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"Taiwanese Foreign Exchange Intervention 2001-2020:
the best proxy for intervention with considering hidden reserve issue
and the estimation of intervention policy reaction function"

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Taiwanese Foreign Exchange Intervention 2001-2020: the best proxy for intervention with considering hidden reserve issue and the estimation of intervention policy reaction function

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Abstract

The secretive Taiwanese foreign exchange intervention (FXI) and hidden reserve issue have posed difficulties for studying the exchange rate policy taken by the Central Bank of Taiwan. To get a clear grasp of the Taiwanese exchange rate policy even in lack of officially disclosed FXI records, firstly, I find out the most accurate proxy for the Taiwanese FXI in the existing literature. Secondly, I estimate the central bank's FXI policy reaction function, using the most accurate proxy. It turns out that there exists one structural change within the central bank's FXI around December 2011. Before December 2011, the central bank basically adopted lean-against-the-wind intervention in the short run, enhanced the New Taiwan Dollar's value in the long run, and asymmetrically conducted the interventions. In contrast, after December 2011, the central bank became less engaged in the outright purchasing/selling operations in the FX spot market.

Keywords: Foreign exchange intervention; Hidden reserves; Exchange rate policy; Structural change

1. Introduction

After the collapse of the Bretton Woods system in February 1973, the Taiwanese monetary authority stuck to the dollar peg until January 1979, and then adopted a central exchange rate system that decided every-business-day central exchange rate and limited the New Taiwan Dollar (TWD) / US Dollar (USD) spot rate fluctuations within certain ranges. Then, in April 1989, the central exchange rate regime shifted to a managed floating regime, which allowed the TWD to float more freely. The Taiwanese monetary authority repeatedly declares that it will intervene in the FX market if there exists excessive volatility in the TWD FX rates[1].

It is well known that the Central Bank of Taiwan strongly engages in FX intervention for the past decades. However, detailed information regarding the Taiwanese central bank's FX intervention is basically not disclosed. The secretive FXI has drawn much attention not only from academic but political fields due to Taiwan's distinctiveness of the lack of IMF membership. The Central Bank of Taiwan seems to act very cautiously and conservatively as it has no "lender of last resort". In the early Taiwanese FXI studies, Frankel et al. (1994) mention that Taiwan had been piling visible international reserves that were close to a world record. Recent research points out that the movements of TWD FX rates have been quite stable (Chen and Wu, 2008; Chang et al., 2017).

These results suggest that the Central Bank of Taiwan strongly engages in FX intervention, which may aim to limit speculation opportunities in normal times and to maintain the economy's financial stability.

Since 2019, the Central Bank of Taiwan began to disclose information on its outright purchasing and selling records in the FX spot markets on a half-year basis. However, the historical FXI records for the period before 2019 and higher-frequency data remain confidential. In the existing literature, there is a divergence of opinion regarding the Taiwanese foreign exchange rate policies: one group suggests that the Central Bank of Taiwan has adopted "asymmetric interventions", especially, the "devaluation policy" (Chen and Wu, 2008; Chen and Wu, 2010; Yao et al.,2010; Chang, 2013; Ko, 2018), to ensure the export advantage. In contrast, the other group suggests that the central bank has consistently adopted "lean-against-the-wind" interventions regardless of whether the TWD appreciates or depreciates. (Wu et al., 2011; Wu et al.,2012; Lin et al., 2012) Because there is no publicly disclosed FXI data, the literature uses proxies for the FXIs. The opinion divergence in the above-mentioned studies is basically generated from the coarse proxies for the Taiwanese FXI. To be more specific, less literature validates the FXI proxies that are constructed, and no study considers the hidden reserves when constructing the Taiwanese FXI proxies.

In the existing literature, the most-used proxies for FXI are based on "Change in FX reserves" (For example, Liu, 1993; Chen and Wu, 2008; Wu et al., 2012; Fratzscher et al., 2020; Adler et al., 2021). Some literature tries to make the "Change in FX reserves" more accurate by excluding the estimated interest income and valuation changes. However, this method does not work in Taiwan's case in consideration of the fact that the Central Bank of Taiwan keeps taking on vast FX derivative exposure and call loan position with domestic financial institutions (Setser, 2019), which are the so-called "hidden reserves". The existence of the huge hidden reserve position dampens the performance of "Change in FX reserve" proxy, and thus may affect the accuracy of the estimation results. Further, Taiwan's lack of IMF membership also makes the central bank postpone producing the IRFCL (International Reserves and Foreign Currency Liquidity), which is an IMF's data release template that discloses the central bank's overall activities in currency markets, including the so-called hidden reserve transactions. Considering this data availability problem, a more accurate proxy which can deal with the hidden reserve issue is required in order to study the Taiwanese FXI and exchange rate policy.

In this study, in order to address the problems resulting from the lack of FXI data and the hidden reserve issue when studying the Taiwanese FXI and exchange rate policy, I first find out a proxy that can deal with the Taiwanese central bank's hidden reserve issue (Setser, 2019). This proxy is constructed of two flow statistics: the "Balance of Payment (BOP) – Reserve assets" and the "Taiwan Financial Statistic Monthly (TFSM) – Factors Responsible for Change in Reserve Money – Foreign assets" (Lee, 2021). Then, in order to validate and prove the predictability of the BOP-TFSM proxy, I use the officially disclosed data and the "news proxy", which is the data collected

from newspaper reports, to check the quality of BOP-TFSM proxy. By going through the rigorous process, the BOP-TFSM proxy is verified to be the most plausible proxy in the existing literature. Next, using the most plausible proxy, I then estimate the Taiwanese central bank's FXI policy reaction functions to discover the central bank's intervention behaviors for the past two decades.

The main findings and the contributions of this paper are as follows. First, finding out the most plausible and accurate proxy for the Central Bank of Taiwan's FX intervention in the existing literature. Second, finding out the Taiwanese central bank's intervention rules for the period from 2001 to Dec. 2011: adopting lean-against-the-wind intervention in the short run, enhancing the New Taiwan Dollar's value in the long run, asymmetrically conducting the interventions, and the intervention itself was positively autocorrelated. Third, identifying the structural change in the central bank's intervention behavior around Dec. 2011. For the period after Dec. 2011, the result shows that the central bank become less engaged in the outright purchasing/selling operations in the FX spot market and no longer followed the intervention rule that it had been used to follow in the previous decade. Also, there is evidence showing that the central bank likely began adopting other methods in this period – such as End-of-day intervention or verbal intervention – to affect the New Taiwan Dollar's value instead of its outright purchasing/selling in the FX spot market.

The remainder of this paper is organized as follows. Section 2 presents the most plausible proxy for Taiwanese FX spot intervention (The detailed process of searching and constructing the most plausible proxy is presented in the online appendix). Section 3 analyzes the Taiwanese exchange rate policy using the most plausible proxy. Section 4 discusses the Taiwanese "End-of-day" interventions. Section 5 concludes.

2. The Most Plausible proxy

The general steps for searching for the most plausible proxy for Taiwanese FXI are presented in the following. (The detailed procedure of searching and constructing the most plausible proxy is presented in the online appendix: Section A1)

Step 1: *Reviewing the proxies used in the existing literature, and examining whether the methods adopted in the literature are appropriate for constructing the Taiwanese central bank's FXI proxies, with considering the hidden reserve positions.*

After going through this process, it turns out that the proxy constructed of "Balance of Payment (BOP) – Reserve assets" (quarterly data) and "the Taiwan Financial Statistic Monthly (TFSM) – Factors Responsible for Change in Reserve Money – Foreign assets" (Monthly data) (Lee, 2021) is theoretically the best one in the literature.

Step 2: *Stripping out the interest receipt flows from the "BOP—reserve assets" and the "TFSM—Financial Assets" data. Then getting the monthly BOP-TFSM proxy.*

The interest receipt flows are estimated by evenly dividing the actual annual interest revenues (which can be obtained from the Taiwanese central bank's annual income statements[2]) into the monthly interest revenues. The sample period of this study depends on the availability of the CBT's historical annual income statements. As the earliest disclosed annual income statement is the 2001 one, the sample period of this study is from January 2001 to December 2020.

