goods. Thus, there is a positive relationship between the real exchange rate and trade openness (Edwards 1989; Juthathip Jongwanich 2010).

Note that all the variables are in log form. Economic theory indicates that the relationship between the real exchange rate *q* and each economic fundamental can be summarized as follows (the positive and negative signs underneath each variable in the parenthesis are the expected signs):

$$\underset{(+/-)\quad(-)\quad(+/-)\quad(+/-)\quad(+)}{q_t = q\ (\ nfa_t,\ tnt_t,\ cg_t,\ tot_t,\ open_t\ )} \tag{5}$$

2.2 Data and Estimation Results

All the data are adopted from the International Financial Statistics (IFS) of the IMF and AREMOS, which is a dataset maintained by Taiwan's Ministry of Education. The Appendix shows the data sources. Table 2 shows the correlation coefficients of the six variables used in our estimation of the equilibrium real exchange rate. In accordance to the theoretical relationship presented above, there is a positive correlation between openness and the real exchange rate, and the other variables have a negative correlation with the real exchange rate.

We employ the co-integration regression to estimate the FEER. Before implementing the cointegration estimation, we need to assure that the integrated order of each variable has the property of I(1), which can be determined by using the unit root test. The test regression of the unit root can be sensitive to the lags selected. The principle for selecting the lags is to eradicate the serial correlation of the error term. In practice, so as to not overuse the lags, the Akaike information criterion (AIC) is adopted. We also follow the general-to-specific procedure proposed by Water Enders

(2004) by first selecting the regression model using both the trend and constant terms, and then sequentially deleting the insignificant trend and constant term if the testing result does not reject the null hypothesis of unit root. We also implement another unit root test with higher power of the test - namely, DF-GLS unit root tests (Graham Elliott, Thomas T. Rothenberg, and James H. Stock 1996). As seen in Table 3, the unit root tests (Said E. Said and David A. Dickey 1984; Elliott, Rothenberg, and Stock 1996) show that all the variables follow the I(1) process.

The ensuing Johansen cointegration test (Johansen 1988; Johansen and Juselius 1990), based on the E-view program to run the Johansen co-integration estimation, indicates that six variables have one cointegrated vector as shown in Table 4. There are five models with different specifications in the co-integration estimation presented in the E-view program. Model 3, which considers that there is a constant in the co-integrated vector, is selected. Table 4 shows that there are two cointegrated vectors under the trace test, while there is only one cointegrated vector detected under the maximum eigenvalue (λ-*Max*) test. Johansen and Juselius (1990) suggested using λ-*Max* tests when there are different results between the trace test and λ-*Max* tests.

Based on q, we normalize this cointegrated vector and express it as equation (6) as follows:

$$\begin{array}{ccccccc} q = 2.65 + 0.12nfa - 0.93tnt + 0.48tot + 0.47cg + 1.18open \\ (0.02) \quad (0.18) \quad (0.18) \quad (0.22) \quad (0.14) \\ [-5.20] \quad [5.16] \quad [-2.64] \quad [-2.08] \quad [-8.08] \end{array} \tag{6}$$

In equation (6) the number in the parenthesis under the estimated coefficients is the standard error, and following down the number inside the bracket is the *t*-value. The estimated coefficient of *nfa*, 0.12, indicates that the increase in Taiwan's net foreign assets is accompanied by currency depreciation, which could reflect that Taiwan's government pursues an export-led growth policy by keeping its currency undervalued. The estimated coefficient of *tnt*, -0.93, is negative and is consistent with what we expect whereby high productivity is accompanied by an appreciating currency. The positive estimated coefficients of *tot* and *cg*, 0.48 and 0.47, respectively, indicate that the relative increase in export prices and the increase in government consumption are accompanied by the Taiwan dollar's depreciation. The positive estimated coefficient of openness, 1.18, indicates the fact that openness is accompanied by a depreciating currency, as discussed in Section 3.1.

