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# INTEREST RATE DIFFERENTIALS UNDER AN EXCHANGE RATE CONVERTIBILITY ZONE: A CARRY TRADE PERSPECTIVE

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# Interest Rate Differentials Under an Exchange Rate Convertibility Zone: A Carry Trade Perspective *

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## Abstract

This study is motivated by the negative HKD-USD interest rate differentials observed after the US interest rate hike on December 17, 2015. We first analyse two practical concerns that are typical from the perspective of a carry trader: (1) the difference in borrowing rate and lending rate of a currency, and (2) the exchange rate loss perceived from prevailing HKD/USD market condition using a truncated distribution that reflects full confidence in the HKD/USD Convertibility Zone un-der the Linked Exchange Rate System (LERS). We find that these considerations largely rationalize the observed interest rate differentials. We then perform robust Bayesian statistical inference on the negatively skewed effective carry-to-risk ratios. We find that the most probable and the typical effective carry-to-risk ratios are economically small. Our results are consistent with the Hong Kong Currency Board's intrinsic stabilizing mechanism functioning efficiently.

**Keywords:** Asymmetric Interest Rates, Exchange Rate Loss, Robust Inference, Linked Exchange Rate System, Convertibility Undertaking, Market Efficiency

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# 1 Introduction

Carry trade attempts to profit from the interest rate differentials between currency pairs. In our case, if the interest rates of HKD are below those of USD, then one may borrow HKD at a fixed rate to finance a long position in USD denominated risk free time deposit with matching tenure. This position is almost surely profitable if the exchange rate remains unchanged at maturity, which is true when the currencies are confidently pegged at a fixed target rate. However, under Hong Kong's current Linked Exchange Rate System (LERS), the spot price of HKD vis-a-vis USD is credibly bounded within a "Convertibility Zone" between 7.75 and 7.85 with both numbers included.[1] The Hong Kong Monetary Authority (HKMA) buys USD and sells HKD at HKD7.75/USD to ensure that HKD does not strengthen beyond 7.75 under the strong side Convertibility Undertaking. The HKMA sells USD and buys HKD at HKD7.85/USD to defend HKD from weakening beyond 7.85 under the weak side Convertibility Undertaking.

This study is motivated by the negative HKD-USD interest rate differentials observed after the US interest rate hike on December 17, 2015.[2] As shown in Figure 3, HKD interest rates (proxied by HIBOR ask quote) tend to fall below but occasionally spike above USD interest rates (proxied by USD LIBOR ask quote).[3] This phenomenon seems to be a puzzle for the HKMA's Currency Board system that has a built-in mechanism to eliminate large deviations between HKD and USD interest rates through the following self corrections. A sudden increase in real demand for HKD accompanied by USD inflow increases Hong Kong's monetary base and aggregate balance in the banking system. This might exert upward price pressure on HKD and also drive HKD interest rates to fall below the corresponding USD rates. Carry traders could be induced to take positions shorting HKD and longing USD. Consequently, these trading activities should reverse the level of Hong Kong's monetary base, creating downward price pressure on HKD and pushing HKD interest rates up. Carry trades should therefore help reduce negative interest rate differentials between HKD and USD (HKMA, 2018) [12]. A decrease in real demand for HKD would subject to a similar process but in opposite direction.

Our research question is what discourages carry traders from trading against the

[1] The LERS was introduced in 1983 and the system has been proven to be highly robust. In particular, the system has remained intact under the stressful market conditions throughout the 1997–1998 Asian Financial Crisis, the 2003 SARS outbreak, the 2007 US subprime crisis, the large influx of hot money during the US unconventional monetary policy regime, and the subsequent tapering of US quantitative easing marked by the first lifting of Federal Funds target rate on December 17, 2015. Figure 1 shows that HKD/USD exchange rate moved towards the target rate of 7.8 immediately after the implementation of the LERS on October 17, 1983. Figure 2 shows that the exchange rate was bounded by the weak side Convertibility Undertaking rate of 7.8 following the introduction of the new measure on September 5, 1998. Moreover, the exchange rate has been perfectly bounded within the two-sided Convertibility Zone since its inception on May 19, 2005. The introduction of both strong side and weak side convertibility undertakings has strengthened the credibility of the LERS since the refinements greatly reduce discretionary elements in the Currency Board mechanism (see, e.g., Genberg and Hui (2011) [10]).

[2] The US Federal Reserve raised the Fed Fund's rate target range from 0%–0.25% to 0.25%–0.5% on December 17, 2015 as part of the normalization process of the unconventional monetary policy regime. The December rate hike was the first of a series of upward revisions of Fed Fund's after the US Federal Reserve lowered the Fed Funds rate to 0%–0.25% on September 15, 2008.

[3] LIBOR uses a 365/360-day count convention. The LIBOR rates in this study are adjusted to actual/actual basis with a factor of 360/365. Fong, Valente, and Fung (2010) [7] adopts an adjustment through a compounding factor. Our results are robust to this alternative approach.

negative HKD-USD interest rate differentials. The main idea is as follows. Although the strong (weak) side Convertibility Undertaking limits the loss on the position shorting (longing) HKD, HKD/USD still can freely float within the Zone, hence, HKD/USD might move against the exchange rate position in a proposed carry trade. A zero or low probability of HKD to depreciate (appreciate) but a high probability of HKD to appreciate (depreciate), which is the case when HKD is close to the weak (strong) side Convertibility Undertaking, make carry trades involving short (long) positions in HKD risky. Thus, carry traders might refrain from trading against the observed HKD-USD interest rate differentials due to risk aversion.

First, this study measures the nominal HKD-USD interest rate differential by substracting a HIBOR ask quote from the LIBOR ask quote of the same tenure. This quantity is typically used in the literature. We then examine to what extent the difference between borrowing rate and lending rate of a currency affects incentive to carry trade. On the one hand, when HIBOR ask quote (HKD borrowing rate) is below LIBOR bid quote (USD lending rate), we measure interest rate differential as HIBOR ask quote minus LIBOR bid quote. On the other hand, when HIBOR bid quote (HKD lending rate) is above LIBOR ask quote (USD borrowing rate), we measure interest rate differential as HIBOR bid quote minus LIBOR ask quote. In other scenarios we set interest rate differential to zero to reflect the absence of incentive to carry trade. After this adjustment, the HKD-USD interest rate differentials are somewhat smaller in magnitude and there are more occurrences of zero interest rate differentials. These suggest that the asymmetric interest rates for borrowing versus lending a currency in the HKD and USD money markets partially rationalize the observed interest rate differentials.

Next, we demonstrate that risk to carry, i.e., the exchange rate loss perceived from prevailing HKD/USD market condition, largely reduces incentive to carry trade. On a daily basis, a truncated Normal distribution is fitted to trailing data in a rolling window. This distribution reflects full confidence in the HKD/USD Convertibility Zone under the LERS. We compute higher order moments of the probability density over the possible exchange rate values that generate loss to the exchange rate position in the carry trade under consideration. We then scale the adjusted interest rate differentials by the percevied exchange rate loss. The resulting effective carry-to-risk ratios are rather small in magnitudes. These suggest that the perceived exchange rate loss further rationalize the observed interest rate differentials.