Step 3: *Checking for the monthly BOP-TFSM proxy's accuracy by using the "News proxy" proposed by Ko (2018) and the officially announced information on FXIs (on a half-year basis, disclosed since 2019).*

It turns out that the BOP-TFSM proxy behaves quite consistently with the News proxy for more than half of the whole sample period of this study. Also, the BOP-TFSM proxy can correctly predict the directions as well as the scales of officially disclosed FXIs.

The monthly BOP – TFSM proxy is presented in Figure 1. In Figure 1, the positive value represents the net USD-purchasing (TWD-selling) intervention and the negative value represents the net USD-selling (TWD-purchasing) intervention. Also, to avoid estimation errors, monthly net FXIs within +/- USD 500 million are assumed to be zero.

In Figure 1, one can check the pattern of Taiwanese FX intervention for the period from 2001 to 2020: (1) the magnitudes of the monthly FXIs largely shrank around 2011, but again surged after the 2020 COVID shock. (2) the directions of monthly FXIs seemed to be asymmetric before 2011, but have become relatively symmetric since 2011. While the directions have again turned asymmetric since the 2019 year-end. (3) the FXIs have become less frequent since 2011, but again became frequent in the second half of 2019.

3. The Model of Intervention and Estimation

This section examines whether the Central Bank of Taiwan follows certain "rules" to decide to intervene in the FX spot market. Policy reaction functions of the Taiwanese central bank's FXIs are estimated based on the monthly BOP—TFSM FXI proxy. Due to data availability, literature regarding estimating the Taiwanese central bank's FXI policy reaction function has been lacking. Also, the studying periods regarding the Taiwanese FXIs are mainly before 2013. Further, what exactly the FX policies that the Central Bank of Taiwan has adopted for the past decades (especially in the 2000s) are still under debate in the literature. Analyses in this section aim to fill these gaps.

3.1 The FX policy reaction function

3.1.1 Ordered Probit reaction function

Ito and Yabu (2007) derive FXI policy reaction function from the central bank's cost minimization problem. The Ordered Probit model of Ito and Yabu (2007) is the following:

$$IINTV_t = \begin{cases} +1 & if \quad \mu_2 < y_t^* \\ 0 & if \quad \mu_1 < y_t^* < \mu_2 \\ -1 & if \quad y_t^* < \mu_1 \end{cases} \tag{6}$$

where $IINTV_t$ denotes the ordinal indicator variable of FXIs in month *t*, the value "+1" represents the USD-purchasing intervention, the value "0" represents no intervention, and the value "-1" represents the USD-selling intervention. The {-1,0,+1} variables thus correspond to the signs of monthly BOP – TFSM proxy. (For example, net 1000 million USD-purchasing intervention corresponds to the "+1" variable, net 1000 million USD-selling intervention corresponds to the "-1" variable, and the net intervention within +/- USD 500 million corresponds to zero.)

The latent variable $y_t^* = \beta_1(s_{t-1} - s_{t-1}^{Short}) + \beta_2\left(s_{t-1} - s_{t-1}^{Long}\right) + \beta_3 IINTV_{t-1} + \varepsilon_t$ represents the optimal amount of FXI. (For example, if y_t^* is greater than the value of threshold μ_2, then the central bank conducts USD-purchasing intervention. If y_t^* is smaller than the value of μ_1, then the central bank conducts USD-selling intervention. If y_t^* is among the interval $[\mu_1, \mu_2]$, then the central bank doesn't conduct intervention.) The s_t denotes the natural log of TWD/USD rate at the close of Taipei Forex market at month t, the s_t^{Short} denotes the natural log of representative short-run TWD/USD rate; and the s_{t-1}^{Long} denotes the natural log of representative long-run TWD/USD rate. The error term $\varepsilon_t \sim i.i.d.\mathcal{N}(0, \sigma^2)$. The Ordered Probit reaction function will be estimated using the maximum likelihood method.

Regarding this model, one can expect: (1) if the central bank adopts "lean-against-the-wind" interventions, then $\beta_1 < 0$; (2) if the central bank tends to decelerate the currency's long-run appreciation trend, then $\beta_2 < 0$; (3) if the central bank's FXIs has positive autocorrelation, then $\beta_3 > 0$. The absolute value of threshold parameters μ_1 and μ_2 represent the costs of USD-selling intervention and USD-purchasing intervention, respectively. By comparing the value of μ_1 and μ_2, one can check whether the central bank intervenes in the spot market asymmetrically.

3.1.2 Linear reaction function

The linear version of Ito and Yabu's (2007) Ordered Probit reaction function is also estimated:

$$IINTV_t = \beta_0 + \beta_1(s_{t-1} - s_{t-1}^{Short}) + \beta_2\left(s_{t-1} - s_{t-1}^{Long}\right) + \beta_3 IINTV_{t-1} + u_t \tag{7}$$

where u_t refers to as the error term. Regarding this model, one can also expect: (1) if the central bank adopts "lean-against-the-wind" interventions, then $\beta_1 < 0$; (2) if the central bank tends to decelerate the currency's long-run appreciation trend, then $\beta_2 < 0$; (3) if the central bank's FXIs

has positive autocorrelation, then $\beta_3 > 0$.

3.2 Estimations

The policy reaction functions are estimated in this subsection. Since the model specification Eq. (6) and Eq.(7) uses prior-period variables as the explanatory variables, the estimations are free from the endogeneity problem of the structural relationship between interventions and current FX rate movements. The zero correlation between the lagged value of the intervention ($IINTV_{t-1}$) and the residuals is also detected to ensure that there is no endogeneity stemming from the dynamic regression model. In addition, since the OLS residuals likely fail to be independent in time-series regressions, the serial correlation would be tested in the first place. If serial correlation within the OLS residuals is detected, then the Generalized Least Square (GLS) would be conducted (using Maximum Likelihood estimation). In this way, the autocorrelation structure within the residuals would be specified to generate credible estimation results. If there is no serial correlation within the OLS residuals, then the policy function is simply estimated using the OLS (using heteroskedasticity-consistent standard error estimators).

3.2.1 Data

The sample period is from January 2001 to December 2020. Also, reaction functions Eq. (6) and Eq. (7) would be fitted to the following dataset. The dataset is presented in the Table 1.

3.2.2 Structural change

Before applying OLS to Eq. (7) (Using full sample and 3-year FX rate moving average as the long-run target rate), whether serial correlations are within the residuals is checked. Breusch-Godfrey Test (Breusch, 1978; Godfrey, 1978) is performed to test for autocorrelation within the OLS residuals and it turns out that the OLS residuals follow an AR(3) process.[3] Hence, Generalized Least Square (GLS) specifying the time-series process for the residuals is applied to Eq. (7), using the maximum likelihood estimation. Also, DF-GLS Test (Elliott et al., 1996) is conducted to test whether the left-hand-side and the right-hand-side variables follow the unit root processes. All the variables in the full sample reject the null hypotheses of unit root at 5% significance level.[4]

The GLS estimation results are summarized in Table 2, together with the OLS estimates. It can be concluded that the full sample OLS estimates are quite close to the GLS ones. Therefore, I simply conduct the OLS to check whether there exists structural change.

For the Eq. (7), the sup*F* test (Chow, 1960; Andrews, 1993) is conducted to test for structural change. The structural change would be detected if the null hypothesis of no structural change is rejected. To ensure there is enough data in the subsamples, I follow the common suggestion for

the first 15% and last 15% sample trimming. (Andrews, 1993; Ito and Yabu, 2007) That is, only the middle 70% of the sample period would be tested for possible change.

The test result suggests that the optimal breakpoint occurs at **December 2011** at 10% significance level.[5] This matches the eyeball test result in some way. Therefore, in the following analysis, the full sample would be split into two subsamples: February 2001- December 2011 and January 2012- December 2020.

3.2.3 Linear regression estimations

The linear policy reaction function Eq. (12) is estimated, using 6 datasets: the right-hand-side variable $(s_{t-1} - s_{t-1}^{Long})$ is proxies by $\Delta s_{t-1}^{1YMA}, \Delta s_{t-1}^{3YMA}$, and Δs_{t-1}^{5YMA} (See Table 1) for two subsamples (February 2001- December 2011 and January 2012- December 2020).[6]

For the first subsample (February 2001- December 2011) using either Δs_{t-1}^{1YMA}, Δs_{t-1}^{3YMA}, and Δs_{t-1}^{5YMA} right-hand-side variable, no autocorrelation within the OLS residuals is detected (using Breusch-Godfrey Test). Thus, the OLS regressions (heteroskedasticity-consistent standard errors approach) are applied to estimate the coefficients. In contrast, for the second subsample (January 2012- December 2020), AR(3) processes are detected. Hence, the GLS regressions specifying the time-series processes for the residuals are applied. The estimation results are summarized in Table 3, Table 4, and Table 5.