3. Undervalued Currency and Economic Growth

Based on the equilibrium exchange rate estimated in Section 3, we calculate the exchange rate misalignment and investigate its effect on *GDP*.

3.1 Misalignment of the Taiwan Dollar

Figure 1 shows the estimated equilibrium real exchange rate based on equation (6) and the actual real exchange rate, and Figure 2 shows their difference, which is used for measuring the misalignment. Three sub-periods can be identified according to the

direction of misalignment. The first sub-period, 1982Q1 to 1986Q3, is a regime with currency undervaluation although there were a few periods of overvaluation in the few initial periods (up to 1981Q4). The average undervaluation is about 0.8% and the highest undervaluation is in 1983Q2, with a 2.6% deviation from the equilibrium exchange rate. The second sub-period, 1986Q4 to 1997Q3, is a regime of currency overvaluation, although there is a small magnitude of undervaluation between 1993 and 1994. The average overvaluation is about 3.5% and the highest overvaluation, 9.1%, occurred in 1988Q1. The period 1997Q4 to 2008Q2 is when the Taiwan dollar returned to undervaluation. The average undervaluation is about 3.4% and in 2002Q1 the deviation from equilibrium reached 7.2%, which was the highest in this sub-period. Our results are similar to Chen and Wu (2008), although they use the monetary approach to estimate the equilibrium exchange rate of the NT dollar in terms of the US dollar by using monthly data for the period 1980M12-2004M12. Chen and Wu (2008) found that for the two time periods of 1980M12-1987M6 and 1997M8-2004M12, the Taiwan dollar was significantly undervalued, while it was overvalued during the period of 1987M7-1997M7.

These three sub-periods of exchange rate misalignment reflect Taiwan's economic development. An export-let growth policy has been pursued since the beginning of the 1970s. Under this export promotion policy, special export zones were established and the nominal exchange rate was fixed. As shown in column (2) of Table 1, average *GDP* growth reached 7.2% during 1981-1986, although there was the second oil shock in the early 1980s. Since 1986, Taiwan moved from a fixed exchange rate regime to a flexible one. However, intervention by Taiwan's central bank was never a nuance. With a persistent current account surplus vis-à-vis the U.S., Taiwan (like Japan) confronted pressure from the U.S. and the Taiwan dollar started to appreciate from 35.5 in 1986, reaching its strongest, 26.16, in 1989. Thereafter, it lingered around 27 prior to the 1997-98 Asian currency crises.

Although Taiwan's currency was in an overvaluation region in the second sub-period, the average *GDP* growth rate remained at 7.3% during this period as shown in Table 1. Thereafter, the adverse impact from the Asian currency crisis pushed Taiwan's currency into a series of depreciation moves. The argument of the revived Bretton Woods System pre-supposed that emerging Asian countries intentionally undervalue their currencies to export themselves out of a recession. However, in 2001 with the collapse of the dot.com bubble, which wrought havoc on Taiwan's economy due to its heavy reliance upon the high-tech industry, this resulted in a negative *GDP* growth rate of -1.65%. In the third sub-period, the average *GDP* growth rate still remained at 4.1%. The unfolding of the sub-prime crisis from the end of 2007 and the immediate adjustment of the global imbalance portend the end of relying on an undervalued currency to promote an export-led growth strategy for emerging market countries in general and for Taiwan in particular.

3.2 Causal Relationship between Exchange Rate Misalignment and Economic Growth

In order to examine whether exchange rate misalignment (*misa*) merits economic growth, we employ the four-variable VAR model, which, apart from exchange rate

misalignment and *GDP*, includes two more variables: exports (*ex*) and investment (*inv*). It bears noting that our test on the causal relationship between the exchange rate and *GDP* is different from a large volume of studies on the causal relationship between exports and *GDP* (Giles and Williams 2000). Huang Tai-Hsin Huang (2002) and Chen and Wu (2008) both found that there is cointegration of four variables, including exports, *GDP*, investments, and terms of trade, and presented evidence of export-led growth in Taiwan. In this paper we also employ the four-variable VAR model, but add the exchange rate misalignment to replace terms of trade, which was used in the estimation of the real equilibrium exchange rate.