Finally, we perform Bayesian inference using an extreme value distribution to model data generation of the negatively skewed and leptokurtic effective carry-to-risk ratios with uninformative parameter priors. This approach enables proper statistical inference in the presence of outliers with negative values. We find that the most probable, i.e., the mode, and the typical, i.e., the median, effective carry-to-risk ratios are economically small. Additional analysis shows that the effective carry-to-risk ratios tend to follow autoregressive processes and are weakly associated with trailing macroeconomic and financial market conditions.

The key implication of our results is that the Hong Kong Currency Board's intrinsic stabilising mechanism functions efficiently. This study provides additional implication for central bankers and regulators. Our findings suggest that interest rate differentials might not be sufficient statistics for forecasting fund flows and monitoring financial stability.[4] Interest rate differentials can predict short run supply and demand for the relevant currency pairs only if the differentials effectively provide incentive to carry trade. Therefore, factors such as the market friction and risk to carry studied in this paper should be considered in fund flows modelling and stability analysis.

The paper is organized as follows. Section 2 reviews relevant studies in carry trade. Section 3 reports the nominal HKD-USD interest rate differentials. Section 4 presents the interest rate differentials after taking into account the asymmetric interest rates for borrowing versus lending a currency and the perceived exchange rate loss. Section 5 performs robust Bayesian inference on the effective carry-to-risk ratios. Section 6 analyzes dynamics of the effective carry-to-risk ratios. Section 8 concludes the study.

# 2 Literature Review

Many studies have examined carry trade risk from the view of uncovered interest rate arbitrage. Earlier ones include Barro (2006) [1] and Brunnermeier and Pedersen (2009) [3]. Hui, Lo, and Liu (2018) [13] emphasize that a carry trade could produce significant loss if the currency of the long leg of the trade crashes against the currency being sold short. The worst-case scenario can be demonstrated by the Peso Crisis under which the price change of the Mexican peso is non reverting. Burnside et al. (2011) [4], Dobrynskaya (2014) [5] and Lettau, Maggiorid, and Weber (2014) [15] also find a relation between carry trade and crash risk. Furthermore, Lustig, Roussanov, and Verdelhan (2011) [16] document a relation between global risk aversion and carry trade.

On the one hand, Kent, Hodrick, and Lu (2017) [14] find that carry trade is not exposed to significant amount of risk as measured by the second moment of exchange rate distribution. On the other hand, consistent with Ready, Roussanov, and Ward (2017) [19] and Maurer, To, and Tran (2017) [17], Bekaert and Panayotov (2019) [2] find that carry trade is risky after extending the risk measure to the third moment of exchange rate distribution. Therefore, it is reasonable to assume carry traders are averse to the higher moment exchange rate risk. In our analysis, we measure the perceived exchange rate loss by higher moments of the HKD/USD exchange rate distribution under the LERS.

Alternatively, an investor can cover the adverse exchange rate risk in an interest rate arbitrage with forward contracts. However, the existence of a pure arbitrage opportunity can be delusive (see, e.g., Miller, Muthusamy, and Whaley (1994) [18]). It has been documented that covered interest arbitrage opportunities are in fact unprofitable after factoring in bid ask spreads in interest rates and trading costs involved in the associated spot and forward exchange rate markets (see, e.g., Frenkel and Levich (1975) [8]). Using synchronous executable quote data, Fong, Valente, and Fung (2010) find that covered interest arbitrage opportunities can be attributed to liquidity risk and credit risk since after controlling for these risks, the opportunities can only be exploited by the least cost

[4]For example, under the Currency Board system, the HKD monetary base, which includes Exchange Fund bills and notes, must have at least 100% backing with liquid USD assets. A high volume of selling HKD for USD will lead to a depletion of USD denominated reserve assets and lowering of Hong Kong's monetary base. This might cause sudden spikes in HKD interest rates and deflationary pressure on HKD denominated assets.

traders. Du, Tepper, and Verdelhan (2018) [6] find a persistent pattern of significant violations of interest rate parity for the G10 currencies in the post crisis period. They argue that the seemingly profitable arbitrage opportunities can be explained by costly financial intermediation, international imbalances in cross currency investment demand, and funding supply.

# 3 Nominal HKD-USD Interest Rate Differentials

Daily HIBOR and USD LIBOR ask quotes per annum and HKD/USD bid and ask quotes for the period from 03 January 2006 to 04 Mar 2019 are retrieved from the Bloomberg terminal. HIBOR quotes are provided by the Hong Kong Association of Banks while USD LIBOR quotes are provided by the Intercontinental Exchange. This sample contains observations on interest rate quotes for all active tenures. This period coincides with the latest LERS configuration after the "three refinements"[5].

Our analysis focuses on the period after the US interest rate hike on December 17, 2015 (Post QE). Some results for the period during the US quantitative easing (QE), the period before the quantitative easing (Pre QE), and the full period (All) are presented for reference. The HKD-USD interest rate differential at day $t$ is defined as

$$IRD_{tenure,t} \doteq \text{HIBOR}_{tenure,t} - \text{USD LIBOR}_{tenure,t}$$

with $tenure$ = O/N, 01W, 01M, 02M, 03M, 06M, 12M, where O/N, 01W and 01M refer to overnight, one week, and one month, etc. Figure 3 plots the time series of various HIBOR, USD LIBOR and $IRD$. HIBOR tends to fall below USD LIBOR, i.e., negative $IRD$ is observed, for each tenure. Table 1 reports statistics of $IRD$. Panel A shows that average interest rate differentials are negative. Classical statistical infererence using the Student's t-test suggests that mean interest rate differentials are statistically different from zero at a low significance level. Panel B provides measures of the magnitudes of interest rate differentials in terms of their distances from zero. Panels C and D report the number of interest rate differentials that are strictly positive and negative, respectively.

# 4 Two Practical Concerns for Carry Trade

Carry trade is a major trading strategy that keeps the interest rates of two pegged currencies close to each other. Let $r_{HKD}$ and $r_{USD}$ represent the HKD interest rate and the USD interest rate, respectively, for a certain tenure. Suppose the spot HKD/USD exchange rate is at the credible policy target rate, a restriction that we will relax in Section 4.2, then $r_{HKD} < r_{USD}$ ($r_{HKD} > r_{USD}$) provides risk free profit to a carry trader who shorts (longs) HKD and longs (shorts) USD. These trades should exert upward (downward) pressure on $r_{HKD}$ and downward (upward) pressure on $r_{USD}$. Assume there is no market friction, $r_{HKD}$ should be equal to $r_{USD}$ in equilibrium. Given the US

[5] The "three refinements" represent the second major and latest refinement to the LERS and were implemented on 19 May 2005. The new measures include revision of the weak side Convertibility Undertaking to HKD7.85/USD and the introduction of the strong side Convertibility Undertaking at HKD7.75/USD. The two sided Undertakings aim to foster a symmetric Convertibility Zone around 7.80. Within the Zone, the HKMA may choose to conduct market operations consistent with the Currency Board principles to promote the smooth functioning of the LERS.

interest rate policy imposes a rigid $r_{USD}$, the interest rate convergence relies on the market movement in $r_{HKD}$.