From Table 3, Table 4, and Table 5, it can be concluded that the model fits are quite well in the first period (February 2001- December 2011), but the relationships collapse in the second period (January 2012- December 2020).

In the first period, for estimations using different long-run target FX rates (1-year, 3-year, and 5-year moving averages), the estimated coefficients are quite close and the signs of estimated coefficients are identical. Minor differences among the three cases include: the model using the 5-year moving average fits the best (has the highest adjusted *R*-squared: 0.391), and the 3-year one's performance takes second place.

For the estimated coefficients, the significantly negative β_1s suggest that the Central Bank of Taiwan had adopted "lean-against-the-wind" interventions to offset the TWD appreciation /depreciation in the short run. The significantly positive β_2s suggest that the central bank has long-run targets in mind when intervening in the spot market. If checking TWD/USD spot and 1/3/5-year moving averages (in figure 2), for most of the time in the first period, the spot is lower than long-run moving averages. That is, TWD was in a long-run appreciating trend. Therefore, the central bank also intervened in the market to accelerate this TWD appreciating trend. (e.g., the central bank may want to enhance the purchasing power of TWD in the long run.) The significantly

positive β_3s again verify that the Taiwanese central bank's FX interventions indeed have positive autocorrelations. In short, for the period from February 2001 to December 2011, the Central Bank of Taiwan's operations in the FX spot market averagely followed a "rule" which can be captured by the linear policy reaction function Eq. (7).

By contrast, for the second period, there is no significant evidence for the Taiwanese central bank's reactions to the (previous month) spot deviations from short-run and long-run target FX rates. That is, the central bank no longer followed the rule which can be captured by the linear reaction function Eq. (7) to intervene in the TWD/USD spot market since 2012. The Robustness check for the results is presented in the online appendix: Section A2.

3.2.4 Ordered Probit estimations

Table 6 presents the estimated results of the Ordered Probit model Eq. (6) for 6 datasets. For the first period, the estimated (normalized) coefficients β_i^* $(i = 1,2,3)$ are quite close to the linear regression ones. All the estimates are highly significant and the estimated signs are the same as their linear counterparts. As for the second period, the results also show there is no significant evidence for explaining the central bank's FXI behaviors.

As mentioned in section 3.1.1, the Ordered Probit model helps to find out whether the central bank intervenes in the spot market asymmetrically. The absolute values of (normalized) threshold parameters μ_1^* and μ_2^* can be interpreted as the costs of "selling USD (purchasing TWD)" interventions and the costs of "purchasing USD (selling TWD)" interventions, respectively.

In the first period (in either three cases), the estimated μ_1^* is significantly different from zero, but the estimated μ_2^* is not. This result suggests that there is significant evidence for the Taiwanese central bank's asymmetric FX interventions for February 2001 – December 2011. That is, the central bank tended to conduct "purchasing USD" FXIs more than "selling USD" ones in the 2000s. This result suggests that the Central Bank of Taiwan had adopted "asymmetric interventions". For the second period (in either three cases), both the estimated μ_1^* and μ_2^* are significantly different from zero, but the absolute value of μ_1^* is still higher than μ_2^*. Thus, it can be concluded that the FXI patterns have become less asymmetric since 2012.

In addition, the difference between μ_1^* and μ_2^* can be interpreted as the "neutral band of no intervention". The "neutral band" is narrower in the first period than the one in the second period. This also matches the fact that FXIs have been less conducted since 2012.

To sum up, section 3.2.3 and 3.2.4 provide the empirical evidence that the Central Bank of Taiwan basically followed certain rules to intervene in the FX spot market for February 2001 –

December 2011: adopting lean-against-the-wind intervention in the short run, enhancing the TWD's value in the long run, asymmetrically conducting the FXIs, and the FXIs was positively autocorrelated. However, the Taiwanese central bank's FXI behaviors greatly changed around 2012. For the period from January 2012 to December 2020, the Central Bank of Taiwan no longer kept to the rule that it used to keep to intervene in the FX spot market.

4. The End of Day Intervention

So far, the estimated FXI policy reaction functions suggest that the Central Bank of Taiwan no longer followed certain rules to intervene in the FX spot market since 2012. This may indicate that the Central Bank of Taiwan indeed relaxed the controls on the TWD FX rates since 2012. However, in 2015, the US Treasury officially brought up a different Taiwanese intervention measure – which is the "End-of-day" intervention.[7] In 2021, the existence of the End-of-day intervention was confirmed by the Central Bank of Taiwan.[8] This may provide a possible explanation for the structural change of the Taiwanese central bank's intervention around 2012.

In the October 2015 US Treasury's semiannual report, the US Treasury mentioned that apart from actual foreign currency purchasing by the Central Bank of Taiwan, the central bank also regularly engaged in the End-of-day interventions to affect the day-closing rates. Based on the US Treasury's estimation, the Central Bank of Taiwan often sells the TWD in the last hour of a trading day (local time 15:00-16:00) and this kind of transaction occurred in about 75% of total business days (in the first seven months of 2015). (US Treasury, 2015) This kind of regular and end-of-day intervention, however, is not directly conducted by the Central Bank of Taiwan but by the state-backed banks. Hence, the end-of-day operations in the spot market are hardly captured by the BOP—TFSM proxy as the interbank transactions cannot be recognized as "BOP—reserve assets" and "TFSM—foreign assets" flows. Further, if the Central Bank of Taiwan started preferring to affect the spot rates by the state-backed banks' end-of-day FX operations rather than directly purchasing the foreign exchanges in the spot market (which is the defined FXI in this study) around 2012, then this may be a possible reason for explaining the structural change in the estimated linear Taiwanese central bank's FXI reaction functions. In the press conference soon after the March-19 2021 Taiwanese central bank's monetary policy decision board meeting, Governor Yang confirmed that the late-session moves by the state-backed banks are one kind of intervention.

However, it is little known whether the end-of-day interventions were conducted on each trading day and when did the central bank begin using the end-of-day interventions as the related information also remains undisclosed. Also, the detailed interbank FX spot trading data (including trading amount and trading time) classified by each bank or by state-backed/non-state-backed banks is unavailable. Therefore, identifying the end-of-day intervention is difficult due to data

availability. If there also exists the central bank's heavy use of policy interventions (e.g., directly banning the FX spot trading flows[9]) or verbal interventions (e.g., verbal warnings), capturing the whole picture of the Taiwanese central bank's FX intervention would become a more complicated task for the period after 2012.

5. Conclusion

The main findings of this study include:

(1) the BOP-TFSM proxy proposed by Lee (2021) is the most plausible proxy for estimating the true scales and directions of the Central Bank of Taiwan's interventions (which refer to as the outright purchasing/ selling of foreign currencies in FX spot market) in the existing literature, as it outperforms the proxies constructed based on the stock statistics (which are polluted by the hidden reserves and valuation effects), and can almost correctly predict the official disclosed FXI information and the news proxy's movements.

(2) For the period from 2001 to 2011, the Central Bank of Taiwan basically kept to the following rules to intervene in the FX market: adopting lean-against-the-wind intervention in the short run; accelerating the TWD's appreciating trend in the long run; having a tendency to purchasing the USD (selling the TWD) more than selling the USD (purchasing the USD) on average – which can be referred to as asymmetric intervention; Also, the intervention itself was positively autocorrelated. Regarding the debates over the Taiwanese central bank's true FX policies in the literature, the result in this study supports the opinion of the first literature group – the interventions had been conducted asymmetrically in the 2000s. However, whether the Taiwanese central bank's intervention in this period can be asserted as a kind of "devaluation policy" measure is questioned here, since the interventions appeared to enhance the TWD's value in the long run.

