East Asia Real Exchange Rate Cointegration Analysis

Group 11

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Quantitative Analysis of Finance II

Research Report

Department of Economics

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Introduction

As East Asian economies grow increasingly interconnected through trade, capital flows, and policy coordination, understanding their financial and monetary linkages has become more important than ever. In this context, our project explores whether a set of key macro-financial variables in Hong Kong, mainland China and Japan (including consumer prices, nominal bilateral exchange rates relate to the U.S. dollar, and 3-month money-market rates etc.) share a stable long-run equilibrium over the last decade (2015-2024). In other words, do the three economies now still follow the cointegration economics patterns as suggested by the Generalized Purchasing Power Parity (G-PPP) hypothesis?

While earlier work such as Liang (1999) found evidence of cointegration among East Asian currencies in the pre-crisis period, much has changed since in near 30 years: China has loosened capital controls, the CNY has shifted from a hard USD peg to a managed float, and macroeconomic volatility has increased. This study updates the empirical test of G-PPP with monthly data through 2024, and incorporating some additional macroeconomic fundamentals like GDP per capita, foreign reserves, and real interest rates, to evaluate internal drivers of RER behavior. By structuring the analysis in both across- and within-countries, this study offers a flexible framework to assess both regional integration and domestic macroeconomic consistency.

Methodology

Following Liang (1999), we adopt the Purchasing Power Parity and Optimum Currency Area framework to evaluate the Generalized PPP hypothesis. We begin by testing the stationarity of real exchange rates and selected macroeconomic fundamentals (GDP per capita, foreign reserves, and real interest rate) using Augmented-Dickey Fuller (ADF) and Philips-Perron (PP) tests, with optimal lag length selected using Akaike Information Criterion (AIC) for ADF tests and short lags for PP tests. Only non-stationary variables here are included in the cointegration analysis.

We then apply the Johansen cointegration test to pairwise and trivariate systems involving the RERs of China, Hong Kong, and Japan (against the U.S. dollar as base). Cointegration statistics (λ-max and trace) are used to test for the number of cointegrating vectors, indicating whether a stable long-run relationship exists. The optimal lag lengths are selected using AIC prior to the Johansen cointegration tests.

If cointegration among the real exchange rates had been detected, we would have proceeded to estimate a Vector Error Correction Model (VECM) incorporating macroeconomic fundamentals to capture short-run dynamics and adjustment speeds. However, since no cross-country cointegration was found, we instead estimate separate cointegration relationships between each country's RER and its own fundamentals. This two-step approach allows us to distinguish between external parity conditions and internal macroeconomic anchors. Based on the estimation results, we interpret the structural differences between contemporary East Asian economic patterns and those of the 1990s and make causal inferences about the underlying drivers of this exchange rate dynamics.

Data

Following the methodology of Liang (1999), the real exchange rate is constructed as

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

where s_t is the nominal exchange rate (national currency per USD), p_t^* is the US consumer price index, and p_t is the domestic consumer price index. All variables are expressed in natural logarithms, with the US being the base country. Nominal exchange rate and CPI are mostly obtained from the IMF, except Hong Kong's nominal exchange rate is collected from the Census and Statistics Department of Hong Kong, and Hong Kong's CPI is from the Hong Kong Monetary Authority.

This study also includes some macroeconomic fundamentals that Liang (1999) did not include to capture the macroeconomic influences on real interest rates, further investigate the long-run relationship of these fundamentals, and test the existence of G-PPP. The selected fundamentals are GDP per capita, serving as a proxy for income level and productivity, foreign reserves, indicating the ability to manage exchange rate volatility and trade position (Aizenman and Lee, 2007), and real interest rate, representing the monetary policy stance and the incentives of capital flow.

GDP per capita is sourced from the IMF. The World Bank provides foreign reserves for China and the US, while Japan and Hong Kong's foreign reserves are obtained from their government website, the Ministry of Finance for Japan and the Hong Kong Monetary Authority for Hong Kong. The real interest rate for Japan, Hong Kong, and the US are calculated by the difference between the nominal interest rate and year-on-year inflation rate, measured by changes in CPI. Due to the limited accessibility of China's high-frequency interest rates, the annual real interest rate obtained from the World Bank would serve as a proxy. Federal funds effective rate and the call money rate, reflecting the overnight interbank lending rate are used for the nominal interest rate for the US and Japan, respectively, which is obtained from the Federal Reserve Bank of St. Louis. The composite interest rate, defined as the weighted average of all interest-rate-sensitive liabilities (Hong Kong Monetary Authority, 2025), is used for the nominal interest rate for Hong Kong, obtained from the Hong Kong Monetary Authority. The sources of year-on-year CPI changes are the same as CPI.