## 4.1 Asymmetric Rates for Borrowing versus Lending a Currency

In practice, money markets are not frictionless. At least typically the cost of borrowing a currency is higher than the return to lending the same currency over the same horizon. This asymmetry reflects the compensation demanded by intermediaries for providing financial service and transactional liquidity. Currency borrowers pay the ask interest rates while currency lenders receive the bid interest rates.

Let $r_{HKD}^{ASK}$ ($r_{HKD}^{BID}$) and $r_{USD}^{BID}$ ($r_{USD}^{ASK}$) represent the ask (bid) quote of HKD interest rate and the bid (ask) quote of USD interest rate, respectively, for a certain tenure. Suppose the spot HKD/USD exchange rate is at the credible policy target rate, a restriction that we will relax in Section 4.2, $r_{HKD}^{ASK} < r_{USD}^{BID}$ ($r_{HKD}^{BID} > r_{USD}^{ASK}$) provides risk free profit to the carry trader who shorts (longs) HKD and longs (shorts) USD. These trades should exert upward (downward) presssure on $r_{HKD}^{ASK}$ ($r_{HKD}^{BID}$) and downward (upward) pressure on $r_{USD}^{BID}$ ($r_{USD}^{ASK}$). However, in this environment, one does not expect all the interest rates for a given tenure to equate in equilibrium. This is because the scenario where $r_{HKD}^{BID} < r_{USD}^{ASK}$ and the scenario where $r_{HKD}^{ASK} > r_{USD}^{BID}$ do not provide any incentive to carry trade.

To adjust for this friction, we obtain additional daily data on interest rate bid quotes per annum from DataStream. The HKD and USD deposit rates provided by Thomson Reuters and Tullett Prebon are used as proxies for the bid quotes. Table 2 reports the magnitude of the asymmetry via the ratio of ask quote to bid quote for each tenure. The friction in the HKD market is very substantial while that in the USD market is much less severe. For each *tenure*, the adjusted HKD-USD interest rate differential is measured by[6]

$$AIRD_t \doteq \begin{cases} \text{HIBOR}_t^{ask} - \text{USD LIBOR}_{t-1}^{bid}, & \text{if HIBOR}_t^{ask} < \text{USD LIBOR}_{t-1}^{bid} \\ \text{HIBOR}_t^{bid} - \text{USD LIBOR}_{t-1}^{ask}, & \text{if HIBOR}_t^{bid} > \text{USD LIBOR}_{t-1}^{ask} \\ 0, & \text{otherwise} \end{cases}$$

Table 3 reports statistics of $AIRD$. This adjustment somewhat shrinks the interest rates differentials towards zero. Comparing to Panel B of Table 1, Panel A of Table 3 shows that the distances of interest rate differentials from zero are reduced. This adjustment is also rather effective in identifying scenarios that do not provide any incentive to carry trade. Comparing to Panel C of Table 1, Panel B of Table 3 shows that the count of strictly positive interest rate differentials is much reduced. This is consistent with the asymmetry in HKD interest rates being high and this asymmetry tends to discourage

[6]The HIBOR and LIBOR data being based on last price perhaps poses another problem for measuring interest rate differentials from the perspective of a carry trader. Since there is time zone difference between Hong Kong and US, in practice, a carry trader based in Hong Kong (US) would likely be facing the USD (HKD) interest rates recorded as of the previous (next) day. To address the lagging of the USD interest rate data behind the HKD interest rate data, we synchronize the observations by merging the daily HKD quotes with the previous day's USD quotes. Our results are largely similar if this step is not taken.

carry trade that shorts USD and longs HKD. As there is more asymmetry on interest rate with shorter tenure, there is a higher reduction of positive counts of interest rate differential for shorter tenure. Comparing to Panel D of Table 1, Panel C of Table 3 shows that the count of strictly negative interest rate differentials are reduced, but not as much as the reduction of positive differentials. This might be due to the asymmetry in USD interest rates being mild and this asymmetry does not discourage carry trade that shorts HKD and longs USD as much.

## 4.2 Perceived Exchange Rate Loss

The HKMA has not enforced a single HKD/USD exchange rate target since the "three refinements" implemented on 19 May 2005. In the current configuration of the LERS a symmetric Convertibility Zone around HKD7.80/USD is maintained by the two sided convertibility undertakings. For the strong (weak) side Convertibility Undertaking, the HKMA Currency Board stands to convert HKD into USD, or vice versa, at HKD7.75/USD (HKD7.85/USD) to prevent HKD from further appreciating (depreciating) against USD. Since HKD/USD still can freely float within the Zone, the potential of adverse exchange rate movements makes carry trade risky. For example, the scenario where $r_{HKD} < r_{USD}$ provides incentive to carry trade that shorts HKD and longs USD. But if the spot exchange rate is at the weak side of HKD7.85/USD, then there is positive probability that HKD appreciates against USD yet there is zero probability that HKD depreciates against USD. In this case the likelihood of the return to carry trade being less than $r_{USD} - r_{HKD}$ or being negative is nonnegligible. The higher the potential exchange rate loss, the less incentive an interest rate differential provides to carry trade.[7]

We measure potential exchange rate loss as follows. Each day $t$, we estimate a conditional truncated Normal distribution of future HKD/USD exchange rate

$$\left.\frac{\text{HKD}}{\text{USD}}_{t,T}\right|\mu_t, \sigma_t, a_t, b_t \sim p_t\left(\frac{\text{HKD}}{\text{USD}}_{t,T}; \mu_t, \sigma_t, a_t, b_t\right)$$

represented by the probability density function

$$p_t \doteq \begin{cases} \dfrac{\phi\left(\frac{\text{HKD/USD}_{t,T}-\mu_t}{\sigma_t}\right)}{\sigma_t\left(\Phi\left(\frac{b_t-\mu_t}{\sigma_t}\right)-\Phi\left(\frac{a_t-\mu_t}{\sigma_t}\right)\right)}, & \text{if } 7.75 \leq \frac{\text{HKD}}{\text{USD}}_{t,T} \leq 7.85 \\ 0, & \text{otherwise,} \end{cases}$$

where $T-t = tenure$, $a_t = \frac{7.75-\mu_t}{\sigma_t}$, and $b_t = \frac{7.85-\mu_t}{\sigma_t}$. $\phi(\cdot)$ and $\Phi(\cdot)$ are the standard normal probability density function and the standard normal cumulative distribution function, respectively. Under this probability distribution, it is impossible to realize exchange rate values lower than 7.75 or exchange rate values higher than 7.85. It is only possible to realize exchange rate values between 7.75 and 7.85 inclusively. Hence, this specification reflects a full credible Convertibility Zone while allowing the exchange rate to exhibit meaningful fluctuation. For simplicity, we assume $\mu_t$ and $\sigma_t$ hence $p_t$ are horizon invariant. The time varying mean and volatility are estimated from the rolling window of data observed over the trailing 365 trading days, excluding observation on day $t$.