Table 5 provides descriptive statistics of those four variables. The time series of misalignment of the exchange rate, the residual of the cointegrated vector, is stationary, I(0), and the other three variables are I(1), as shown in Table 6, we use the Augmented Vector Autoregression (VAR) estimation, suggested by Toda and Yamamoda (1995) and Dolado and Lütkepohl (1996), which could avoid any spurious causality inference due to the misspecification of the integrated order of the variables. This test is implemented by estimating a VAR system of the lag order as ($m+d_{\max}$), where $d_{\max}$ is the highest order of integration suspected in the system. The statistical inference of the null hypothesis is based on the Modified Wald (MWald) test, which follows an χ^2 distribution, but the degree of freedom is *m* instead of $m+d_{\max}$. According to the Monte Carlo experimentations exercised by Hector O. Zapada and Alicia N. Rambaldi (1997), despite intentional overfitting, the MWald test performs as well as similar but more complicated testing procedures in samples of at least size 50.

In the spirit of Granger causality, we examine whether past information of one variable helps to predict the other variable (Clive W. J. Granger 1969) by estimating the following augmented VAR system:

$$gdp_t = \alpha_1 + \sum_{i=1}^{m+d_{\max}} \beta_{1i}^{gdp} gdp_{t-i} + \sum_{i=1}^{m+d_{\max}} \beta_{1i}^{misa} misa_{t-i} + \sum_{i=1}^{m+d_{\max}} \beta_{1i}^{inv} inv_{t-i} + \sum_{i=1}^{m+d_{\max}} \beta^{ex}{}_{1i} ex_{t-i} + v_{1t} \quad (7a)$$

$$misa_t = \alpha_2 + \sum_{i=1}^{m+d_{\max}} \beta_{2i}^{gdp} gdp_{t-i} + \sum_{i=1}^{m+d_{\max}} \beta_{2i}^{misa} misa_{t-i} + \sum_{i=1}^{m+d_{\max}} \beta_{2i}^{inv} inv_{t-i} + \sum_{i=1}^{m+d_{\max}} \beta^{ex}{}_{2i} ex_{t-i} + v_{2t} \quad (7b)$$

$$inv_t = \alpha_3 + \sum_{i=1}^{m+d_{\max}} \beta_{3i}^{gdp} gdp_{t-i} + \sum_{i=1}^{m+d_{\max}} \beta_{3i}^{misa} misa_{t-i} + \sum_{i=1}^{m+d_{\max}} \beta_{3i}^{inv} inv_{t-i} + \sum_{i=1}^{m+d_{\max}} \beta^{ex}{}_{3i} ex_{t-i} + v_{3t} \quad (7c)$$

$$ex_t = \alpha_4 + \sum_{i=1}^{m+d_{\max}} \beta_{4i}^{gdp} gdp_{t-i} + \sum_{i=1}^{m+d_{\max}} \beta_{4i}^{misa} misa_{t-i} + \sum_{i=1}^{m+d_{\max}} \beta_{4i}^{inv} inv_{t-i} + \sum_{i=1}^{m+d_{\max}} \beta^{ex}{}_{4i} ex_{t-i} + v_{4t} \quad (7d)$$

Here, *gdp*, *misa*, *inv*, and *ex* are variables as mentioned before; *v* is the error term; α is a constant term; β denotes coefficients to be estimated; *m* represents the lag order selected; $d_{\max}$ is extra lags chosen and will be explained later.