(3) By contrast, for the period from 2012 to 2020, the pattern of the Taiwanese central bank's intervention has largely changed. The results suggest that the Central Bank of Taiwan has become less engaged in outright purchasing /selling operations in the FX spot market since 2012. (The term "less engaged" refers to the shrinkage in intervention magnitudes and the lower intervention frequencies.) Also, the Central Bank of Taiwan no longer followed the intervention rule that it had been used to follow in the previous period. In short, a structural change in the Taiwanese central bank's intervention behaviors around 2012 is thus identified in this study.

There are inherent limitations of this study, however, which originate from the data availability and research boundaries. For example, the true magnitudes of the Taiwanese central bank's FXIs cannot be perfectly approximated since there still exist unavailable factors, such as the portfolio management flows and other unknown factors. Also, the interventions conducted by the state-

backed banks, policy interventions, and verbal interventions cannot be captured in this study. These types of interventions are basically not officially disclosed and may be more secretive than the Taiwanese central bank's direct purchasing/selling in the FX spot market, as they almost left no clue in the official statistics or even in the news articles. (Recalling that the news proxy's performance has declined since 2012.) As a different research direction for economies that have intensive FX interventions, such as Taiwan, the movements of the local currencies' values may already reflect the total effects of all the intervention measures taken by the monetary authorities. Hence, directly studying the FX rate dynamics may be a feasible way to capture the monetary authorities' overall interventions.

6. Footnotes

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1. In this study, the central bank's FXI is defined as the outright purchasing/outright selling of the US Dollar (USD) in the FX spot market and exclude the operations in FX derivative markets. (e.g., FX forward, future, option, and swap) The Taipei foreign exchange market is relatively thin, so the most effective way to affect the TWD FX rates is through spot trades. Also, the Taiwanese FX derivative interventions are mainly composed of FX swap transactions. Since an FX swap contract is composed of one "spot leg" and one "forward leg", this derivative contract would eventually offset its long/short spot positions and thus have few effects on TWD spot rates.
2. Source: Central Bank of Taiwan Income Statements (Fiscal Year 2001-2020) Link
3. Under the null hypothesis of no serial correlation of any order up to 3, the Lagrange multiplier statistic is 13.228 and the null hypothesis is rejected at 1% significance level. In addition, the regression residuals may follow higher-order autocorrelation structures, but the Likelihood-Ratio test results suggest that the AR(3) specification already fits well and the fit does not significantly fall behind the other higher order AR specifications.
4. The optimal lags are determined by Akaike Information Criterion (AIC). For all the variables, null hypotheses of unit root are rejected at 5% significance level.
5. The sup-F statistic is 14.744 and the p-value is 0.087.
6. Here, DF-GLS Test is also conducted to test whether all the variables (in 6 subsamples) follow the unit root processes. It turns out that: (1) For the first period, all the time series in 3 subsamples reject the null of unit root at 5% significance level. (2) For the second period, except for Δs_{t-1}, all the time-series data cannot reject the null of unit root at 5% significance level. Hence, test for cointegration (Phillips-Ouliaris Cointegration test, proposed by Phillips and Ouliaris, 1990) is applied. It turns out that the time-series data are cointegrating in the 3 subsamples.
7. Source: US Treasury October 2015 semiannual report, p.26, Link
8. Source: Bloomberg news, Taiwan Central Bank Acknowledges Regular FX Intervention,

March 19, 2021. Link

9. Source: Reuters news, Exclusive: Taiwan central bank seeks to limit fund flows, sources say, as currency surges, March 22, 2017. Link

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9. Tables

Table 1. The dataset

Variable	Proxied by	Description	Frequency	Source
$\boldsymbol{IINTV_t}$	--	Ordinal BOP—TFSM proxy	monthly	Own estimation (Section 2)
$\boldsymbol{s_{t-1} - s_{t-1}^{Short}}$	Δs_{t-1}	First difference of log TWD/USD: $s_{t-1} - s_{t-2}$	monthly	Central Bank of Taiwan
$\boldsymbol{s_{t-1} - s_{t-1}^{Long}}$	Δs_{t-1}^{1YMA}	log TWD/USD at month t-1 minus log TWD/USD moving average over the past 1 year (250 business days): $s_{t-1} - s_{t-1}^{1YMA}$	monthly	Central Bank of Taiwan
	Δs_{t-1}^{3YMA}	log TWD/USD at month t-1 minus log TWD/USD moving average over the past 3 years (750 business days): $s_{t-1} - s_{t-1}^{3YMA}$	monthly	Central Bank of Taiwan
	Δs_{t-1}^{5YMA}	log TWD/USD at month t-1 minus log TWD/USD moving average over the past 5 years (1250 business days): $s_{t-1} - s_{t-1}^{5YMA}$	monthly	Central Bank of Taiwan
$\boldsymbol{IINTV_{t-1}}$	--	lagged values of $IINTV_t$	monthly	Own estimation (Section 2)

※ **s_t denotes the log closing TWD/USD rate of Taipei Forex market at the end of month *t*; s_t^{Short} denotes the representative short-run TWD/USD rate proxied by the log closing TWD/USD at previous month-end; s_t^{Long} denotes the representative long-run TWD/USD rate proxied by the log 1/3/5-year FX rate moving averages (250 business days per year).**

Table 2. Coefficient estimates of GLS (with specifying AR(3) error structure) and OLS

Model: $IINTV_t = \beta_0 + \beta_1(s_{t-1} - s_{t-2}) + \beta_2(s_{t-1} - s_{t-1}^{3YMA}) + \beta_3 IINTV_{t-1} + \nu_t$ (7′)

where $\nu_t = \psi_1\nu_{t-1} + \psi_2\nu_{t-2} + \psi_3\nu_{t-3} + \upsilon_t$; υ_t is a white noise.

Sample period: 2001.02 - 2020.12	Coefficient estimates				
	β_0	β_1	β_2	β_3	OBS
GLS	0.159**	-10.248***	4.027***	0.328***	239
	(0.063)	(3.625)	(1.441)	(0.061)	
OLS	0.146***	-10.354***	3.565***	0.365***	239
	(0.050)	(3.509)	(1.167)	(0.064)	

Note: (1) A double asterisk denotes significance at the 5% level, and a triple asterisk denotes a value significance at the 1% level.

(2) Standard errors in parentheses.

(3) Estimates of AR(3) parameters ψ_1, ψ_2 and ψ_3 are 0.004, 0.033 and 0.235, respectively.

Table 3. Estimated linear reaction function (using 1-year TWD/USD moving averages)

Model for 1st subsample: $IINTV_t = \beta_0 + \beta_1(s_{t-1} - s_{t-2}) + \beta_2(s_{t-1} - s_{t-1}^{1YMA}) + \beta_3 IINTV_{t-1} + u_t$ (7)

where u_t is an error term.

Model for 2nd subsample: $IINTV_t = \beta_0 + \beta_1(s_{t-1} - s_{t-2}) + \beta_2(s_{t-1} - s_{t-1}^{1YMA}) + \beta_3 IINTV_{t-1} + \nu_t$ (7′)

where $\nu_t = \psi_1\nu_{t-1} + \psi_2\nu_{t-2} + \psi_3\nu_{t-3} + \upsilon_t$; υ_t is a white noise.

	Coefficient estimates				
sample period	β_0	β_1	β_2	β_3	OBS
2001.02 - 2011.12	0.141*	-13.693***	4.500**	0.526***	131
	(0.072)	(4.544)	(1.824)	(0.085)	
2012.01 - 2020.12	0.115	-0.262	1.897	0.123	108
	(0.103)	(6.123)	(4.020)	(1.255)	

Note: (1) A single asterisk denotes significance at the 10% level, a double asterisk denotes significance at the 5% level, and a triple asterisk denotes significance at the 1% level.

(2) Standard errors in parentheses.

(3) For 1st subsample, the *F*-statistic is 24.500 and the p-value is 0.000. The adjusted-R^2 is 0.352.

(4) For 2nd subsample, estimates of AR(3) parameters ψ_1, ψ_2, and ψ_3 are 0.073, -0.049, and 0.342, respectively.

Table 4. Estimated linear reaction function (using 3-year TWD/USD moving averages)

Model for 1st subsample: $IINTV_t = \beta_0 + \beta_1(s_{t-1} - s_{t-2}) + \beta_2(s_{t-1} - s_{t-1}^{3YMA}) + \beta_3 IINTV_{t-1} + u_t$ (7)

where u_t is an error term.