[7] Following the finance literature in general, we assume the representative investor is averse to risk. According to the studies reviewed in Section 2, a carry trader should be particularly averse to higher moment risks.

For example, on 15 Oct 2018, the spot exchange rate is HKD7.835/USD. The estimated $\mu_t$ and the estimated $\sigma_t$ are 7.826 and 0.019, respectively. Figure 4 shows the plot of the $p_t(\cdot)$ simulated with these estimates. The probability densities beyond 7.75 and 7.85 are zero as enforced by the truncation. $AIRD$ is -1.46%, -1.14%, -0.67%, -0.49%, -0.33%, -0.30%, -0.29% for $tenure$ = O/N, 01W, 01M, 02M, 03M, 06M, 12M. A carry trader would look into shorting HKD and longing USD, and would consider exchange rates falling below the spot rate of HKD7.835/USD and the corresponding probabilities. This motivates measuring the perceived exchange rate loss at trading day $t$ as the conditional $n$-th moment of the distribution $p_t(\cdot)$

$$ERL_t \doteq \begin{cases} \left(\int_{x<\frac{\text{HKD}}{\text{USD}}_t} \left|x - \frac{\text{HKD}}{\text{USD}}_t\right|^n p_t(x)dx\right)^{\frac{1}{n}} \times 100\% & \text{if } 7.75 < \frac{\text{HKD}}{\text{USD}}_t \leq 7.85 \\ 1 & \text{if } \frac{\text{HKD}}{\text{USD}}_t = 7.75 \end{cases}$$

when the carry trade under consideration shorts HKD, and

$$ERL_t \doteq \begin{cases} \left(\int_{x>\frac{\text{HKD}}{\text{USD}}_t} \left|x - \frac{\text{HKD}}{\text{USD}}_t\right|^n p_t(x)dx\right)^{\frac{1}{n}} \times 100\% & \text{if } 7.75 \leq \frac{\text{HKD}}{\text{USD}}_t < 7.85 \\ 1 & \text{if } \frac{\text{HKD}}{\text{USD}}_t = 7.85 \end{cases}$$

when the carry trade under consideration longs HKD. We use $n \geq 3$ as the literature suggests that carry traders are averse to risks of higher moments. When there is no perceived exchange rate loss, i.e., HKD is shorted (longed) at the strong (weak) side of the Zone, the measure is set to one for a reason that will be obvious shortly.

To numerically approximate $ERL$, we randomly draw 10,000 samples from $p_t(\cdot)$ and compute the average

$$\widehat{ERL_t} \doteq \left[\frac{1}{C}\sum \left|i - \frac{\text{HKD}}{\text{USD}}_t\right|^n\right]^{\frac{1}{n}} \times 100\%$$

with summation over the subset $\underline{s} \doteq \{i : i < \frac{\text{HKD}}{\text{USD}}_t\}$ and $C = |\underline{s}|$ when the carry trade under consideration shorts HKD and summation over the subset $\overline{s} \doteq \{i : i > \frac{\text{HKD}}{\text{USD}}_t\}$ and and $C = |\overline{s}|$ when the carry trade under consideration longs HKD. $\widehat{ERL_t}$ is empirically greater than or equal one in our sample and it takes a higher value when the exchange rate market poses a higher potential loss to the carry trade under consideration. In the current example, $ERL$ takes the value of 2.68% and 2.98% for $n = 3, 4$. We then scale the adjusted interest rate differentials by the perceived exchange rate loss to obtain the effective carry-to-risk ratio

$$ECR_{tenure,t} \doteq \frac{AIRD_{tenure,t}}{\widehat{ERL_t}}$$

As shown in Section 4.1, higher asymmetry in the interest rates for a currency reduce the numerator of $ECR$, hence reducing $ECR$. Higher perceived exchange rate loss increases the denominator of $ECR$, hence reducing $ECR$. When there is no perceived exchange rate loss ($ERL = 1$), there is no reduction of incentive to carry trade ($ECR = AIRD$).

Thus, $ECR$ represents the effective incentive to carry trade HKD-USD interest rate differentials, after taking into account friction in the HKD and USD money markets and risk to carry. The closer the $ECR$ to zero, the more the friction and the risk we consider rationalize the observed HKD-USD interest rate differentials.

In the current example, $ECR$ is -0.55%, -0.42%, -0.25%, -0.18%, -0.12%, -0.11%, -0.11% for $tenure$ = O/N, 01W, 01M, 02M, 03M, 06M, 12M when $n = 3$. When $n = 4$, the corresponding values are -0.49%, -0.38%, -0.23%, -0.17%, -0.11%, -0.10%, and -0.10%. These illustrate that perceived exchange rate loss further rationalizes the observed interest rate differentials. The remaining analysis examines the times series of daily $ECR$ averaged across $n = 3$ and $n = 4$. Figure 5 plots the time series of $IRD$ and that of $ECR$. $ECR$ is visually much closer to zero than $IRD$ is for all tenures. Table 4 reports average absolute values of $ECR$. Comparing to the adjusted interest rates differentials in Panel A of Table 3, the distances of effective carry-to-risk ratios are much closer to zero.

# 5 Robust Bayesian Inference on the Effective Carry-to-risk Ratios

The Jarque-Bera test indicates that the hypothesis of Normal distribution is violated for $ECR$ of all $tenure$. Furthermore, the skewness test shows that $ECR$ is negatively skewed and the kurtosis test shows that $ECR$ is leptokurtic. Therefore, classical statistical inference such as the Student t-test presented in Table 1 is not appropriate for analyzing the effective carry-to-risk ratios and it is also distorted by outliers with negative values.

We perform statistical inference using the Bayesian approach. Using a viable distribution that describes the negative skewness and the heavy left tail in the data generating process of $ECR$, this approach is robust to outliers with negative values. This approach also accounts for parameter uncertainty. In particular, we employ the following Bayesian network

$$ECR_{tenure,\tau}|\mu_{tenure}, \beta_{tenure} \overset{iid}{\sim} \mathcal{G}_l(\mu_{tenure}, \beta_{tenure}), \quad \tau = 1, \ldots, T'$$
$$\mu_{tenure} \sim \mathcal{L}(0, 1)$$
$$\beta_{tenure} \sim \mathcal{T}_h(1, 10)$$

This hierarchy models the joint likelihood of data on $ECR$ given the prior distributions of the latent parameters of the likelihood for each tenure. The data likelihood $\mathcal{G}_l$ is the left Gumbel distribution, a Generalized Extreme Value distribution that exhibits negative skewness and heavy left tail. $T'$ is the number of days in the sample. $\mu_{tenure}$ is the location parameter, which is also the mode of $\mathcal{G}_l$. $\beta_{tenure}$ is the scale parameter that determines the variance of the distribution. The median and the variance of $\mathcal{G}_l$ are given by $\mu + \beta \ln(\ln 2)$ and $\frac{\pi^2\beta^2}{6}$, respectively. The prior $\mathcal{L}$ for $\mu_{tenure}$ is the Laplace distribution around zero. This prior is uninformative, hence, the inference on the location of $\mathcal{G}_l$ solely depends on the data. The prior $\mathcal{T}_h$ for $\beta_{tenure}$ is the half Student T distribution that reflects the belief of low to moderate variance in $\mathcal{G}_l$.