In the case of equation (7a), the null hypotheses of Granger non-causality from *misa*, *inv*, and *ex* to *gdp* are $\beta_{1i}^{misa} = 0$, $\beta_{1i}^{inv} = 0$, and $\beta_{1i}^{ex} = 0$, for all $i = 1, 2, ..., m$, respectively. The rejection of the null hypothesis accordingly indi-

cates evidence of Granger causality. Using a similar procedure, the other three equations (7b, 7c, and 7d) can be estimated and tested. For instance, $\beta_{2i}^{gdp} = 0$, $\beta_{3i}^{gdp} = 0$, and $\beta_{4i}^{gdp} = 0$, for all $i = 1, 2, ..., m$, are the null hypotheses of Granger non-causality going from *gdp* to *misa*, *inv*, and *ex*, respectively. To select the lag order (*m*) used for the VAR system, we use the Akaike Information Criterion (AIC). Since *misa* is I(0), and the other three variables are integrated of order of 1, $d_{\max}$ is set to equal 1.

We first test Granger non-causality for the whole sample period. Since there are three sub-periods during 1981Q1 to 2008Q2, characterized with two undervalued periods (1981Q1-1986Q3 and 1997Q4-2008Q2) and one overvalued period (1986Q4-1997Q3), we also implement the Granger causality test for each sub-period to investigate whether there is a different causal relationship between the undervalued and overvalued currency periods. It is worth noting that lag selection of a VAR model can be sensitive to the causality test results. Due to the short sample size for each sub-period, we use ACI as the guide for model selection. We start by using the maximal 8 lags for the whole sample, 4 lags for the 1st sub-period, and 6 lags for the 2nd and 3rd sub-periods. We then sequentially decrease the lags by one until the one with the minimized AIC. Table 7 presents the causality test based on the MWald test. The m that we select for the whole sample period is 6 lags, while 2 lags, 6 lags, and 6 lags for the first, second, and third sub-periods, respectively.

For the whole sample period, non-Granger causality from *misa* to *gdp* can be rejected under the 5% significance level. We also detect that there is Granger causality from *GDP* to investment and bi-directional causality between investment and exports. However, we are unable to find any evidence of Granger causality from exports to *GDP* as found by Huang (2002) and Chen and Wu (2008). This interesting disparity could result from the inclusion of exchange rate misalignment, which might downplay exports' influence.

For the three sub-periods, and particularly for the first sub-period, we have to take the results with caution due to the relatively small sample sizes. For the first sub-period when the currency was mostly undervalued, there is hardly any causal relationship between *misa* and *gdp* detected under the 5% significance level, although there is causality from exports and *GDP* to investment and from investment and *GDP* to exports. In the second sub-period under the overvaluation regime, there is hardly any significant causality relationship detected under the 5% significance level. In the third sub-period when there was an undervalued currency of the Taiwan dollar vis-à-vis the US dollar, there is a significant causal relationship going from *misa* to *gdp* under the 5% significance level, as shown in Table 7.

In sum, it is evident that the exchange rate misalignment Granger causes *GDP* for the whole sample period. This result mostly comes from the 3rd sub-period when the exchange rate was undervalued. The causality relationship between exports and *GDP* is underplayed when adding the exchange rate misalignment.

4. Conclusions and Policy Implications

An undervalued currency has been claimed to be one of the best attainable industrial policies for sustained development in developing countries. It is better, more auto-

matic, less manipulatable, and less easily distorted by corruption and rent-seeking than when subsidizing domestic industries, as predicated by Stephen S. Cohen and Bradford DeLong (2010). Variant empirical studies have supported this argument, such as Rodrik (2008) and Freund and Pierola (2008), but most of them focus on the estimation of cross country data mixed with time series data. In this paper we study Taiwan's case by using the fundamental equilibrium real exchange rate approach to determine the direction of exchange rate misalignment. We first determine the misalignment of Taiwan's currency by estimating the fundamental equilibrium exchange rate, which is determined by macroeconomic variables including net foreign assets, productivity difference, government consumption, terms of trade, and trade openness. We find that prior to the 1997-98 Asian currency crises, the Taiwan dollar experienced undervaluation before 1987, and afterwards it sailed toward a moderate overvaluation regime until the next Asian currency crisis in 1997, in which thereafter it went back to an undervaluation regime. Second, we detect a causal relationship going from exchange rate misalignment to real *GDP,* and this seems to mainly come from the undervalued currency period of 1998Q1-2008Q2.