Model for 2nd subsample: $IINTV_t = \beta_0 + \beta_1(s_{t-1} - s_{t-2}) + \beta_2(s_{t-1} - s_{t-1}^{3YMA}) + \beta_3 IINTV_{t-1} + v_t$ (7′)

where $v_t = \psi_1 v_{t-1} + \psi_2 v_{t-2} + \psi_3 v_{t-3} + \upsilon_t$; υ_t is a white noise.

	Coefficient estimates				
sample period	β_0	β_1	β_2	β_3	OBS
2001.02 -	0.168**	-13.481***	4.558***	0.476***	131
2011.12	(0.071)	(4.251)	(1.221)	(0.089)	
2012.01 -	0.113	0.274	1.350	0.157	108
2020.12	(0.096)	(5.703)	(2.411)	(0.098)	

Note: (1) A single asterisk denotes significance at the 10% level, a double asterisk denotes significance at the 5% level, and a triple asterisk denotes significance at the 1% level.

(2) Standard errors in parentheses.

(3) For 1st subsample, the *F*-statistic is 27.460 and the p-value is 0.000. The adjusted-R^2 is 0.379.

(4) For 2nd subsample, estimates of AR(3) parameters ψ_1, ψ_2, and ψ_3 are 0.037, -0.060, and 0.336, respectively.

Table 5. Estimated linear reaction function (using 5-year TWD/USD moving averages)

Model for 1st subsample: $IINTV_t = \beta_0 + \beta_1(s_{t-1} - s_{t-2}) + \beta_2\left(s_{t-1} - s_{t-1}^{5YMA}\right) + \beta_3 IINTV_{t-1} + u_t$ (7)

where u_t is an error term.

Model for 2nd subsample: $IINTV_t = \beta_0 + \beta_1(s_{t-1} - s_{t-2}) + \beta_2\left(s_{t-1} - s_{t-1}^{5YMA}\right) + \beta_3 IINTV_{t-1} + v_t$ (7′)

where $v_t = \psi_1 v_{t-1} + \psi_2 v_{t-2} + \psi_3 v_{t-3} + \upsilon_t$; υ_t is a white noise.

	Coefficient estimates				
sample period	β_0	β_1	β_2	β_3	OBS
2001.02 -	0.172**	-13.887***	4.606***	0.447***	131
2011.12	(0.070)	(4.320)	(1.106)	(0.091)	
2012.01 -	0.097	-1.416	0.061	0.152	108
2020.12	(0.072)	(6.275)	(1.687)	(0.098)	

Note: (1) A single asterisk denotes significance at the 10% level, a double asterisk denotes significance at the 5% level, and a triple asterisk denotes significance at the 1% level.

(2) Standard errors in parentheses.

(3) For 1st subsample, the *F*-statistic is 28.770 and the p-value is 0.000. The adjusted-R^2 is 0.391.

(4) For 2nd subsample, estimates of AR(3) parameters ψ_1, ψ_2, and ψ_3 are 0.029, -0.058, and 0.339, respectively.

Table 6. Estimated Ordered Probit reaction function

Model: $IINTV_t = \begin{cases} +1 & if \quad \mu_2 < y_t^* \\ 0 & if \quad \mu_1 < y_t^* < \mu_2 \\ -1 & if \quad y_t^* < \mu_1 \end{cases}$ (6)

where $y_t^* = \beta_1(s_{t-1} - s_{t-1}^{Short}) + \beta_2(s_{t-1} - s_{t-1}^{Long}) + \beta_3 IINTV_{t-1} + \varepsilon_t$, and the error $\varepsilon_t \sim i.i.d.\mathcal{N}(0, \sigma^2)$.

	(1) $s_{t-1}^{Long} = s_{t-1}^{1YMA}$		(2) $s_{t-1}^{Long} = s_{t-1}^{3YMA}$		(3) $s_{t-1}^{Long} = s_{t-1}^{5YMA}$	
	Sample period		Sample period		Sample period	
	2001.02-2011.12	2012.01-2020.12	2001.02-2011.12	2012.01-2020.12	2001.02-2011.12	2012.01-2020.12
β_1^*	-25.406***	-3.565	-25.563***	-4.174	-26.534***	-2.144
	(9.454)	(10.651)	(8.960)	(9.818)	(8.928)	(9.611)
β_2^*	9.884**	1.581	9.331***	2.318	9.301***	0.045
	(4.313)	(5.400)	(2.886)	(3.035)	(2.620)	(2.593)
β_3^*	0.843***	0.240	0.763***	0.229	0.716***	0.240
	(0.139)	(0.150)	(0.139)	(0.151)	(0.141)	(0.150)
μ_1^*	-0.600***	-0.788***	-0.670***	-0.796***	-0.690***	-0.787***
	(0.139)	(0.136)	(0.145)	(0.137)	(0.146)	(0.138)
μ_2^*	0.095	0.484***	0.050	0.480***	0.041	0.484***
	(0.131)	(0.128)	(0.134)	(0.128)	(0.135)	(0.129)
Macfadden's R^2	0.208	0.013	0.229	0.015	0.238	0.012
OBS	131	108	131	108	131	108

Note: (1) A single asterisk denotes significance at the 10% level, a double asterisk denotes significance at the 5% level, and a triple asterisk denotes significance at the 1% level.

(2) Standard errors in parentheses.

(3) Due to identification issue, β_i (i = 1,2,3) and μ_j (j = 1,2) cannot be directly estimated. Instead, the normalized parameters $\beta_i^* \equiv \beta_i/\sigma$ (i = 1,2,3) and $\mu_j^* \equiv \mu_j/\sigma$ (j = 1,2) are estimated.

10. Figures

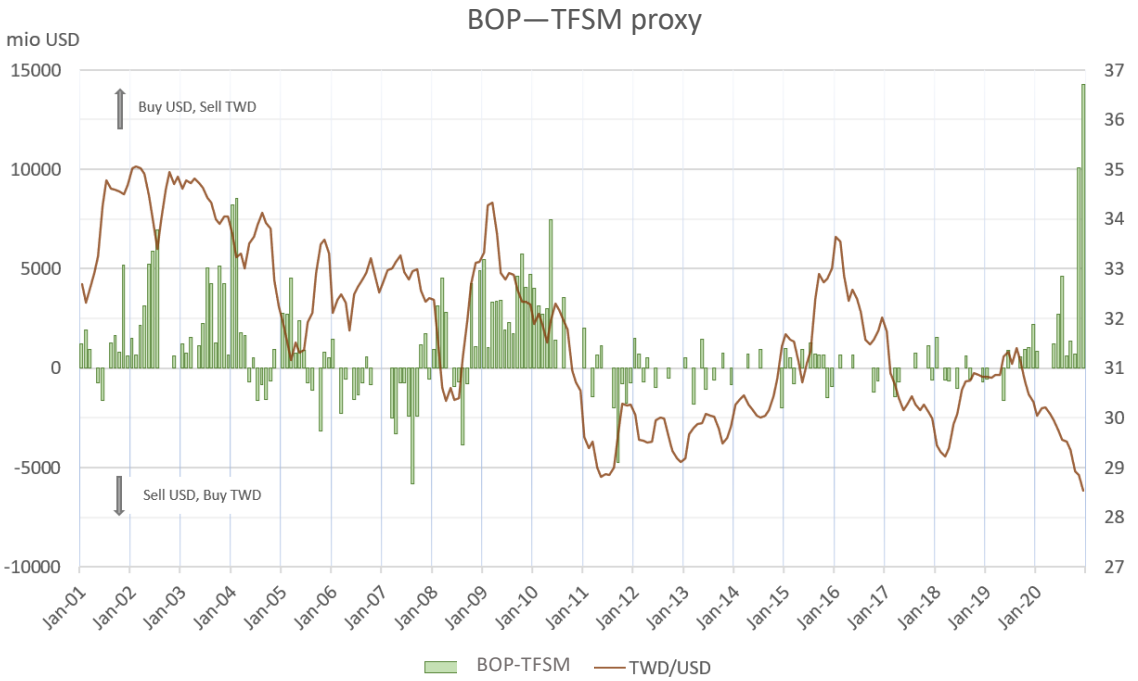

Figure 1. Validated BOP—TFSM proxy for FXIs of Central Bank of Taiwan, January 2001 – December 2020