Most data are collected at a monthly frequency. Annual variables (GDP per capita, foreign reserves for China and the US, real interest rate for China) are converted to monthly data by Denton-Cholette interpolation. Daily variables (nominal exchange rate for Japan and China) are converted by computing monthly averages.

Following Liang (1999), this study will test the stationarity of each variable in the following section. Variables found to be stationary will not be included in subsequent cointegration analysis since stationary series do not contribute to long-run cointegration relations.

Model

To examine the long-run equilibrium relationships among real exchange rates (RER) and macroeconomic fundamentals in Mainland China, Hong Kong SAR, and Japan, this study extends the empirical framework of Liang (1999). The analysis aims to test the Generalized Purchasing Power Parity (G-PPP) hypothesis and further investigate whether macroeconomic fundamentals explain RER behavior in each economy.

For each country j, the long-term relationship between its RER relative to the benchmark country 1 and the fundamentals is defined as follows:

$$q_{1jt} = x'_{jt}\beta_j + \varepsilon_{jt} \qquad j = 1, \ldots\ldots, n \tag{2}$$

In our case, q_{1jt} is the real exchange rate of country j (China, Hongkong and Japan) against the US dollar. The x'_{jt} is a vector of country-specific macroeconomic fundamentals, including logarithm of GDP per capita, logarithm of foreign reserves, and real interest rate. β_j is the vector of coefficients and ε_{jt} is the stationary error term. If x'_{jt} is stationary and the relationship of cointegration holds, then q_{1jt} is stationary and PPP will hold, if one data in x'_{jt} is non-stationary, PPP will no longer hold.

Following Liang (1999), the G-PPP hypothesis can be expressed in a stacked multivariate form where real exchange rates across n countries relative to a common base country are jointly determined by a common set of mmm macroeconomic fundamentals:

$$Q_t = \beta X_t + E_t \tag{3}$$

where Q_t is a $n \times 1$ vector of real exchange rates q_{1jt}, X_t is an $m \times 1$ vector of non-stationary fundamentals (e.g. GDP per capita, reserves, real interest rate), β is an $n \times m$ coefficient matrix and E_t is the vector of stationary errors.

The presence of cointegration among the RER series implies that the real exchange rates and fundamentals move together in the long run, consistent with the G-PPP condition. This formulation justifies the use of the Johansen cointegration test in our empirical analysis.

When the G-PPP hypothesis test holds, the RER of any country j relative to base country can be represented as weighted linear combination of the other countries' RERs:

$$q_{12t} = a_0 + a_{13}q_{13t} + a_{14}q_{14t} + \cdots + a_{1n}q_{1nt} + \varepsilon_t \tag{4}$$

These a_{jk} are functions of the parameters in the cointegration system and reflect the economic interdependence among countries in the potential currency area. They capture not only trade linkages, but also broader relationships such as cross-border investment, technology diffusion, labor mobility, and capital flows.

Results & Interpretation

Unit Root Testing

For a multi-country setting, the G-PPP hypothesis requires that all the RERs first be non-stationary. ***Table 1*** and ***2*** display results from an Augmented-Dickey Fuller (ADF) and Philips-Perron (PP) test on the RERS of China, Hong Kong SAR and Japan against the U.S. dollar. We specified a model that allows for an intercept term because upon visual inspection of the RERs in ***Figure 1*** and ***2***, the series appears to fluctuate around a non-zero mean with no clear trend, it could also be checked that each of the ϕ is insignificant under 5% significance level. In the former, the null hypothesis of non-stationarity is not rejected for each country. To confirm, we look at the results of our PP tests. Again, we fail to reject the null hypothesis that the series is non-stationary for every country. Hence, we can be confident that the RERs of all 3 countries are non-stationary with the US. Dollar as a base.

As an extension to Liang (1999)'s study, we have also conducted ADF and PP tests on select macroeconomic variables for each country to check for non-stationarity to prepare them for cointegration analysis. Should CN, HK and JP prove not to be an optimal currency area (that is there are zero cointegrating vectors between their RERs and the G-PPP hypothesis does not hold) we can check if the individual RERs are instead driven by internal economic fundamentals rather than international parity alone.

Table 3 and ***4*** display results from ADF and PP tests on Hong Kong's GDP, foreign reserves and real interest rates. We follow the same process as before: using the most general version of the specification then omitting trend if ϕ is statistically insignificant and retesting for a unit root. We cannot reject the null of non-stationarity for FR and RIR but do so for GDP at the 5% level. Our PP tests tell a different story: GDP and FR are non-stationary while RIR is stationary. The stationarity of GDP might be driven by the interpolation, which constrains movements to sum to the annual benchmarks and smooth out the stochastic shocks and will thus keep it in our cointegration analysis.