The undervalued currencies of Asian emerging countries since the 1997-98 Asian currency crisis have been perceived as analogous to what Dooley, Folkerts-Landau, and Garber (2003) argued about the revived Bretton Woods system, whereby emerging Asian countries, similar to Japan and Western Europe after WWII, used the U.S. as the central country to target their exports through undervalued currencies. Although an undervalued currency brings about benefits, it is prone to eliciting countervailing "beggar thy neighbor" policies (Peter B. Henry 2008). Freund and Pierola (2008) argued that the marginal benefit of an undervalued currency will decrease. Aaditya Mattoo and Arvind Subramanian (2008) suggested that an undervalued currency is similar to subsidizing exports or imposing a tariff on imports. Therefore, the WTO should duly punish those national policies obstructing international trade.

The enduring global current account imbalance has invoked the sentiment of protectionism or the accusation of exchange rate manipulation. Japan's experience in the 1980s offers a good lesson. With the expanding trade imbalance between Japan and the U.S., the Japanese yen was forced to appreciate after the U.S. accused Japan of currency manipulation. Notwithstanding this, in the middle of the 1980s Taiwan's own persistent current account surplus vis-à-vis the U.S. instigated a decade-long appreciation of the Taiwan dollar and lasted until the 1997-98 Asian currency crises. The Taiwan dollar's ensuing undervaluation, accompanied with other emerging Asian countries' undervalued currencies, has been ascribed as one of the reasons causing this global imbalance and the U.S. sub-prime crisis. As the U.S. economy remains in the doldrums, it almost sounds the death knell for this round of undervaluation. If past experience is any guide, then having an undervalued currency as a growth strategy for emerging market economies cannot last long, and the gains from undervaluation will pare down as time goes by.

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Appendix: Data Sources

Variables	Data sources	Unit
Real *GDP*	AREMOS – NIAQ	Million USD
CA: current account	AREMOS – IFS	Million USD
FA: financial account	AREMOS – IFS	Million USD
KA: capital account	AREMOS – IFS	Million USD
ERR: errors and omissions	AREMOS – IFS	Million USD
BOP: balance of payments	AREMOS – IFS	Million USD
FR: total reserves minus gold	AREMOS – IFS	Million USD
E: exchange rate, NTD/USD	AREMOS – IFS	NTD
CPI: consumer price index	AREMOS – IFS	Index
CPI (US)	IMF – IFS	Index
NFA: net foreign assets	Lane and Milesse-Ferreti (2007)	Million USD
Nominal *GDP*	AREMOS – IFS	Billion NTD
G: government expenditure	AREMOS – QNET	Billion NTD
XPI: export price index	AREMOS – PRICE	Index
MPI: import price index	AREMOS – PRICE	Index
Exports	AREMOS – IFS	Billion NTD
Imports	AREMOS – IFS	Billion NTD
Real *GDP*	AREMOS – NIAQ	Billion NTD
GDP per capita	AREMOS – IFS	Thousand USD
GDP per capita (US)	IMF – IFS	Thousand USD
Investment	AREMOS – QNET	Million NTD

Note: All the data are adopted from IMF and AREMOS, which is maintained by Taiwan's Ministry of Education. Unless indicated as the U.S., all the data refer to Taiwan (TW). The sample period is 1981Q1-2008Q2.

Source: Authors.

