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The Structural Shift of China's Foreign Exchange Reserves in the Trend Function

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Abstract: China's foreign exchange reserves kept growing quickly for a decade; however, they have decreased since 2014. The paper aims to test for a break date probably existing on the trend function of foreign exchange reserve series. Monthly series covered the period from January 2000 to March 2018. A standard ADF unit root test, an ERS DF-GLS test along with the modified AIC, and an MZ_{α} test along with GLS detrending were conducted. Structural shift tests were the Perron test (in a mixed IO Model C and Model A or crash model), and the Zivot-Andrews test (in a mixed IO Model C and Model A). Empirical analyses show that at least two unit roots exist in the variable, implying a robust long memory. A break point took place most likely in January 2014. US exit out of quantitative easing (QE) and federal funds interest rate hikes may be (at least partially) attributable to the shift.
Keywords: Break date, foreign exchange reserves, innovational outlier, long memory, shock, unit root.

INTRODUCTION

China's foreign exchange reserves have kept growing since 2000. They peaked in June 2014 (3.9932 trillion US dollars). Then, the reserves seem to move downwards until now. Reserves fell below three trillion US dollars in January 2017 (Figure-1) [1].

While China's foreign exchange reserves began to decline, in October 2014, the US Federal Reserve Board (FRB) announced that it would withdraw from quantitative easing (QE) and increased interest rates. Since late 2015, Federal funds effective rates have proliferated (Figure-2) [2]. The rate in December 2017 was 11.82 times that in January 2015. The US interest rate hike event may have been a shock to changes in China's foreign exchange reserves because the considerable amount of "hot dollars" is flowing out of China and then entered the United States.

This paper aims to test if a structural break of the foreign exchange reserves series in China occurred.

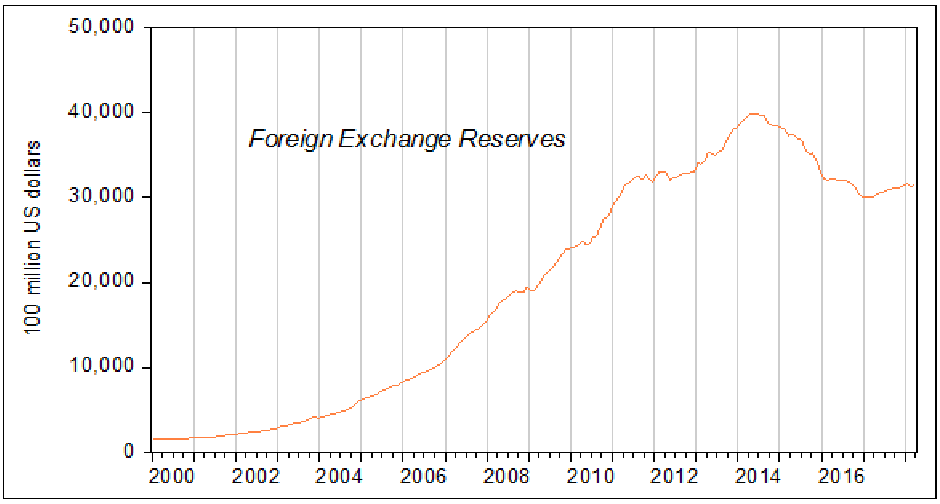

Fig-1: Monthly changes in China's foreign exchange reserves (2000-2018)