We conducted the same diagnostics for China and its macroeconomic variables; the results are found in ***Table 5*** and ***6.*** Unit roots in GDP, FR, and RIR are found by PP tests. Though all the fundamentals are concluded as stationary by ADF tests, we would consider it being affected by interpolation. Given that RIR is theoretically expected to be non-stationary (I(1)) in the long run, and visual inspection does not suggest mean-reversion, we attribute the conflicting result to the low power of unit root tests in finite samples.

Lastly, we would conclude there were unit roots in all three macroeconomic variables for Japan. The stationarity of GDP of the ADF test would be attributed to the interpolation, therefore it would still be treated as I(1) variable and proceed to the cointegration test. The results from the ADF and PP test are displayed in ***Table 7*** and ***8.***

Cointegration Testing

Moving onto our cointegration analysis, we conduct G-PPP tests on varying combinations of the four economies (HK, CN, JP and US as a base country). ***Table 9*** displays the results of a

G-PPP test conducted on the RERs of HK, CN, and the US. λ_{Max} tests the null of r cointegrating vectors against an alternative hypothesis of r+1. While λ_{Trace} tests the null against a general alternative. The test statistics cannot reject the null of zero cointegrating vectors between the HK-US and CN-US RERs. G-PPP is not maintained between these three economies, so we can surmise that they do not jointly form a potential currency area.

In fact, the G-PPP tests from ***Table 10*** **(HK, JP, US)** ***Table 11*** **(CN, JP, US)** and ***Table 12 (HK, JP, CN, US)*** all fail to reject the null hypothesis of no cointegration. We can hence conclude that none of these economies meet the conditions to form an optimal currency area together.

Though our results from ***Table 9*** align with the findings of Liang (1999), Our G-PPP tests for HK, JP, CN and US differ, where he finds there is one cointegrating vector between the countries' RER. The exchange rate and monthly CPI series he uses ends in June 1998. Around the same time the Asian Financial Crisis occurred, causing major disruptions in exchange rate regimes and macroeconomic fundamentals in East Asia. For example, since 2005, the CNY is no longer pegged to the USD and has instead transitioned to a managed floating exchange rate. Hence, the long run equilibrium relationships Liang observed may have held in a pre-crisis world of more coordinated regimes, but not in the more volatile post-2000 era. For this reason, we are unable to specify a vector error correction model like in the original study since there is nothing driving convergence

Though the RERs are not jointly cointegrated across countries, they might be anchored by domestic macroeconomic forces. We check for this by performing a cointegration test between a country's RER and its GDP, FR, and RIR. ***Table 13*** shows the result for this test on Hong Kong. The test statistics reject the null and point to the presence of at one cointegrating vector. This suggests that RER does not drift randomly but is driven by domestic fundamentals in the long run.

We conduct the same test on China. ***Table 14*** shows how the test statistics reject the null and point to the presence of at two co-integrating vectors. Like Hong Kong and China, the test statistics on the cointegration test for Japan (***Table 15***) also reject the null and accepts the alternative hypothesis, having one cointegrating vector. There are several implications for RER's cointegration with these macroeconomic variables. For GDP, it suggests that countries with higher productivity growth experience RER appreciation (otherwise known as the Balassa-Samuelson effect) (Balassa, 1964). Overall, we find that each country's RER reflects its own economic fundamentals and policy regime. And when it deviates, internal forces tend to pull it back. Foreign assets accumulation as a policy instrument to stabilise the balance of exchange rate and mitigate external volatility is reflected in the long-run relationship between RER and FR. A stable long-run relationship with RIR suggest that capital flows driven by interest rate changes are a fundamental force behind RER movements and should the exchange rate deviate from its long-run equilibrium, it will adjust back, consistent with uncovered interest parity.

Conclusion

Our study re-examines the Generalized Purchasing Power Parity (G-PPP) hypothesis in the context of China, Hong Kong SAR, and Japan using updated monthly data through 2024. While our results show no evidence of cointegration among the real exchange rates across the three economies, we find robust long-run relationships between each country's RER and its domestic fundamentals, including GDP per capita, foreign reserves, and real interest rates. These findings suggest that regional monetary integration in East Asia remains limited, and that domestic macroeconomic factors continue to play a dominant role in long-run exchange rate behavior.

The contrast with earlier findings, such as Liang (1999), points to important structural changes over the past three decades. Since the late 1990s, the region has experienced increased exchange rate flexibility, shifts in capital control policies (especially in China mainland), and asymmetric responses to global shocks. As a result, the pre-crisis dynamics which used to support G-PPP, is no longer hold. Our findings capture this growing heterogeneity in macroeconomic patterns across East Asia and the continued importance of domestic policy's guidance.