Table 1 Open Macroeconomic Data of Taiwan (1981-2008)

Year	*GDP*(1)	*Y(%)*(2)	*CAG*(3)	*FAG*(4)	*BOPG*(5)	*FR*(6)	*E*(7)
1981	49,154	6.46	1.1	8.6	9.7	7,235	37.84
1982	49,621	3.97	4.5	-2.3	2.2	8,532	39.91
1983	54,109	8.32	8.2	-2.0	6.2	11,859	40.27
1984	60,969	9.32	11.4	-4.9	6.5	15,664	39.47
1985	63,197	4.07	14.6	-4.2	10.3	22,556	39.85
1986	77,801	11.00	20.9	9.0	30.0	46,310	35.50
1987	103,713	10.68	17.4	9.7	27.1	76,748	28.55
1988	122,020	5.57	8.3	-9.5	-1.1	73,897	28.17
1989	151,580	10.28	7.5	-8.0	-0.5	73,224	26.16
1990	164,747	6.87	6.5	-8.9	-2.4	72,441	27.11
1991	184,870	7.88	6.5	-1.3	5.2	82,405	25.75
1992	219,974	7.56	3.7	-3.1	0.6	82,306	25.40
1993	231,531	6.73	2.9	-2.2	0.7	83,573	26.63
1994	252,665	7.59	2.4	-0.6	1.8	92,454	26.24
1995	274,728	6.38	1.8	-3.2	-1.4	90,310	27.27
1996	287,913	5.54	3.6	-3.2	0.4	88,038	27.49
1997	298,773	5.48	2.3	-2.5	-0.2	83,502	32.64
1998	275,080	3.47	1.2	0.6	1.8	90,341	32.22
1999	299,010	5.97	2.6	3.6	6.2	106,200	31.40
2000	326,101	5.80	2.6	-1.9	0.8	106,742	32.99
2001	293,712	-1.65	6.4	-0.5	5.9	122,211	35.00
2002	301,087	5.26	8.7	2.5	11.2	161,656	34.75
2003	310,939	3.67	9.8	2.1	11.9	206,632	34.00
2004	340,278	6.19	5.8	2.0	7.8	241,738	31.90
2005	364,606	4.70	4.8	0.7	5.5	253,290	32.90
2006	376,723	5.44	6.9	-5.3	1.6	266,148	32.60
2007	393,613	5.98	8.4	-9.4	-1.0	270,311	32.40
2008	403,127	0.73	6.1	0.4	6.5	291,707	32.9

Note: *GDP* indicates gross domestic product (2005 base) in millions of US dollars; y is the real *GDP* growth rate; *FR* is total reserves minus gold in millions of US dollars; *E* denotes the exchange rate of one US dollar in terms of one Taiwan dollar; *CAG*, *FAG*, and *BOPG* represent current account (including capital account balance, *KA*), financial account (including errors and omissions, *ERR*), and balance of payments as a share of *GDP*, respectively. See Appendix for the variables' descriptions and the data sources.

Source: Authors.

Table 2 Correlation Coefficients of 6 Variables

	q	***nfa***	***tnt***	***tot***	***cg***	***open***
q	1	-0.43	-0.19	-0.57	-0.66	0.67
nfa		1	0.49	0.42	0.10	-0.29
tnt			1	0.20	0.04	-0.06
tot				1	0.73	-0.85
cg					1	-0.85
open						1
Max.	3.55	4.10	0.03	0.36	0.08	0.27
Min.	3.10	0.91	-0.20	-0.18	-0.33	-0.37
Mean	3.33	2.90	-0.07	0.19	-0.09	-0.17
St.d.	0.15	0.81	0.06	0.11	0.10	0.15
Obs.	110	110	110	110	110	110

Note: *q* (real exchange rate) is obtained by dividing E*CPI(US) with CPI(TW); *nfa* (net foreign assets) is measured by using the stock of net foreign assets in 1980 as the base and adding the current account of 1981.1 to obtain *nfa* of 1981.1, and the rest of the quarterly *nfa* are duly obtained; all the *nfa* are in terms of *GDP*; *tnt* is measured by the difference of the growth rate per capita *GDP* between Taiwan and the U.S.; *tot* represents terms of trade and is obtained by dividing *XPI* with *MPI*; *cg* is government expenditure in terms of *GDP*; *open* is obtained by the calculation on (*imports + exports)/GDP*. All the six variables have been expressed as natural log. See Appendix for the variables' descriptions and the data sources.