We use the Markov Chain Monte Carlo algorithm with No-U-Turn Sampler (NUTS) (see Hoffman and Gelman (2014) [11]) to update the priors in this network and simulate the posterior distributions of the latent parameters for each tenure. Three Markov chains are utilized with the first 2,000 simulation draws from each chain used for burn in. As the chains become more or less stable, the subsequent 4,000 draws from each chain, i.e., a total of 12,000 draws, are used to examine the posteriors. We summarize the draws by constructing 95% credible intervals on the latent parameters and the implied medians and variances. The 95% credible interval contains 95% of the ordered draws, hence there is 95% probability that a latent parameter or the implied statistic lies in this interval.

Table 5 reports the results. The representative values of $\mu^{[PostQE]}$, i.e., the mode of the effective carry-to-risk ratio since the US interest rate hike on December 17, 2015, across all tenures range from -0.05 to -0.23. The representative values of the implied $Median^{[PostQE]}$ across all tenures range from -0.05 to -0.31. These values are negative but considered to be small in economic terms; the practical return from trading against an observed HKD-USD interest rate differential tends to be just a small fraction of the amount of risk involved in carrying the currencies.

The representative values of $\mu^{[QE]}$ and those of $Median^{[QE]}$ are extremely close to zero. Since the Zero Lower Bound phenomenon pushes both HKD interest rates and USD interest rates towards zero, the HKD-USD interest rate differentials during the period of US quantitative easing tend to be very small. This period also coincides with extremely high Hong Kong aggregate balance or interbank liquidity (see Figure 6). Although the aggregate balance has dropped sharply since the US interest rate hike on December 17, 2015, the average aggregate balance in Post QE is still high relatively to that in Pre QE. If lower interbank liquidity poses additional concern to carry trade, then the contrast in aggregate balance across Pre QE and Post QE can explain why the representative values of $\mu^{[PreQE]}$ and the representative values of $Median^{[PreQE]}$ are higher than those of $\mu^{[PostQE]}$ and those of $Median^{[PostQE]}$, respectively. Fung, Holder, and Tse (2011) [9] examine intraday data and find that the HKD/USD exchange rate market is thin during the night sessions after Hong Kong banking hours. Since carry trade against HKD-USD interest rate differential of short tenure requires frequent trading during night sessions, it is subject to additional concern on implementation shortfall. This can explain why the magnitudes of the representative values of $\mu^{[PostQE]}$ and those of $Median^{[PostQE]}$ increase as tenure decrease.

# 6 Dynamics of the Effective Carry-to-risk Ratios

Figure 7 shows the empirical autocorrelation functions of $ECR$ and Figure 8 shows the empirical partial autocorrelation functions of $ECR$. The autocorrelation for each tenure decays towards zero and it falls within the 95% confidence intervals around zero (the red shaded area) in approximately 40 lags. The partial autocorrelation for each tenure cuts off in one to three lags. These suggest that the dynamics of $ECR$ follow low order autoregressive processes.

We also consider macroeconomic factors in modelling the dynamics of $ECR$. The candidate factors include Hong Kong Aggregate Balance (HKAB), Hong Kong Monetary Base (HKMB), Fed Target Interest Rate (FRate), US Banks' Reserves (USRes), the

TED Spread (TED), the Hang Seng Index (HSI), the S&P 500 index (SP500), the HSI Volatility Index (VHSI), and the CBOE Volatility Index (VIX). Daily observations of these factors are obtained from the Bloomberg terminal. Panel A of Table 6 reports the sample correlations among these factors. As a number of these factors are correlated, we reduce the dimension of the factor space by performing Principal Component Analysis (PCA) on the factors after standardizing them to have zero mean and unit variance. The PCA finds that the first four principal components explain more than 95% of the total variance. Panel B of Table 6 reports the loadings on the factors by each of the four principal components. The first component (PC1) tends to capture Hong Kong and US interbank liquidities with some offset against the Hong Kong and US equity markets. The second component (PC2) tends to capture volatilities in the Hong Kong and US equity markets. The third component (PC3) tends to capture monetary liabilities of the HKMA and perceived credit risk on interbank loans. The fourth component tends to capture banks' reserves in US in addition to monetary liabilities of the HKMA.

We extend the probabilistic model in Section 4.2 to the following

$$ECR_{tenure,\tau}|\mu_{tenure}, \beta_{tenure} \overset{ind}{\sim} \mathcal{G}_l(\mu_{tenure}, \beta_{tenure}), \quad \tau = 1, \ldots, T''$$

$$\mu_{tenure} = \mu^0_{tenure} + \sum_{j=1}^{3} \mu^j_{tenure} ECR_{\tau-i} + \sum_{f=1}^{4} \gamma^f_{tenure} M^f_{\tau-1}$$

$$\mu^0_{tenure}, \mu^j_{tenure}, \gamma^f_{tenure} \overset{iid}{\sim} \mathcal{L}(0,1), \quad j = 1,2,3, \quad f = 1,2,3,4$$

$$\beta_{tenure} = \beta^0_{tenure} + \beta^1_{tenure} ECR_{tenure,\tau-1}$$

$$\beta^i_{tenure} \sim \mathcal{L}(1,1), i = 0,1$$

$T''$ is the number of days in Post QE. The location parameter $\mu$ for a tenure depends on $ECR$ of the same tenure over the three previous trading days in view of the autoregressive structures observed in the empirical autocorrelation functions and the empirical partial autocorrelation functions. The location parameter also depends on the four principal components of macroeconomic factors $M^f$ in the previous trading day. The prior distributions of the latent coefficients in the equation of the location parameter are uninformative Laplace distributions around zero. We further allow for possible heterogeneity by relating the scale parameter $\beta$ for a tenure to $ECR$ of the same tenure in the previous trading day. The prior distributions of the latent coefficients in the equation of the scale parameter are Laplace distributions. The prior for $\beta^0$ centres at one to ensure the scale parameter takes positive values. The prior for $\beta^1$ is uninformative. The Laplace distribution enables some regularization on the latent coefficients and this reduces the influence of idiosyncratic noise in the data. We use the algorithm in Section 4.2 to update the priors in this network and construct 95% credible intervals on the latent coefficients for each tenure.