One limitation of this study is the use of interpolated monthly data for certain annual indicators, which may smooth over short-term volatility. Future research could extend this framework by incorporating additional economies in the region (for example, South Korea and Singapore), accounting for structural breaks, or applying nonlinear cointegration techniques to capture these dynamics.

Appendix

Figure 1. Evolution of Real Exchange Rates for China and Hong Kong SAR (Base country = the United States) (January 2004-January 2024)

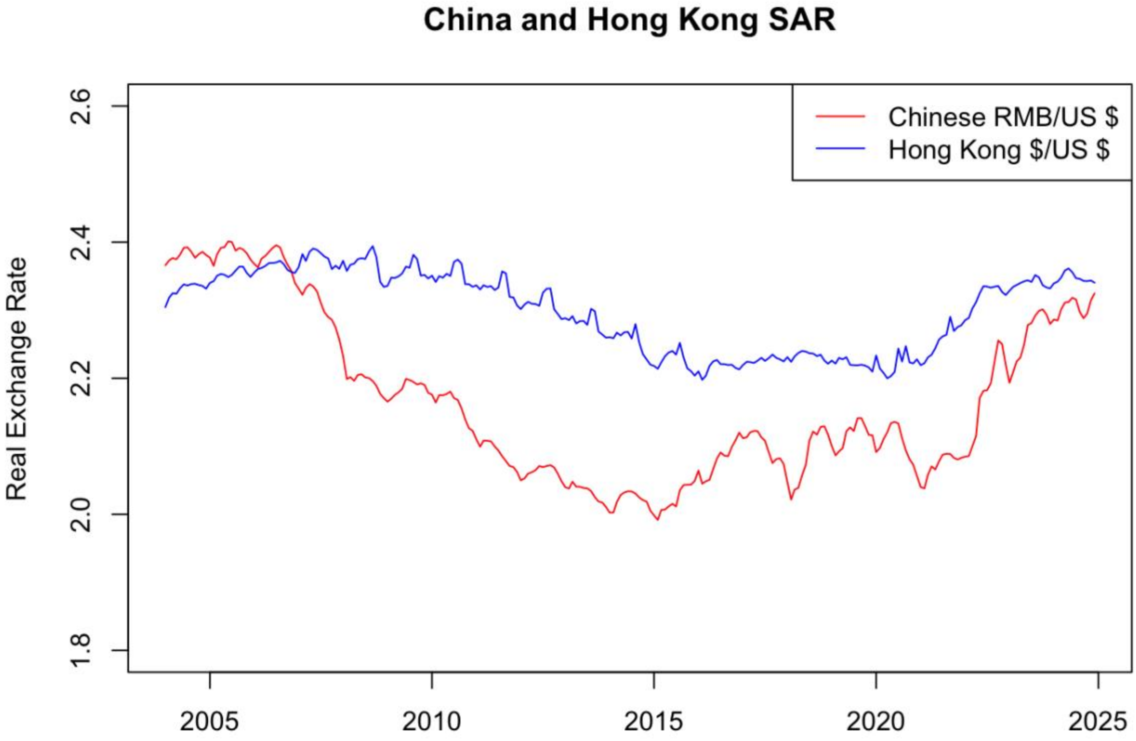

Figure 2. Evolution of Real Exchange Rates for Japan (Base country = the United States) (January 2004-January 2024)