Source: Authors' estimations.

Table 3 Unit Root Test for 6 Variables in Cointegration Estimation

	Level		**1st difference**	
	ADF	**DF-GLS**	**ADF**	**DF-GLS**
q	-2.59(12)	-1.77(5)	-2.53(12)***	-3.10(4)**
nfa	-2.52(7)	-0.53(6)	-2.23(6)***	-2.28(6)**
tnt	-1.54(9)	-1.41(4)	-2.72(8)***	-5.43(1)***
tot	0.74(0)	0.19(1)	9.26(0)***	-9.28(0)***
cg	0.02(6)	-0.66(6)	-4.02(5)***	-3.18(4)***
open	-0.54(5)	-0.66(4)	-6.39(4)***	-4.28(2)***

Note: The ADF statistics are obtained by using the regression model, which follows the procedures of Enders (2004). The lags selected (in the parenthesis) in the regression for the ADF and DF-GLS tests are based on AIC. ***, **, and * represent the 1%, 5%, and 10% significance levels, respectively.

Sources: Authors' estimations.

Table 4 Cointegration Estimation

	Trace test	C. V. (5%)	λ-Max	C. V. (5%)
r = 0	140.84**	95.75	65.16**	40.08
r ≦1	75.68**	69.82	30.59	33.88
r ≦2	45.09	47.86	21.32	27.58
r ≦3	23.76	29.80	13.91	21.13
r ≦4	9.85	15.49	8.84	14.26
r ≦5	1.01	3.84	1.01	3.84

Note: C.V. represents the critical value under the 5% significance level. ** denotes the 5% significance level.

Source: Authors' estimations.

Table 5 Correlation Coefficients of 4 Variables

	gdp	misa	inv	ex
gdp	1	0.31	0.98	0.97
misa		1	0.22	0.33
inv			1	0.92
ex				1
Max.	5.04	0.23	4.34	4.82
Min.	4.25	-0.32	3.64	3.91
Mean	4.71	-0.003	4.10	4.40
Std. Dev.	0.24	0.13	0.24	0.24
Obs.	110	110	110	110

Note: *gdp* represents real *GDP* after taking log; *misa* denotes misalignment of the exchange rate, which denotes the difference between the estimated fundamental equilibrium exchange rate and the actual real exchange rate; *inv* and *ex* denote investment and exports, respectively, and are expressed in log form. See Appendix for the variables' descriptions and the data sources.

Source: Authors' estimations.

Table 6 Unit Root Test for 4 Variables in Causality Estimation

	Level		1st difference	
	ADF	DF-GLS	ADF	DF-GLS
gdp	2.86(1)	2.86(1)	-5.80(0)***	-5.80(0)***
misa	-1.70(0)*	-0.95(0)	-4.92(2)***	-3.43(4)***
inv	-1.69(5)	-0.28(5)	-3.27(4)***	-2.55(2)***
ex	-2.31(4)	-1.57(4)	-6.09(3)***	-6.15(3)***

Note: The ADF statistics are obtained by using the regression model, which follows the procedures of Enders (2004). The lags selected (in the parenthesis) in the regression for the ADF and DF-GLS tests are based on AIC. ***, **, and * represent 1%, 5%, and 10% significance levels, respectively.