Source: Central Bank of Taiwan, Taipei Forex Commercial Times (in Mandarin), and Own estimations (monthly net FXIs within +/- USD 500 million are assumed to be zero)

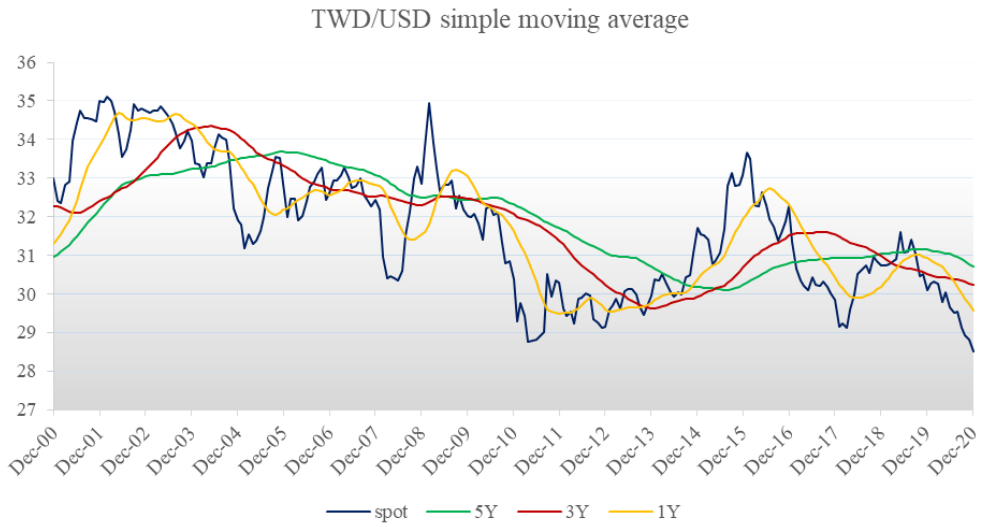

Figure 2. TWD/USD month-end spot and 1/3/5-year simple moving averages, December 2000 – December 2020

Source: Central Bank of Taiwan

Appendix

A1. Searching for the Most Plausible Proxy

In this section, I first examine whether the methods adopted in the existing literature are appropriate for constructing the Taiwanese central bank's FXI proxies even in the presence of "hidden reserves". It turns out that the proxy constructed of "Balance of Payment (BOP) –Reserve assets" and "the Taiwan Financial Statistic Monthly (TFSM) – Factors Responsible for Change in Reserve Money – Foreign assets" (Lee, 2021) is theoretically the best one, because the "BOP—Reserve assets" is originally not polluted by the hidden reserve transactions due to the BOP's residency principle. Then, I strip out the estimated interest income from the "BOP—reserve assets" and the "TFSM—Financial Assets" data and get the BOP-TFSM proxy. Next, I check for the BOP-TFSM proxy's accuracy by using the "News proxy" proposed by Ko (2018) and the officially announced information on FXIs (on a half-year basis, disclosed since 2019). It turns out that the BOP-TFSM proxy behaves quite consistently with the News proxy for more than half of the whole sample period of this study. Also, the BOP-TFSM proxy can correctly predict the directions as well as the scales of officially disclosed FXIs.

Figure A1 presents the simple linear regression between the two most up-to-date FXI proxies of the Central Bank of Taiwan. The proxy proposed by Adler et al. (2021) is constructed based on the Change in FX reserves (using IFS's total reserves excluding gold) and has stripped out valuation changes and investment incomes. Whereas, the proxy proposed by Lee (2021) is constructed based on "Balance of Payment (BOP) – reserve assets" and "Taiwan Financial Statistic Monthly (TFSM) Table 4 – foreign assets" and it has also removed the interest incomes. However, when regressing Adler's proxy on Lee's, the slope coefficient is 0.81 and the goodness-of-fit performs not well ($R^2 = 0.3141$). Also, the signs of the two series are diverse at many time points. Ideally, if both proxies approximate the central bank's true FXIs well, then the signs of the approximated FXI amounts should behave more identically. The following subsections examine whether the methods and underlying data used for constructing the Taiwanese central bank's FXI proxies in literature are appropriate.

A1.1 The FXI proxies in the existing literature

A1.1.1 Change in FX reserves

Since the net purchases of foreign exchanges directly contribute to FX reserve accumulations, much of the literature uses the first differences of the FX reserve time series to estimate the central banks' FX interventions. (For example, Liu, 1993; Chen and Wu, 2008; Wu et al., 2012; Ito et al., 2020; Fratzscher et al., 2020; Adler et al.,2021; and etc.) Nevertheless, the central banks' net purchasing/selling of foreign exchanges is not the only factor that contributes to the Change in FX reserves. Except for the FXIs, the factors that result in the Change in FX reserves further include:

(1) interest incomes generated from the whole FX reserve portfolio; (2) valuation profits or losses due to fluctuations in FX rates/asset market prices; (3) changes due to central banks' portfolio management[A1] (e.g., investing in illiquid assets that cannot be classified as reserve assets).

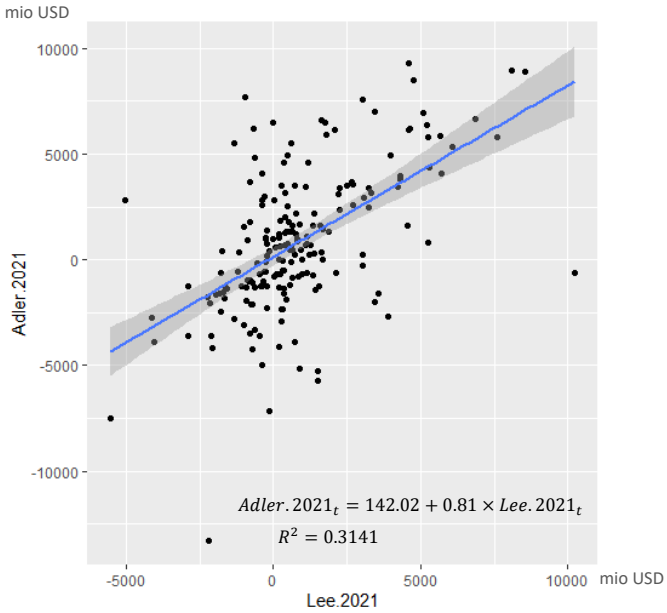

Figure A1. Widely diverse proxies for Taiwanese FXI, January 2000 — December 2015

Source: Adler et al. (2021); Lee (2021)

Adler et al. (2021) adopt this method to construct the proxy for Taiwanese FXIs, and the underlying data on FX reserves is IFS's total reserves excluding gold. However, with vast hidden reserves, this method would result in unneglectable errors in estimating the change in total FX exposures and thus in the proxies for Taiwanese FXIs. Theoretically, the compositions of the Taiwanese central bank's change in total FX exposures can be expressed by Equation (A1):

$$\Delta TTR_t = \Delta TREG_t + \Delta HR_t = TVAL_t + TINT_t + \Delta ForeignP_t + INTV_t + error_t \qquad (A1)$$

Where ΔTTR_t, $\Delta TREG_t$, and ΔHR_t refer to as the change in "total true reserve exposures", the change in "total reserves excluding gold" levels and the change in "hidden reserves" levels, respectively, in period t. $TVAL_t$, $TINT_t$, $\Delta ForeignP_t$, $INTV_t$ and $error_t$ refer to as total valuation profits or losses that come from both total reserves excluding gold and hidden reserves, total interest incomes that come from both total reserves excluding gold and hidden reserves, change in reserves due to portfolio management, the true FXIs, and the error term, respectively, in period t.

After arranging the terms of Eq. (A1), the approximated FXI in period *t* can be obtained:

$$INTV_t \approx \Delta TREG_t + \Delta HR_t - TVAL_t - TINT_t - \Delta ForeignP_t \quad (A2)$$

In Eq. (A2), the term $\Delta TREG_t$ can be obtained from the foreign exchange reserves in the Taiwanese central bank's statistical database.[A2] Whereas, all the other terms ΔHR_t , $TVAL_t$, $TINT_t$ and $\Delta ForeignP_t$ require respective estimations. Nevertheless, the estimation of true FXI in Eq. (A2) is basically infeasible because there is no information on the Taiwanese central bank's historical hidden reserves. In addition, the lack of information on currency structure, asset composition, and maturity composition of the FX reserve asset portfolio also poses difficulties for estimating the total valuation changes and the total interest incomes.