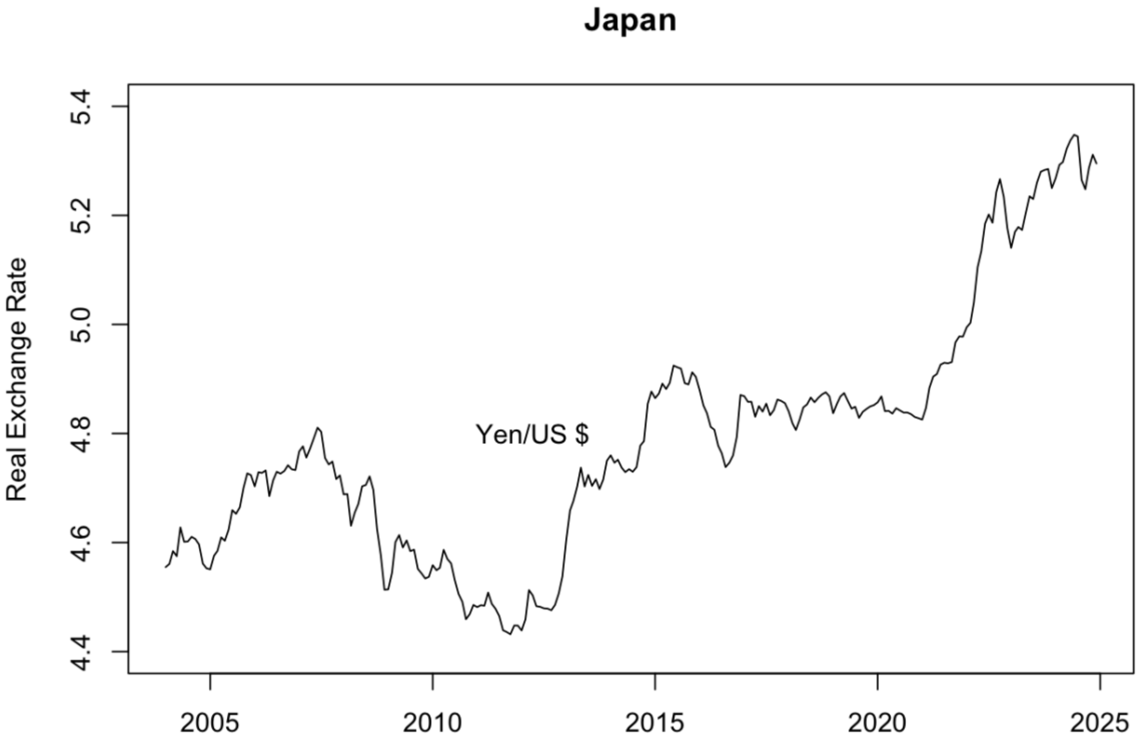

Table 1. ADF Test Results for Real Exchange Rates in CN, HK, and JP

Variable	Model	ϕ2	CVϕ(0.05)	Decision	τ	CVτ(0.05)	Conclusion
CN	Trend	1.879	4.71	Drop Trend	-0.526	-3.420	
CN	Drift	NA	NA		-1.458	-2.870	Non-Stationary
HK	Trend	0.483	4.71	Drop Trend	-0.966	-3.420	
HK	Drift	NA	NA		-1.192	-2.870	Non-Stationary
JP	Trend	1.836	4.71	Drop Trend	-1.560	-3.420	
JP	Drift	NA	NA		-0.200	-2.870	Non-Stationary

Table 2. PP Test Results for Real Exchange Rates in CN, HK, and JP

Country	Model	PP Stat.	CV(0.05)	Conclusion
CN	Constant	-1.285	-2.873	Non-Stationary
HK	Constant	-1.131	-2.873	Non-Stationary
JP	Constant	-0.038	-2.873	Non-Stationary

Figure 3. Macroeconomic Fundamentals in Hong Kong SAR (January 2004- January 2024)