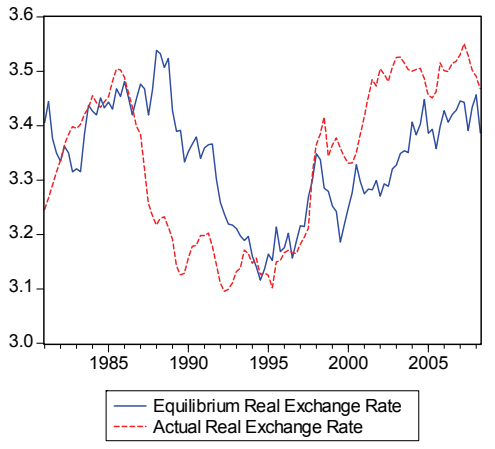
Source: Authors' estimations.

Table 7 Causality Test on *gdp*, *misa*, *inv*, and *ex*

		Dependent variables			
	Lagged variables	***gdp***	***misa***	***inv***	***ex***
1981Q1-2008Q2[6]	*gdp*		1.81(0.93)	17.1(0.00)***	6.08(0.41)
	misa	14.40(0.02)**		7.23(0.29)	3.70(0.71)
	inv	5.60(0.46)	5.60(0.46)		12.4(0.05)**
	ex	6.56(0.36)	8.54(0.20)	13.3(0.03)**	
1981Q1-1986Q3[2]	*gdp*		1.14(0.56)	7.14(0.02)**	9.80(0.00)***
	misa	0.56(0.75)		3.45(0.17)	1.64(0.43)
	inv	0.79(0.67)	3.73(0.15)		6.71(0.03)**
	ex	2.45(0.29)	2.85(0.23)	10.0(0.00)***	
1986Q4-1997Q3[6]	*gdp*		5.13(0.52)	6.75(0.34)	3.23(0.77)
	misa	10.4(0.11)		9.29(0.15)	12.0(0.06)*
	inv	9.22(0.16)	9.63(0.14)		10.5(0.11)
	ex	10.9(0.09)*	4.74(0.57)	9.68(0.13)	
1997Q4-2008Q2[6]	*gdp*		8.97(0.17)	9.16(0.16)	6.81(0.33)
	misa	13.5(0.03)**		8.52(0.20)	8.29(0.21)
	inv	6.73(0.34)	8.47(0.20)		4.27(0.63)
	ex	9.62(0.14)	7.56(0.27)	4.41(0.62)	

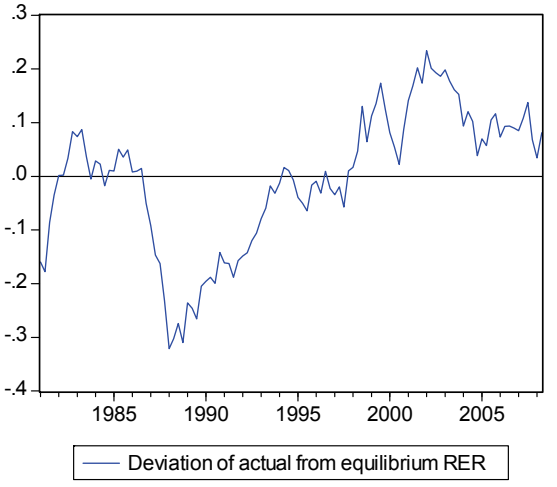
Note: *gdp* represents real *GDP* after taking a natural log; *misa* denotes misalignment of the exchange rate, which denotes the difference between the estimated fundamental equilibrium exchange rate and the actual real exchange rate; *inv* and *ex* denote investment and exports, respectively, and both are expressed in log form. See Appendix for the variables' descriptions and the data sources. The test is based on the modified Wald test. The number in the bracket beside the time period is the degree of freedom of χ^2. The number in the parenthesis beside the modified Wald test statistics is the P-value. ***, **, and * represent the 1%, 5%, and 10% significance levels, respectively.

Source: Authors' estimations.



Source: Authors.

Figure 1 Actual and Estimated Equilibrium Real Exchange Rates of the Taiwan Dollar in Terms of the US Dollar



Source: Authors.

Figure 2 Misalignment of the Taiwan Dollar

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