Table 7 reports the results. The location parameters mainly depend on lagged $ECR$. The principal components of macroeconomic factors in the previous day mostly affect the location parameters for overnight and one-week tenures. Yet, overall, the effects of macroeconomic factors are rather weak. $ECR$ in the previous day affects the scale parameters for all tenures. On the one hand, for tenures longer than one month, higher $ECR$ tends to increase next day's scale parameter, hence, volatility. On the other hand, for overnight tenure, higher $ECR$ tends to decrease next day's scale parameter. The effect of $ECR$ on next day's scale parameter for one week tenure is ambiguous.

# 7 Conclusion

This paper examines the recently observed negative HKD-USD interest rate differentials from a carry trader's point of view. In particular, we analyse the typical market friction and risk involved in carry trading the currency pair. For market friction, we consider the difference in borrowing rate and lending rate of a currency. For risk, we consider carry trader's aversion to the exchange rate loss perceived from prevailing HKD/USD market condition under the Convertibiliy Zone. These considerations largely rationalize the observed interest rate differentials. Robust Bayesian inference shows that the mode and median of the effective carry-to-risk ratios are economically small. Overall, our results are consistent with the Hong Kong Currency Board's intrinsic stabilising mechanism functioning efficiently.

# References


[1] Barro, Robert J., 2006. *Rare Disasters and Asset Markets in the Twentieth Century.* Quarter Journal of Economics 121, 823–866.

[2] Bekaert, Geert, and George Panayotov, 2019. *Good Carry, Bad Carry.* Journal of Financial and Quantitative Analysis, forthcoming.

[3] Brunnermeier, Markus K., and Lasse Heje Pedersen, 2009. *Market Liquidity and Funding Liquidity.* Review of Financial Studies 22, 2201—2238.

[4] Burnside, Craig, Martin Eichenbaum, Isaac Kleshchelski, and Sergio Rebelo, 2011. *Do Peso Problems Explain the Returns to the Carry Trade?.* Review of Financial Studies 24, 853—891.

[5] Dobrynskaya, Victoria, 2014. *Downside Market Risk of Carry Trades.* Review of Finance 18, 1885–1913.

[6] Du, Wenxin, Alexander Tepper, and Adrien Verdelhan, 2018. *Deviations from Covered Interest Rate Parity.* Journal of Finance 73, 915–957.

[7] Fong, Wai-Ming, Giorgio Valente, and Joseph K.W. Fung, 2010. *Covered Interest Arbitrage Profits: The Role of Liquidity and Credit Risk.* Journal of Banking and Finance 34, 1098–1107.

[8] Frenkel, Jacob A., and Richard M. Levich, 1975. *Covered Interest Arbitrage: Unexploited Profits?.* Journal of Political Economy, 83, 325–338.

[9] Fung, Joseph K.W., Mark Holder, and Yiuman Tse, 2011. *The Impact of Monetary Policy Change on Carry Trade and Liquidity in the Foreign Exchange Markets.* Working Paper.

[10] Genberg, Hans, and Cho-Hoi Hui, 2011. *The Credibility of Hong Kong's Link from the Perspective of Modern Financial Theory.* Journal of Money, Credit and Banking 43, 185–206.

[11] Hoffman, Matthew D., and Andrew Gelman, 2014. *The No-U-Turn Sampler: Adaptively Setting Path Lengths in Hamiltonian Monte Carlo.* Journal of Machine Learning Research 30, 1593–1623.

[12] Hong Kong Monetary Authority, 2018 *Linked Exchange Rate System Operations – Mechanism and Theory.* Hong Kong Monetary Authority Quarterly Bulletin, Issue No. 97, December 2018.

[13] Hui, Cho-Hoi, Chi-Fai Lo, and Chi-Hei Liu, 2018. *Exchange Rate Solutions with Currency Crashes.* HKIMR Working Paper No.25.

[14] Kent, Daniel, Robert J. Hodrick, and Zhongjin Lu, 2017. *The Carry Trade: Risks and Drawdowns.* Critical Finance Review 6, 211–262.

[15] Lettau, Martin, Matteo Maggiorid, Michael Weber, 2014. *Conditional Risk Premia in Currency Markets and Other Asset Classes.* Journal of Financial Economics 114, 197–225.

[16] Lustig, Hanno, Nikolai Roussanov, and Adrien Verdelhan, 2011. *Common Risk Factors in Currency Markets*. Review of Financial Studies 24, 3731-–3777.

[17] Maurer, Thomas A., Thuy Duong To, and Ngoc-Khanh Tran, 2017. *Optimal Factor Strategy in FX Markets*. Working Paper.

[18] Miller, Merton, Jayaram Muthuswamy, and Robert E. Whaley, 1994. *Mean Reversion of Standard & Poor's 500 Index Basis Changes: Arbitrage-Induced or Statistical Illusion?*. Journal of Finance 49, 479–513.

[19] Ready, Robert, Nikolai Roussanov, and Colin Ward, 2017. *Commodity Trade and the Carry Trade: A Tale of Two Countries*. Journal of Finance 72, 2629–2684.