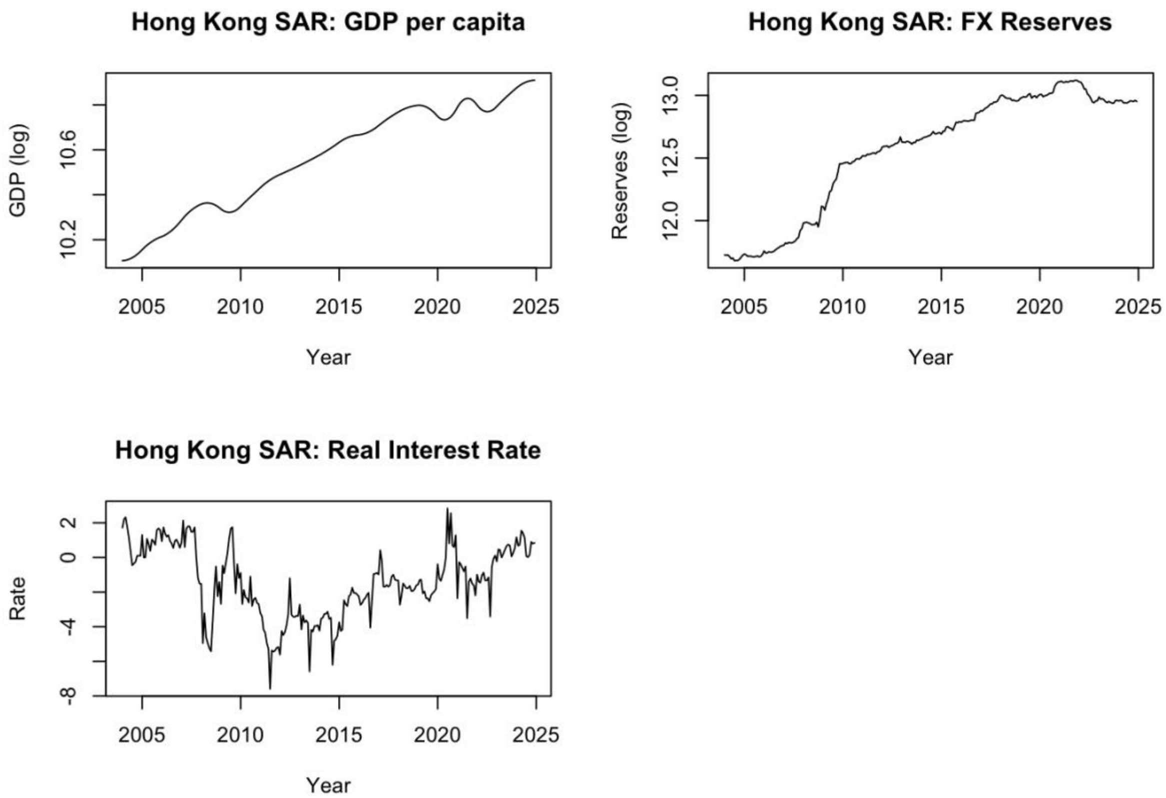

Table 3. ADF Test Results for Hong Kong Macroeconomic Variables

Variable	Model	ϕ2	CVϕ(0.05)	Decision	τ	CVτ(0.05)	Conclusion
HK_GDP	Trend	18.325	4.71	Keep Trend	-7.239	-3.420	Stationary
HK_FR	Trend	6.284	4.71	Keep Trend	0.295	-3.420	Non-Stationary
HK_RIR	Trend	2.936	4.71	Drop Trend	-2.804	-3.420	
HK_RIR	Drift	NA	NA		-2.835	-2.870	Non-Stationary

Table 4. PP Test Results for Hong Kong Macroeconomic Variables

Country	Model	PP Stat.	CV(0.05)	Conclusion
HK_GDP	Trend	-1.683	-3.429	Non-Stationary
HK_FR	Trend	0.162	-3.429	Non-Stationary
HK_RIR	Constant	-3.416	-2.873	Stationary

Figure 4. Macroeconomic Fundamentals in China (January 2004- January 2024)

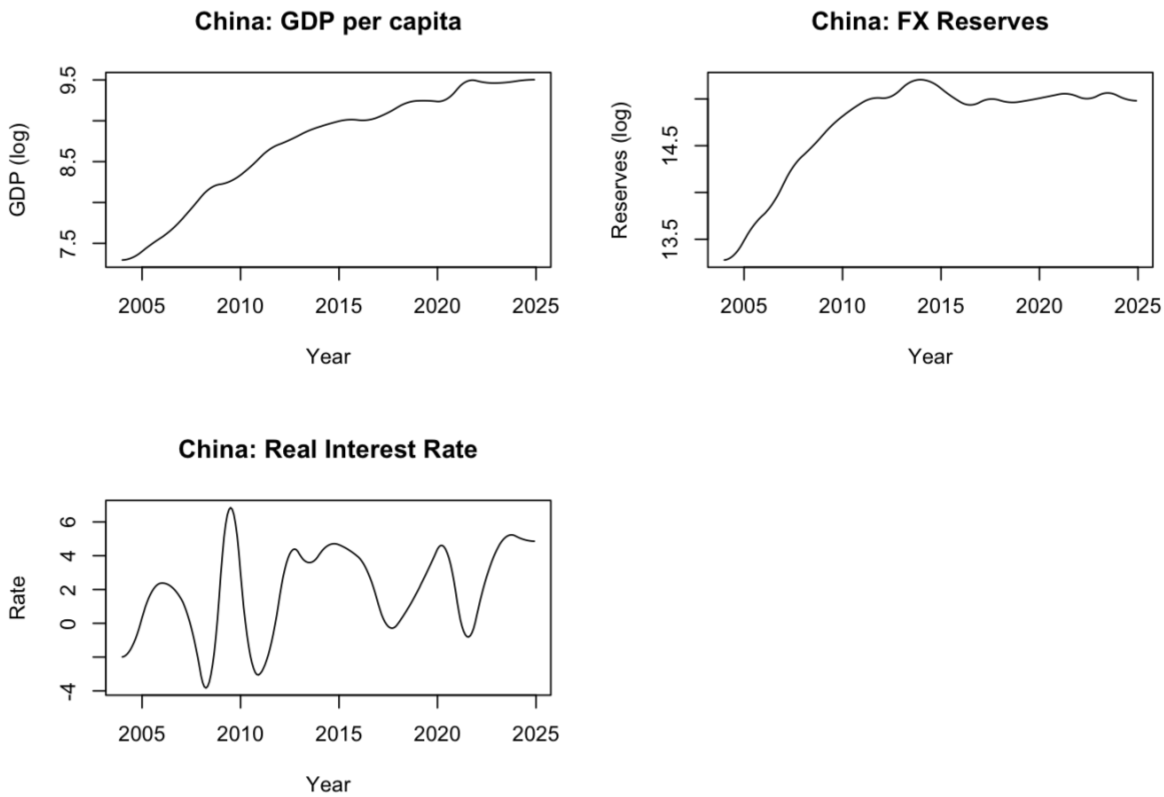

Table 5. ADF Test Results for China Macroeconomic Variables

Variable	Model	$\phi 2$	$CV\phi(0.05)$	Decision	τ	$CV\tau(0.05)$	Conclusion
CN_GDP	Trend	10.521	4.710	Keep Trend	-4.637	-3.420	Stationary
CN_FR	Trend	17.482	4.710	Keep Trend	-6.777	-3.420	Stationary
CN_RIR	Trend	86.731	4.710	Keep Trend	-16.129	-3.420	Stationary