The next sub-section introduces "BOP—reserve assets", which is a flow statistic on official reserve assets. The Change in FX reserves is a flow variable computed from the total reserves less gold or the IRFCL—official reserve assets, which are stock statistics. However, including valuation profits or losses is a common characteristic of statistics on assets (namely, stock statistics). In contrast, flow statistics usually exclude valuation changes and thus may be closer to the concept of FXIs than stock statistics. (These can be checked from the preparing standards in the IFS Introductory note and the BPM6.)

A1.1.2 Balance of Payment (BOP) – Reserve Assets

The BOP records all the transactions between a country's residents and the rest of the world (RoW) within a certain period. According to the BPM6, the BOP only summarizes "flows associated with transactions (at market prices)". Hence, the reserve asset transaction flows with the nonresidents are recorded in the BOP – Reserve assets. Taiwan's BOP is released on a monthly basis.

Theoretically, the composition of BOP—Reserve assets can be expressed by Equation (A3).

$$BOP\_RA_t = INTV_t + INT_t + ForeignP_t + error_t \quad (A3)$$

where BOP_RA_t refers to the reserve asset transaction flows in period t. $INTV_t$, INT_t, $ForeignP_t$ and $error_t$ refer to as the true FXIs, net interest receipts, portfolio management flows and the error term in period t, respectively.

Arranging the terms of Equation (A3), the approximated FXIs in period *t* can be obtained:

$$INTV_t \approx BOP\_RA_t - INT_t - ForeignP_t \quad (A4)$$

For the hidden reserve issue, the Taiwanese central bank's FX swaps, foreign currency call loans, and foreign currency deposit transactions with resident financial institutions are not recorded in the BOP—Reserve assets due to the BPM6's residency principle. Since the hidden reserve transactions have neglectable effects on FX rates[A3], it can be concluded that the BOP—Reserve assets, which serve as a proxy for FXIs, is originally not polluted by the hidden reserves. Therefore, using the BOP—reserve assets as the underlying data is a better choice than using the Change in FX reserves for constructing the proxy for Taiwanese FXIs. Further, if the interest receipts/payments and the portfolio management flows are stripped out from "BOP—reserve assets", then it is quite close to the true FXIs of the Central Bank of Taiwan.

A1.1.3 Taiwan Financial Statistics Monthly (TFSM) – Table 4: Factors Responsible for Change in Reserve Money – Foreign Assets

The "TSFM – Table 4: Factors Responsible for Change in Reserve Money" records the "changes in official foreign assets holdings" that contributes to the change in monetary bases (reserve money) in the Taiwanese money market (Wang, 2005; Chen, 2016; Lee, 2021). The "Financial assets" in TSFM Table 4 captures the Taiwanese central bank's foreign asset claims on nonresidents within a defined period. This concept is the same as the BOP – Reserve assets, so the "TFSM Table 4 – Reserve assets" is also not affected by the hidden reserve transactions. For the period between 1987-2015, the correlation coefficient between quarterly BOP – Reserve assets and quarterly TFSM Table 4 – Foreign assets is higher than 0.995 (Lee, 2021). Therefore, the approximated FXI using TFSM Table 4 – Foreign assets can be expressed by the following equation which is almost identical to Eq. (A4):

$$INTV_t \approx TFSM\_FA_t - INT_t - ForeignP_t \qquad (A5)$$

where $TFSM\_FA_t$ denotes the TFSM Table 4 – foreign assets in period t, $INTV_t$, INT_t, $ForeignP_t$ and $error_t$ refer to as the true FXIs, net interest receipts, portfolio management flows and the error term in period t, respectively.

The above discussions – with considering the Taiwanese hidden reserve issue – suggest that using the flow statistics is the best choice for constructing the central bank's FXI. In the following analysis, I use the method proposed by Lee (2021) to decompose the quarterly BOP – Reserve assets into monthly data by using the monthly TFSM—Foreign assets. Then, I strip out the monthly interest receipt flows from the monthly BOP – Reserve assets.[A4]

A1.2 The interest receipt flows

For estimating the interest incomes, much literature uses the representative interest rates (such as the yields of the US Treasury bonds/Treasury bills) as the rates of return of the whole FX reserve asset

portfolios. (Chen et al., 2008; Chen, 2016; Ito et al., 2020) In addition, with the developments of the IMF's IRFCL template and the COFER (Currency Composition of Official Foreign Exchange Reserves) dataset[A5], there is literature that uses the board asset compositions (such as deposits and securities) or the global reserve assets' currency composition to estimate the interest incomes of the FX reserve asset portfolio. (Dominguez et al., 2012; Adler et al., 2021)

Lee (2021) mentions that the yields of the Taiwanese central bank's FX reserve portfolio are higher than the representative interest rates. Hence, using the representative rates may underestimate the true level of the interest revenues of the reserve asset portfolio. Moreover, neither the IRFCL nor the COFER regarding the Taiwanese central bank's international reserve portfolio is disclosed.[A6] Therefore, the above-mentioned two methods are appropriate for approximating the Taiwanese central bank's interest income. Instead, the monthly interest receipt flows are estimated by evenly dividing the actual annual interest revenues (which can be obtained from the Taiwanese central bank's annual income statements[A7]) into the monthly interest revenues. The sample period of this study thus depends on the availability of the Taiwanese central bank's historical annual income statements. Since the earliest disclosed annual income statement is the 2001 one, the sample period of this study is from January 2001 to December 2020.

After stripping away the approximated interest receipts, the BOP—TFSM proxy is obtained.

A1.3 Accuracy check

To check the accuracy of the BOP—TFSM proxy, I make use of the most up-to-date news proxy: Ko (2018)'s news proxy. In addition, information regarding the Taiwanese central bank's net purchasing/selling of foreign exchanges is disclosed in the Governor's presentations to the Financial Committee of the Taiwanese Legislature in March 2020 and March 2021. The officially released information is also used to validate the BOP—TFSM proxy.

Regarding Ko's (2018) news proxy, the proxy is constructed using a news database that collects all historical daily news from "Commercial Times" (which is one of the representative economic newspapers in Taiwan) since 1994. Also, as a more precise identification strategy of the Taiwanese central bank's FXIs, the days with FXI news are then validated under the Taipei Forex spot market's daily turnover: only the days with FXIs news that have a daily turnover higher than the 5-day moving average daily turnover would be identified as "with the occurrence of the Taiwanese central bank's FXI". As the sample period of Ko (2018) is January 4, 2000 – December 28, 2012, I follow Ko's method to identify the Taiwanese central bank's interventions and construct the news proxy from January 2, 2013 – December 31, 2020. Then I compare the directions of the news proxy and BOP –TFSM proxy to check the BOP—TFSM proxy's accuracy for the period from January 2001 to December 2020.

It turns out that the BOP—TFSM proxy can predict the directions of Ko's (2018) News proxy quite well for the period before 2011 (January 2001 – December 2011). However, for the period after 2011 (January 2012 – December 2020), the directions of the two proxies are not similar anymore. A possible explanation for this divergence is that the FXI magnitudes have shrunk largely since 2012. (See Figure 1) When the FXI amount/volume becomes small, the probability of reporting related news decreases. (Klein, 1993; Chang, 2006; Fratzscher et al. 2021) In fact, the number of related news also decreased for the period after 2012. (See Table A1)

In short, with the shrinkage of FXI magnitudes around 2012, the news proxy's quality declines. However, this ill-behaved news proxy somehow matches the FXI magnitude shrinkage fact.

As for the information officially disclosed by the Central Bank of Taiwan or by Governor Yang, there are: (1) the net FXI directions in May 2019 (net selling FX), June 2019 (net purchasing FX), and September 2019 (net purchasing FX); and (2) the net FXI amounts in the first-half/second-half of 2019, 2020 and 2021.