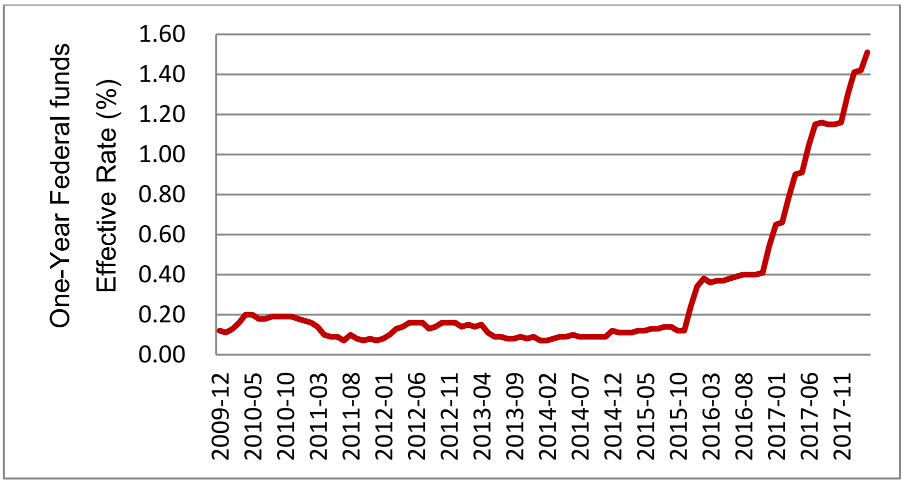

Fig-2: Monthly changes in US Federal Funds Rate

METHODS

We conducted the standard augmented Dickey–Fuller (ADF) test [3, 4]. Also, an ERS DF-GLS test in conjunction with the modified AIC (MAIC) was conducted [5, 6]. We conducted the MZ_α test, a modified version of the PP test. Size can gain from this test [6-8].

A break date is assumed to be unknown *priori*. We conducted the Perron test and the Zivot–Andrews test [9, 10]. The former rejects a unit root more often than the latter.

Break-date tests were conducted using the innovational outlier (IO) Model C. Model C simultaneously allows for a change in the level (intercept) as well as a change in the slope of the trend function [10-12]. This mixed model is recommended where the break is unknown [13].

Break-date tests were conducted using the IO Model A. Model A is called the crash model. It assumes that a shift takes place slowly in the level.

The Perron test Model C is [10, 11].

$$y_t = \mu + \theta DU_t + \beta t + \gamma DT_t + \delta D(TB)_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \qquad (1)$$

Where $DU = 1$ if $t > T_b$ and 0 otherwise; $DT = t - T_b$ if $t > T_b$ and 0 otherwise; and $D(TB) = 1$ if $t = T_b + 1$ and 0 otherwise with 1(.) the indicator function. T is the sample. T_b is the break date. Under the null hypothesis of a unit root, $\mu \neq 0$ (in general), $\theta = 0$ (except in Model C), $\beta = 0$, $\gamma = 0$, $\delta \neq 0$, and $\alpha = 1$. Under the alternative hypothesis of stationary fluctuations around a deterministic trend function, $\mu \neq 0$, $\theta = 0$, $\beta = 0$, $\gamma = 0$ (in general), $\delta \neq 0$, and $\alpha < 1$.

Data

Data was the foreign exchange reserves series (*FORE EXCH RESERVES*). Monthly variations covered the period of 2000-2018 [1]. Table-1 is details of the raw data.

Empirical Results

The ADF and ERS DF-GLS tests consistently suggest a unit root (Table 2 and 3). The Ng-Perron MZ_α test suggests more than two unit roots (Table-4). A structural shift may raise the order of data integrity.

The Perron Model A test showed a shift occurred in January 2014 (Table-5). The Zivot-Andrews Model A test showed a shift in November 2014 (Table-6). The Perron mixed Model C test showed a shift occurred in September 2013 (Table-7). The Zivot-Andrews mixed Model C test showed a shift in October 2013 (Table-8).

Table-1: Descriptive statistics of the data

Variable	FORE EXCH RESERVES (100 million US dollars)
Mean	19470.87
Median	19460.30
Maximum	39932.13
Minimum	1561.00
Std. Dev.	13478.28
Skewness	-0.03
Kurtosis	1.40
Jarque–Bera	23.44
Probability	0.00
Type	Time series
Frequency	Monthly
Period of study	Jan 2000 to March 2018
Seasonally adjustment method	No

Table-2: The Unit root tests (ADF tests)

Variable	*k*	Level	*k*	First difference	*k*	Second difference
FORE EXCH RESERVES	10	-1.48	9	-2.60	12	-5.62***

Notes: Test contained an intercept and a trend according to [14, 15]. The lag length *k* was decided using the *t*-test for the ADF test. The *k* was selected between two and twelve in search for a tradeoff between the size and power [16]. ***denotes rejection of the null of a unit root at the levels of 1%.