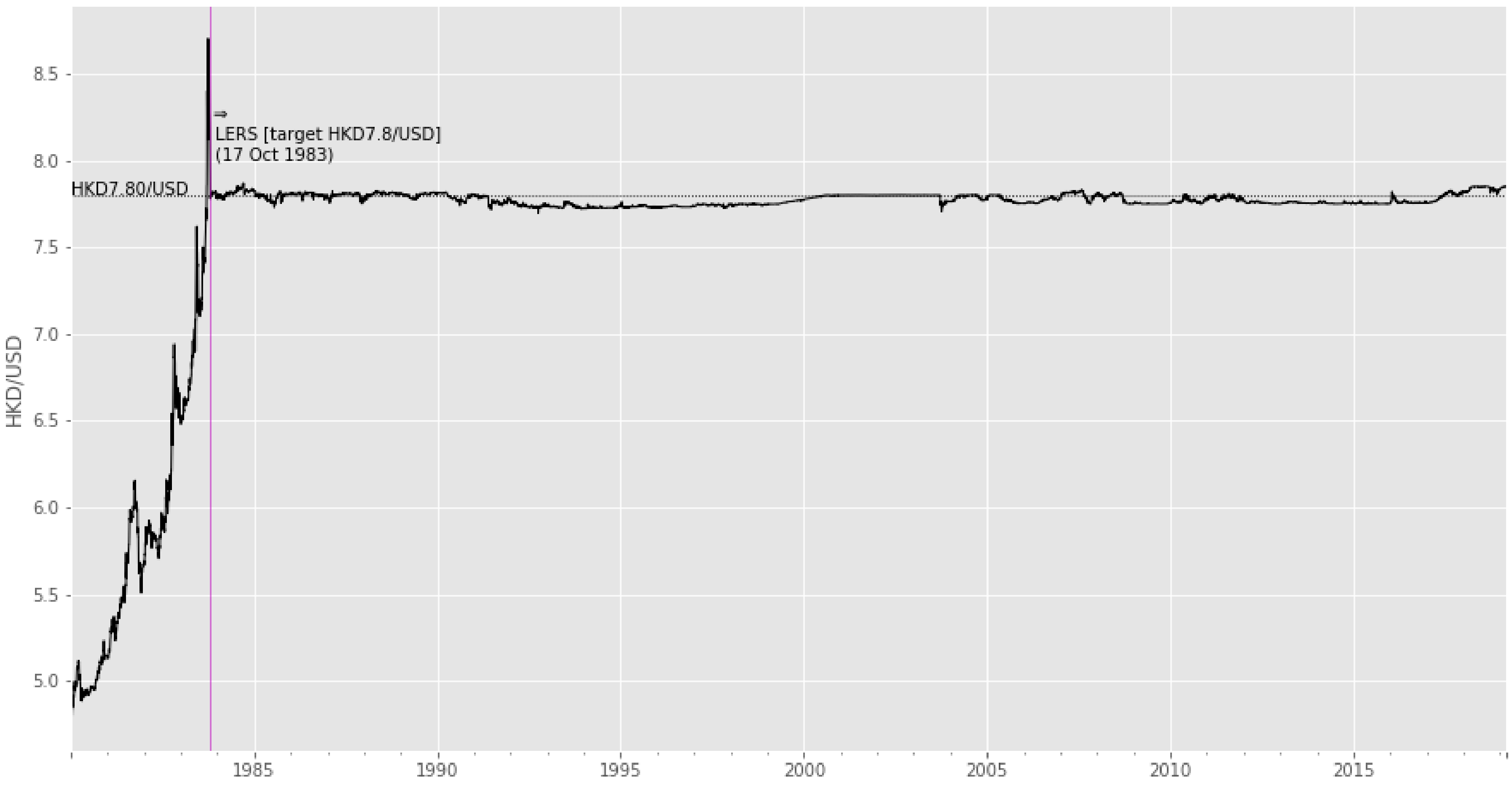


Figure 1: HKD/USD exchange rate since 1980 (Daily ask quotes are retrieved from Bloomberg)

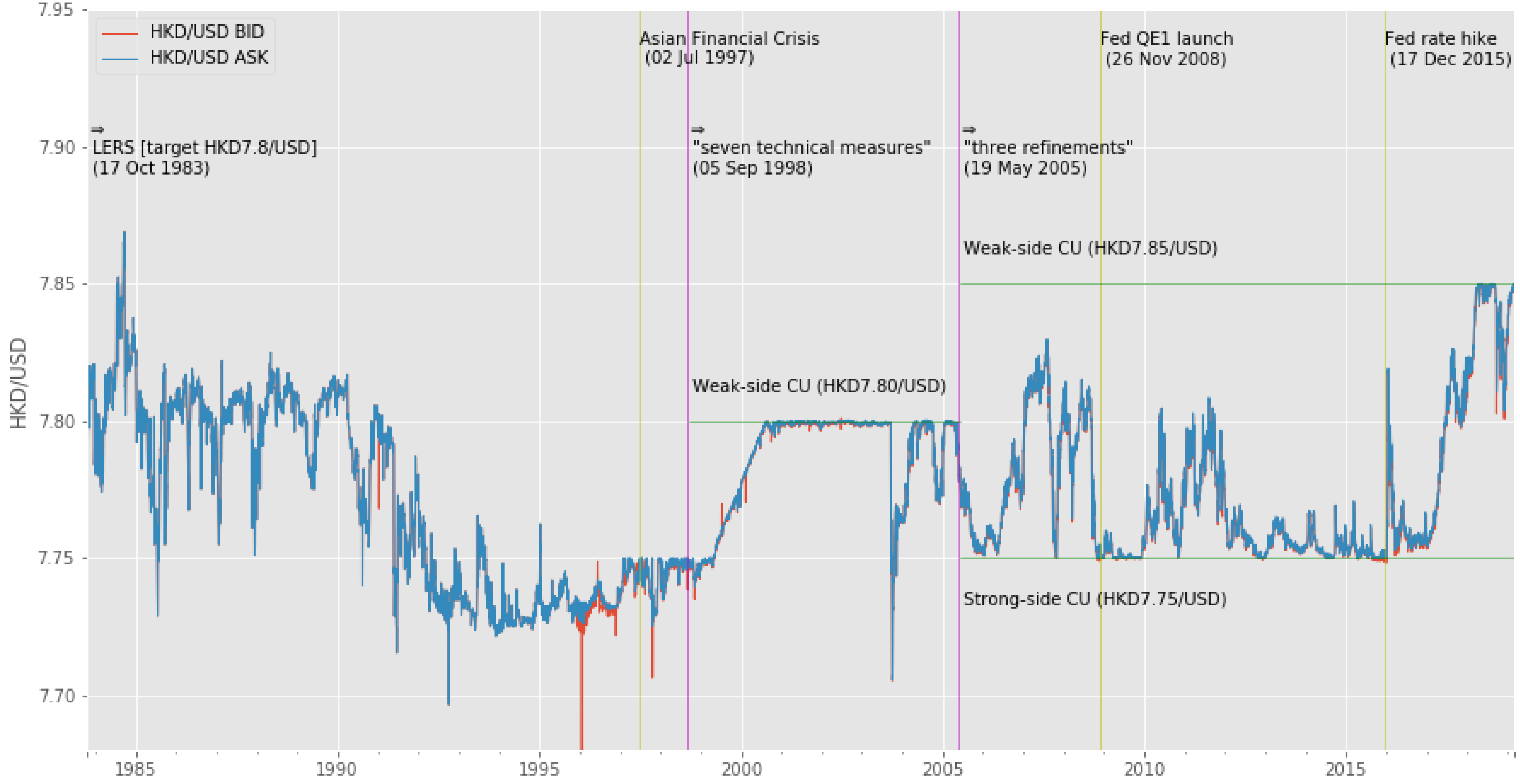


Figure 2: HKD/USD exchange rate dynamics under the LERS (daily bid and ask quotes are retrieved from Bloomberg)