For the net FXI directions, the BOP—TFSM proxy acts identically to the officially disclosed information. For the net FXI amounts, the BOP—TFSM proxy also shows good predictability. (See Table A2)

In sum, based on the discussions so far, in a case like Taiwan which possesses huge hidden reserves and lacks publicly disclosed information on its FXIs, "flow statistics" is a better choice than "stock statistics" for constructing proxy for FXIs. The BOP—TFSM proxy also shows a good degree of predictability of the true FXI directions/amounts. However, there are caveats stemming from assumptions, such as "zero portfolio management flow". For economies like Taiwan whose reserve assets obviously exceed the precautionary requirement (Borio et al., 2008), their monetary authorities may have incentives to invest in some ill-liquid assets in order to earn higher yields. (Aizenman et al., 2014) Further, the shortage of global safe assets (Caballero et al., 2017) may also lead to unneglectable portfolio management flows. Hence, in order to: (1) avoid estimation errors due to unavailable factors (such as portfolio management flows); (2) accommodate the BOP—TFSM proxy to the following model settings, I turn the BOP—TFSM proxy into $\{-1, 0, +1\}$ ordinal variables (hereafter, ordinal BOP—TFSM proxy) based on the sign of estimated FXI amount. The variable -1 refers to monthly net "selling USD (purchasing TWD)" interventions, and the variable $+1$ refers to monthly net "purchasing USD (selling TWD)" interventions. As for variable 0, this category is used to represent the "purchase-sell-balanced" type FX interventions, which includes the monthly net FXIs within +/- USD 0.5 billion. That is, monthly net FXIs that don't cross a certain amount threshold would be defined as a "purchase-sell-balanced" type of intervention. By doing so, the possible estimation errors within the BOP—TFSM proxy can be mitigated as well.

	Number of days with FXI news	
Year	2000~2012	2013~2020
Number of total business days	3280	1985
(a) No turnover threshold		
FXI news	694	195
buy USD (sell TWD)	394	183
sell USD (buy TWD)	140	7
no clear direction	160	5
(b) Daily turnover ≥ 5-day simple moving average		
FXI news	443	115
buy USD (sell TWD)	244	108
sell USD (buy TWD)	101	6
no clear direction	98	1

	Percentage of days with FXI news in total business days	
Year	2000~2012	2013~2020
Number of total business days	3280	1985
(a) No turnover threshold		
FXI news	21.16%	9.82%
buy USD (sell TWD)	12.01%	9.22%
sell USD (buy TWD)	4.27%	0.35%
no clear direction	4.88%	0.25%
(b) Daily turnover ≥ 5-day simple moving average		
FXI news	13.51%	5.79%
buy USD (sell TWD)	7.44%	5.44%
sell USD (buy TWD)	3.08%	0.30%
no clear direction	2.99%	0.05%

Table A1. Comparison of the number of days with FXI news for periods before 2012 and after 2012

Source: Ko (2018), Commercial Times (in Mandarin), Taipei Forex

	Officially disclosed FXI amount	BOP—TFSM proxy	Adler et al. (2021)
2019H1	−1100 million USD	−1455 million USD	−7128 million USD
2019H2	+6600 million USD	+4837 million USD	+5126 million USD
2020H1	+3900 million USD	+5396 million USD	−5907 million USD
2020H2	+35200 million USD	+31452 million USD	+22603 million USD
2021H1	+8730 million USD	+9306 million USD	+22425 million USD
2021H2	+390 million USD	+1946 million USD	+7685 million USD

Table A2. Amount validation of BOP—TFSM proxy and Adler et al. (2021)'s proxy

Source: 2020-03-12 Regular Presentation to the Financial Committee of Taiwanese Legislature (in Mandarin) p.28 Link; 2021-03-11 Regular Presentation to the Financial Committee of Taiwanese Legislature (in Mandarin) p.V, p.30 Link; Own estimations, Adler et al. (2021)

A2. Robustness Check

This section provides the robustness check of the estimated linear FXI policy reaction functions in section 3, for the first period (February 2001 – December 2011). Instead of the ordinal BOP-TFSM proxy, the natural log of BOP-TFSM proxy (which is the natural log of estimated FXI scales) is used here in both the left-hand-side variable ($INTV_t$) and the right-hand-side variable ($INTV_{t-1}$). The other explanatory variables (Δs_{t-1}, Δs_{t-1}^{1YMA}, Δs_{t-1}^{3YMA}, and Δs_{t-1}^{5YMA}) remain the same as the ones in section 3. The steps for conducting estimation here are also the same: firstly, testing whether there is serial correlation within the OLS residuals and whether $INTV_t$ series follow the unit root processes. It turns out that there is no serial correlation in the 3 datasets[A8] and the $INTV_t$ series do not follow the unit root process[A9]. Thus, the OLS is applied to FXI policy reaction function Eq. (7). The estimation results are presented in Table A3.

From the results in Table A3, it can be concluded that the estimations FXI reaction functions Eq. (7) are close to the previous ones. All the variables are highly significant and all the signs of estimated coefficients are identical to their counterparts in section 3. Therefore, the robustness of the estimated FXI reaction functions in section 3 is demonstrated.

Table A3. Estimated reaction function, using the natural log of BOP-TFSM proxy

Model: $INTV_t = \beta_0 + \beta_1\left(s_{t-1} - s_{t-1}^{Short}\right) + \beta_2\left(s_{t-1} - s_{t-1}^{Long}\right) + \beta_3 INTV_{t-1} + u_t \quad (7'')$

where u_t is an error term.

	(1) $s_{t-1}^{Long} = s_{t-1}^{1YMA}$	(2) $s_{t-1}^{Long} = s_{t-1}^{3YMA}$	(3) $s_{t-1}^{Long} = s_{t-1}^{5YMA}$
	Sample period	Sample period	Sample period
	2001.02-2011.12	2001.02-2011.12	2001.02-2011.12
β_0	0.502***	0.575***	0.590***
	(0.190)	(0.189)	(0.187)
β_1	-45.614***	-44.468***	-45.545***
	(13.691)	(12.693)	(12.555)
β_2	11.543*	11.313***	11.674***
	(6.131)	(4.039)	(3.632)
β_3	0.549***	0.508***	0.483***
	(0.071)	(0.071)	(0.072)
F-statistic	27.900	30.210	31.550
p-value	0.000	0.000	0.000
Adjusted R^2	0.383	0.403	0.414
OBS	131	131	131

Note: (1) A single asterisk denotes significance at the 10% level, a double asterisk denotes significance at the 5% level, and a triple asterisk denotes significance at the 1% level.

(2) Standard errors in parentheses.

Footnotes:

A1. This is usually neglected in much literature, (e.g., Fratzscher et al., 2020 and Adler et al. 2021) since there is almost no information available.

A2. This is equivalent to the IFS's total reserve excluding gold.

A3. An FX swap contract is composed of one spot leg and one forward leg, so this kind of derivative intervention would eventually offset its long/short spot positions and thus have few effects on TWD spot rates.

A4. The differences between the quarterly BOP series and quarterly TFSM data series are not considerable. However, the TFSM's lack of clear preparing standards (in comparison with the BPM6) may pose difficulties for interpreting the results. Therefore, the BOP amounts are used as the underlying data for estimating the FXI scales.

A5. The IMF's COFER data provides quarterly information on the currency composition of the monetary authorities' foreign exchange reserves (based on the IFS's definition). The COFER data for individual reporters is not available. Only the aggregated ones (including the global, the advanced economies, and the emerging and developing economies) are available. Source: the IMF's website, Link

A6. Governor Yang has mentioned the rough information on the Taiwanese central bank's COFER in his presentation to the Financial Committee of the Taiwanese Legislature on March 12, 2020. He stated that the share of the USD-denominated claims in the Taiwanese central bank's total FX reserves was higher than the share of the USD-denominated claims in the global FX reserves, which was around 60% in 2020. Source: "2020-03-12 Regular Presentation to the Financial Committee of the Taiwanese Legislature (in Mandarin) p.31" Link

A7. Source: Central Bank of Taiwan Income Statements (Fiscal Year 2001-2020) Link

A8. Using the Breusch-Godfrey test (Breusch, 1978; Godfrey, 1978), all the three subsamples do not reject the null of "no serial correlation of any order up to 3" at 5% significance level.

A9. DF-GLS Test (Elliott et al., 1996) is conducted, using AIC to determine the optimal lag. The null hypotheses of unit root are rejected at 1% significance level.