Table-3: The Structural break test for FORE EXCH RESERVES (Perron test Model A)

Parameter & variable	Coefficient	Std. Error	*t*-Statistic	*P*-value	T_B
θ	-0.01	0.01	-1.92	0.06	
β	0.00	0.00	0.90	0.37	
δ	0.01	0.01	0.41	0.68	
α	0.99	0.00	**212.84**	0.00	Jan 2014
Δ, t-1	0.23	0.07	3.24	0.00	
Δ, t-2	0.08	0.07	1.08	0.28	
Δ, t-3	0.11	0.07	1.45	0.15	
Δ, t-4	0.02	0.07	0.30	0.77	
Δ, t-5	0.02	0.07	0.33	0.74	
Δ, t-6	0.12	0.07	1.64	0.10	
Δ, t-7	-0.17	0.07	-2.29	0.02	
Δ, t-8	0.03	0.07	0.38	0.70	
Δ, t-9	0.01	0.07	0.20	0.84	
Δ, t-10	0.11	0.07	1.46	0.15	
Δ, t-11	-0.10	0.07	-1.34	0.18	
Δ, t-12	0.01	0.07	0.09	0.92	
Δ, t-13	0.16	0.07	2.21	0.03	
Intercept	0.07	0.03	2.08	0.04	
R-squared	1.00	Mean dependent var	9.59		
Adjusted R-squared	1.00	S.D. dependent var	0.98		
S.E. of regression	0.01	Akaike info criterion	-5.70		
Sum squared resid	0.03	Schwarz criterion	-5.41		
Log likelihood	602.44	Hannan-Quinn criter.	-5.58		
F-statistic	63839.61	Durbin-Watson stat	1.98		
Prob(F-statistic)	0.00				

Notes: Δ indicates the first difference. t-1, t-2, ..., t-*k* are lagged terms. Truncation lag orders *k* (between 2 and 13) were selected using the data-dependent method [10, 16]. The trimming fraction λ was 0.15. λ was suggested to be 0.15 [18]. *t*-statistic for the *k*th term was greater than or equal to 1.8 in absolute value. T_b was the possible break date. The critical values for $T = 100$ were −5.70, −5.10, and −4.82 at 1%, 5%, and 10% levels, respectively [10].

Table-4: The Unit root tests (the ERS DF-GLS Tests)

Variable	*k*	Level	*k*	First difference	*k*	Second difference
FORE EXCH RESERVES	7	-1.31	9	-2.30	12	-3.12**

Notes: Truncation lags, *k*, were chosen using the modified Akaike information criterion (MAIC) [6]. The *k* was selected between 2 and 12 in search for a tradeoff between the size and power [16]. Following Figure 1, the test equation contained both the trend and intercept. Critical values used are in Table-1 [5]. **denotes rejection of the null of a unit root at the levels of 5%.

Table-5: Unit root tests (the Ng-Perron MZ_α test)

		MZ_α						
Variable	*k*	Level	Critical value	*k*	First difference	Critical value	Second difference	Critical value
Fore exch reserves	7	-6.04	-14.2*	9	-8.73	-14.20*	-2.33	-14.20*

Notes: Test contained the intercept and trend according to [14, 15]. The modified Akaike information criterion (MAIC) in conjunction with GLS detrending is recommended in search of a trade-off between the size and power [6]. The *k* was selected between 2 and 12 [16]. *P*-value denotes MacKinnon's (1996) *P*-value [17]. Critical values used are in Table 1 [6]. *denotes acceptance of the null of a unit root at the levels of 1%.