Table 6. PP Test Results for China Macroeconomic Variables

Country	Model	PP Stat.	CV(0.05)	Conclusion
CN_GDP	Trend	-0.508	-3.429	Non-Stationary
CN_FR	Trend	-3.002	-3.429	Non-Stationary
CN_RIR	Trend	-2.814	-3.429	Non-Stationary

Figure 5. Macroeconomic Fundamentals in Japan (January 2004- January 2024)

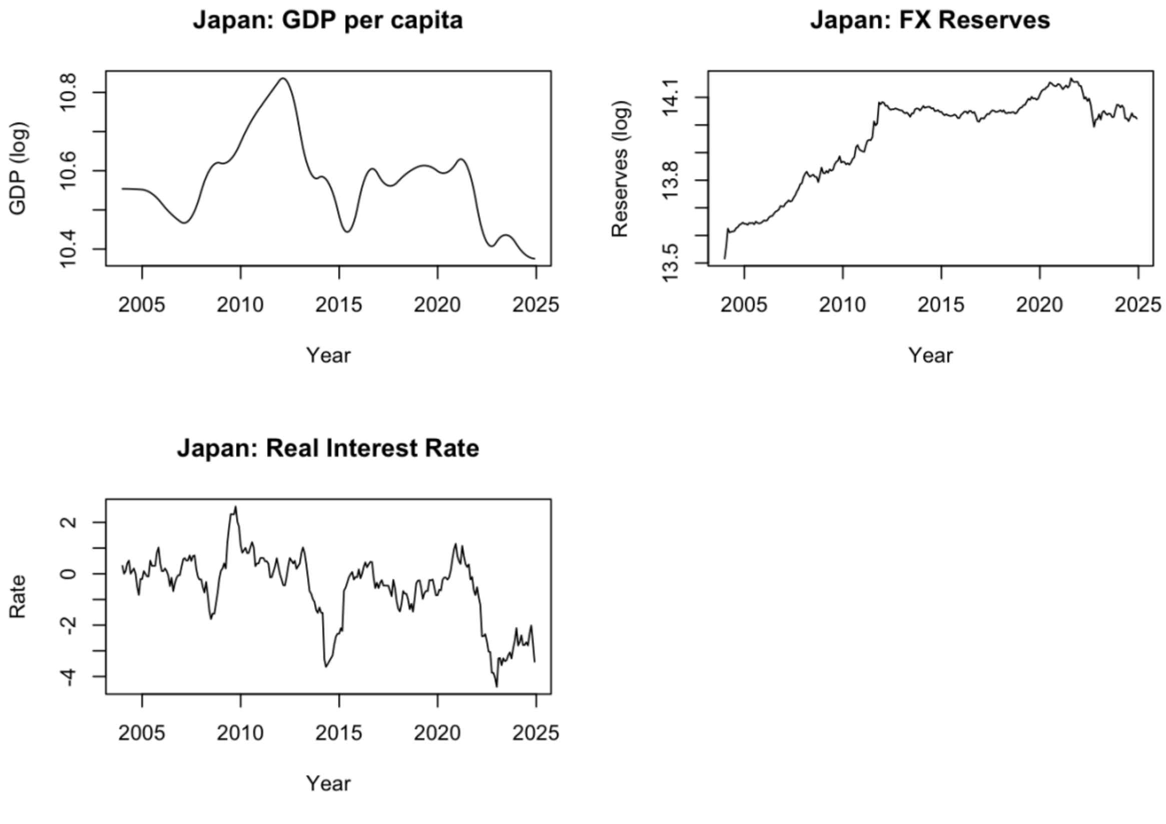

Table 7. ADF Test Results for Japan Macroeconomic Variables

Variable	Model	$\phi 2$	$CV\phi(0.05)$	Decision	τ	$CV\tau(0.05)$	Conclusion
JP_GDP	Trend	14.457	4.71	Keep Trend	-6.578	-3.420	Stationary
JP_FR	Trend	4.089	4.71	Drop Trend	-1.071	-3.420	
JP_FR	Drift	NA	NA		-2.807	-2.870	Non-Stationary
JP_RIR	Trend	2.812	4.71	Drop Trend	-2.772	-3.420	
JP_RIR	Drift	NA	NA		-1.938	-2.870	Non-Stationary