Table-3: The Structural break test for FORE EXCH RESERVES (Zivot-Andrews test Model A)

Parameter & variable	Coefficient	Std. Error	*t*-Statistic	*P*-value	T_λ
θ	0.00	0.01	-0.26	0.79	
β	0.00	0.00	-0.93	0.35	
α	1.00	0.00	232.62	0.00	Nov 2014
Δ, t-1	0.24	0.07	3.47	0.00	
Δ, t-2	0.08	0.07	1.16	0.25	
Δ, t-3	0.13	0.07	1.82	0.07	
Δ, t-4	0.06	0.07	0.84	0.40	
Δ, t-5	0.03	0.07	0.43	0.67	
Δ, t-6	0.12	0.07	1.67	0.10	
Δ, t-7	-0.13	0.07	-1.82	0.07	
Intercept	0.01	0.03	0.38	0.70	
R-squared	1.00	Mean dependent var	9.53		
Adjusted *R*-squared	1.00	S.D. dependent var	1.03		
S.E. of regression	0.01	Akaike info criterion	-5.72		
Sum squared resid	0.04	Schwarz criterion	-5.55		
Log likelihood	614.89	Hannan-Quinn criter.	-5.65		
F-statistic	122559.10	Durbin-Watson stat	1.99		
Prob(*F*-statistic)	0.00				

Notes: Δ indicates the first difference. t-1, t-2, ..., t-*k* are lagged terms. Truncation lag orders *k* (between 2 and 13) were selected using the data-dependent method [10, 16]. The trimming fraction λ was 0.15. λ was suggested to be 0.15 [18]. *t*-statistic for the *k*th term was greater than or equal to 1.8 in absolute value. T_λ was the possible break date. the critical values for $T = 159$ were −5.40, −4.84, and −4.57 at the 1%, 5%, and 10% levels, respectively [9].

CONCLUDING REMARKS

While a decline in foreign exchange reserves in China began in mid-2014, The US Federal Reserve was withdrawing from quantitative easing (QE) and increased federal funds interest rates. We argue that the US federal rate hike and exit from QE produced a significant financial event or financial shock that might have caused a trend shift in China's foreign exchange reserves. This article aims to test for a structural shift probably occurred on the trend function of the reserves.

Three tests (the standard ADF test, the ERS DF-GLS test along with the modified AIC, and the MZ_α test along with GLS detrending) suggest two unit roots, which implies a robust long memory.

Table-4: The Structural Break Test for FORE EXCH RESERVES (Perron Test Model C)

Parameter & variable	Coefficient	Std. Error	*t*-Statistic	*P*-value	T_B
θ	1299.47	919.22	1.41	0.16	
β	6.70	2.37	2.83	0.01	
γ	-8.84	5.11	-1.73	0.09	
δ	415.02	322.42	1.29	0.20	
α	0.98	0.01	107.48	0.00	Sept 2013
Δ, t-1	0.21	0.07	2.94	0.00	
Δ, t-2	0.08	0.07	1.14	0.26	
Δ, t-3	0.24	0.07	3.32	0.00	
Δ, t-4	-0.02	0.07	-0.25	0.80	
Δ, t-5	0.04	0.07	0.62	0.53	
Δ, t-6	0.18	0.07	2.49	0.01	
Δ, t-7	-0.21	0.07	-2.84	0.01	
Δ, t-8	-0.03	0.07	-0.43	0.67	
Δ, t-9	-0.07	0.07	-0.96	0.34	
Δ, t-10	0.19	0.07	2.65	0.01	
Intercept	-143.05	83.35	-1.72	0.09	
R-squared	1.00	Mean dependent var	20416.64		
Adjusted R-squared	1.00	S.D. dependent var	13169.04		
S.E. of regression	286.25	Akaike info criterion	14.23		
Sum squared resid	15732537.00	Schwarz criterion	14.48		
Log likelihood	-1463.44	Hannan-Quinn criter.	14.33		
F-statistic	29194.39	Durbin-Watson stat	2.00		
Prob(F-statistic)	0.00				

Notes: Δ indicates the first difference. t-1, t-2, ..., t-*k* are lagged terms. Truncation lag orders *k* (between 2 and 13) were selected using the data-dependent method [10, 16]. The trimming fraction λ was 0.15. λ was suggested to be 0.15 [18]. *t*-statistic for the *k*th term was greater than or equal to 1.8 in absolute value. The critical values for $T = 100$ were −6.21, −5.55, and −5.25 at 1%, 5%, and 10% levels, respectively [10].