Table 8. PP Test Results for Japan Macroeconomic Variables

Country	Model	PP Stat.	CV(0.05)	Conclusion
JP_GDP	Trend	-1.160	-3.429	Non-Stationary
JP_FR	Constant	-3.349	-2.873	Stationary
JP_RIR	Constant	-1.958	-2.873	Non-Stationary

Table 9. G-PPP Tests Across Hong Kong SAR, China and the United States (Base Country) *(5% Critical Values)*

H_0	H_A	λ_{Max}	CV_{Max}	λ_{Trace}	CV_{Trace}	Conclusion
r = 0	r = 1	12.399	15.670			Not rejected
r = 1	r = 2	2.708	9.240			Not rejected
r = 0	r > 0			15.106	19.960	Not rejected
r ≤ 1	r > 1			2.708	9.240	Not rejected

Table 10. Cointegration Tests of Real Exchange Rate for Hong Kong SAR and Japan (vs US) *(5% Critical Values)*

H_0	H_A	λ_{Max}	CV_{Max}	λ_{Trace}	CV_{Trace}	Conclusion
r = 0	r = 1	3.370	15.670			Not rejected
r = 1	r = 2	1.734	9.240			Not rejected
r = 0	r > 0			5.103	19.960	Not rejected
r ≤ 1	r > 1			1.734	9.240	Not rejected

Table 11. Cointegration Tests of Real Exchange Rate for China and Japan (vs US) ***(5% Critical Values)***

H_0	H_A	λ_{Max}	CV_{Max}	λ_{Trace}	CV_{Trace}	Conclusion
r = 0	r = 1	8.490	15.670			Not rejected
r = 1	r = 2	2.551	9.240			Not rejected
r = 0	r > 0			11.041	19.960	Not rejected
r ≤ 1	r > 1			2.551	9.240	Not rejected

Table 12. G-PPP Tests Across China, Hong Kong SAR, Japan (vs US) ***(5% Critical Values)***

H_0	H_A	λ_{Max}	CV_{Max}	λ_{Trace}	CV_{Trace}	Conclusion
r = 0	r = 1	9.776	22.000			Not rejected
r = 1	r = 2	6.094	15.670			Not rejected
r = 2	r = 3	2.670	9.240			Not rejected
r = 0	r > 0			18.540	34.910	Not rejected
r ≤ 1	r > 1			8.764	19.960	Not rejected
r ≤ 2	r > 2			2.670	9.240	Not rejected

Table 13. Johansen Cointegration Test Results for Hong Kong ***(5% Critical Values)***

H_0	H_A	λ_{Max}	CV_{Max}	λ_{Trace}	CV_{Trace}	Conclusion
r = 0	r = 1	73.134	31.460			Rejected
r = 1	r = 2	17.400	25.540			Not rejected
r = 2	r = 3	9.412	18.960			Not rejected
r = 3	r = 4	8.752	12.250			Not rejected
r = 0	r > 0			108.697	62.990	Rejected
r ≤ 1	r > 1			35.564	42.440	Not rejected
r ≤ 2	r > 2			18.164	25.320	Not rejected
r ≤ 3	r > 3			8.752	12.250	Not rejected

Table 14. Johansen Cointegration Test Results for China *(5% Critical Values)*

H_0	H_A	λ_{Max}	CV_{Max}	λ_{Trace}	CV_{Trace}	Conclusion
r = 0	r = 1	33.927	31.460			Rejected
r = 1	r = 2	25.981	25.540			Rejected
r = 2	r = 3	13.141	18.960			Not rejected
r = 3	r = 4	8.578	12.250			Not rejected
r = 0	r > 0			81.627	62.990	Rejected
r ≤ 1	r > 1			47.700	42.440	Rejected
r ≤ 2	r > 2			21.719	25.320	Not rejected
r ≤ 3	r > 3			8.578	12.250	Not rejected

Table 15. Johansen Cointegration Test Results for Japan *(5% Critical Values)*

H_0	H_A	λ_{Max}	CV_{Max}	λ_{Trace}	CV_{Trace}	Conclusion
r = 0	r = 1	38.360	31.460			Rejected
r = 1	r = 2	15.470	25.540			Not rejected
r = 2	r = 3	12.721	18.960			Not rejected
r = 3	r = 4	3.750	12.250			Not rejected
r = 0	r > 0			70.301	62.990	Rejected
r ≤ 1	r > 1			31.941	42.440	Not rejected
r ≤ 2	r > 2			16.471	25.320	Not rejected
r ≤ 3	r > 3			3.750	12.250	Not rejected

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