Table-5: The Structural Break Test for FORE EXCH RESERVES (Zivot-Andrews Test Model C)

Parameter & variable	Coefficient	Std. Error	*t*-Statistic	*P*-value	T_λ
θ	-126.38	105.52	-1.20	0.23	
β	6.95	2.37	2.94	0.00	
γ	-10.00	5.04	-1.98	0.05	
α	0.98	0.01	107.62	0.00	Oct. 2013
Δ, t-1	0.23	0.07	3.33	0.00	
Δ, t-2	0.08	0.07	1.11	0.27	
Δ, t-3	0.24	0.07	3.34	0.00	
Δ, t-4	-0.03	0.07	-0.45	0.65	
Δ, t-5	0.04	0.07	0.52	0.60	
Δ, t-6	0.19	0.07	2.69	0.01	
Δ, t-7	-0.20	0.07	-2.80	0.01	
Δ, t-8	-0.04	0.07	-0.55	0.58	
Δ, t-9	-0.05	0.07	-0.76	0.45	
Δ, t-10	0.18	0.07	2.57	0.01	
Intercept	-151.94	83.20	-1.83	0.07	
R-squared	1.00	Mean dependent var	20416.64		
Adjusted R-squared	1.00	S.D. dependent var	13169.04		
S.E. of regression	286.74	Akaike info criterion	14.22		
Sum squared resid	15868306.00	Schwarz criterion	14.47		
Log likelihood	-1464.34	Hannan-Quinn criter.	14.32		
F-statistic	31173.48	Durbin-Watson stat	1.98		
Prob(F-statistic)	0.00				

Notes: Δ indicates the first difference. t-1, t-2, ..., t-*k* are lagged terms. Truncation lag orders *k* (between 2 and 13) were selected using the data-dependent method [10, 16]. The break fraction λ was 0.15. λ was suggested to be 0.15 [18]. *t*-statistic for the *k*th term was greater than or equal to 1.8 in absolute value. T_λ was the possible break date. the critical values for *T* (the sample size) = 159 were −5.40, −4.84, and −4.57 at the 1%, 5%, and 10% levels, respectively [9].

Various tests suggest a structural shift in the trend function. The break date has minor differences. For tests applying Model A (the crash model), the shift occurred in January 2014 (the Perron technique) or in November 2014 (the Zivot-Andrews technique). For tests applying Model C (the mixed model), the shift occurred in September 2013 (the Perron technique) or in October 2013 (the Zivot-Andrews technique). The crash model mainly considered a level shift that accords with our level data and declining reserves. The mixed model not only took a slope change but also took a level change into account. To be a balance, the shift occurred between October 2013 and January 2014. In collaboration with Figure 1, we suggest that the shift took place most likely in early 2014.

Structural break tests provide evidence for the US federal funds rate hike shock to the trend change in China's foreign exchange reserves. Rate hikes occurred almost at the same time with the break date implied in this study. Compared with January 2014, the one-year rate rose by 0.01 percentage points in March 2014, 0.02 percentage points in April and May 2014, 0.03 percentage points in June, and 0.05 percentage points in December 2014.

However, many other determinants of the decreasing reserves must be jointly considered. For example, along with rising wages over the past years, many foreign firms and factories move to Southeast Asian countries such as Viet Nam and Thailand. China has markedly increased its foreign investments.

Conflicts of Interest

The authors declare no conflicts of interest.

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