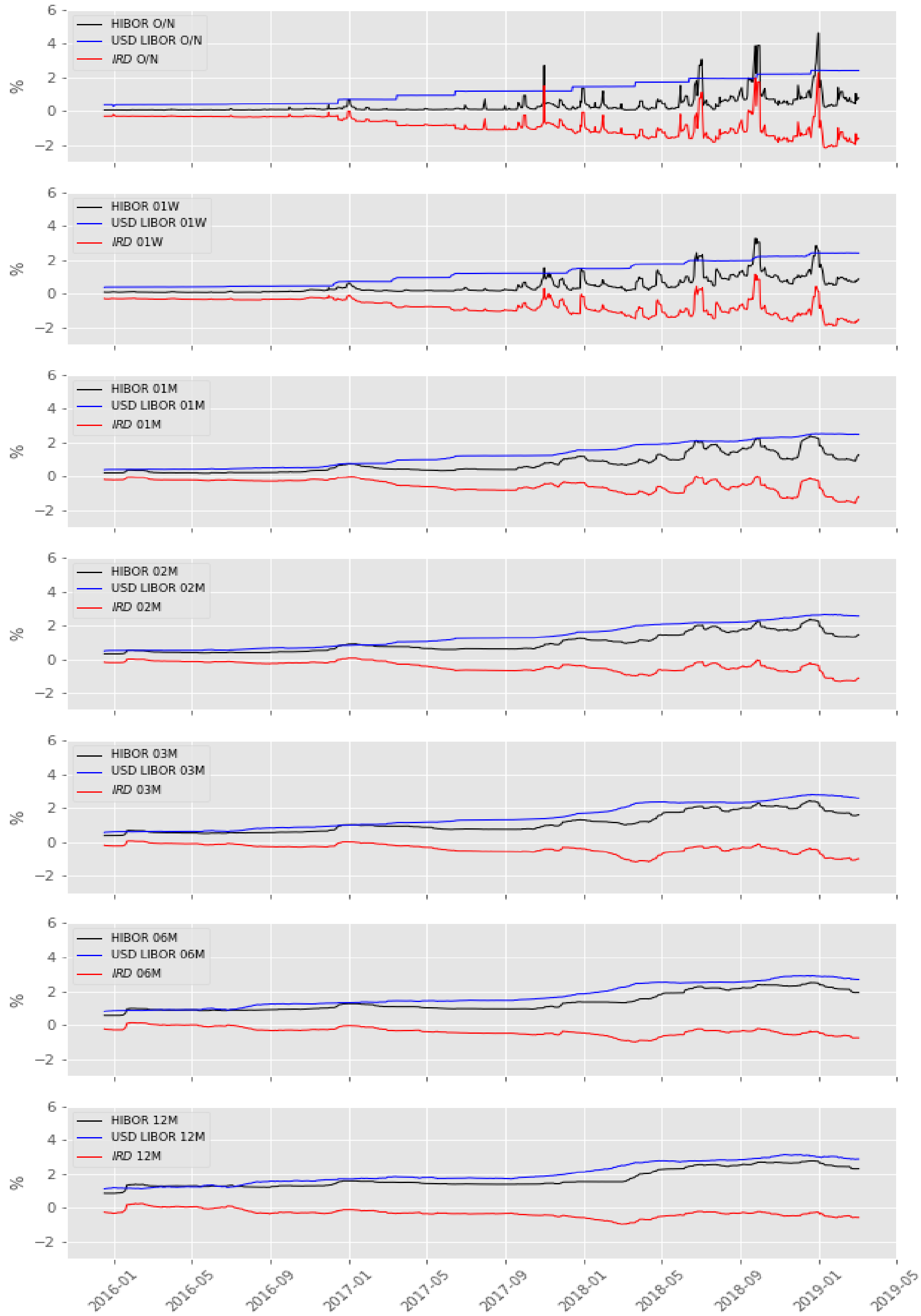


Figure 3: HKD and USD interest rates and nominal differentials

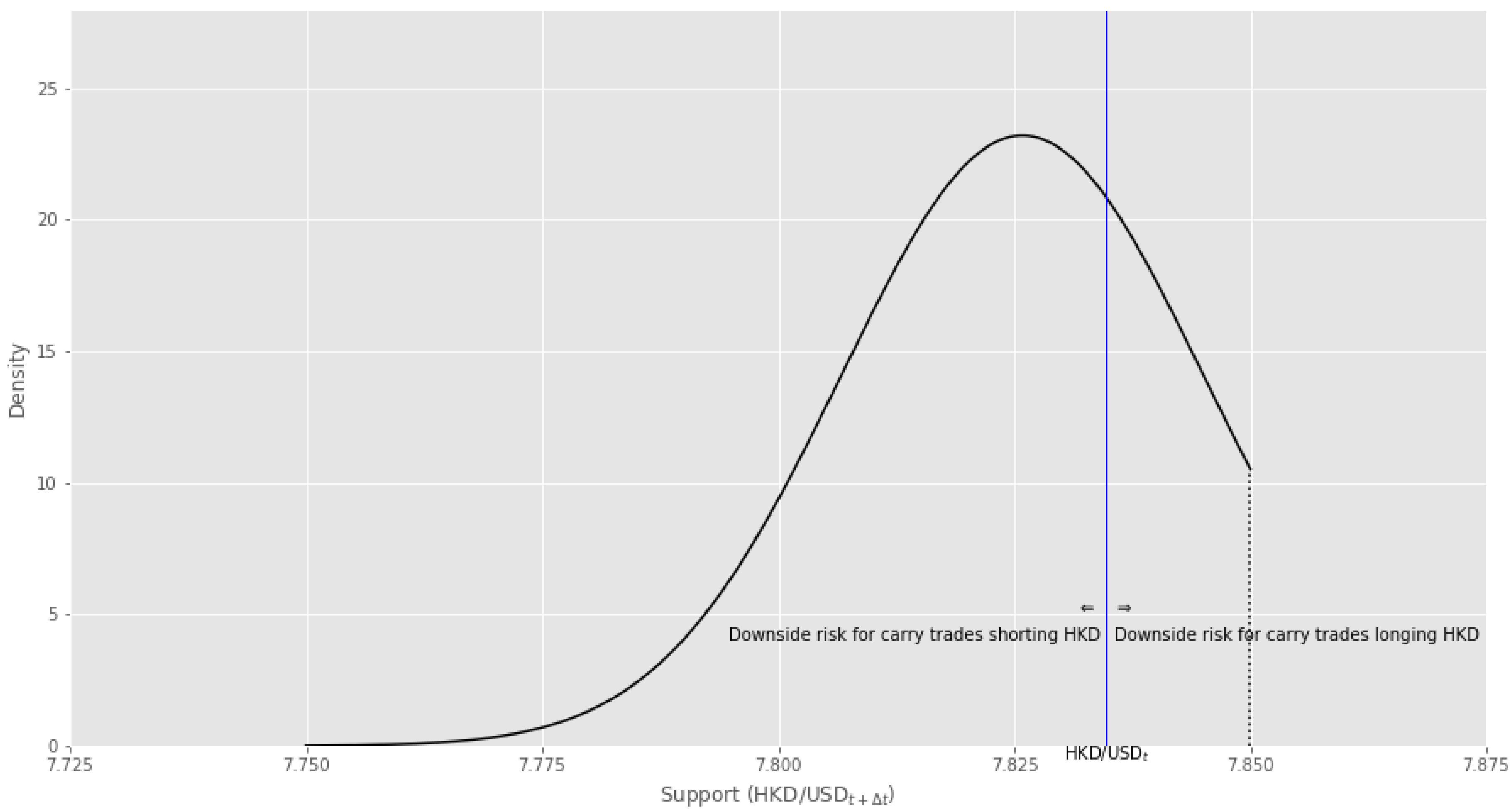


Figure 4: Truncated distribution of HKD/USD with full confidence on the Convertibility Undertakings

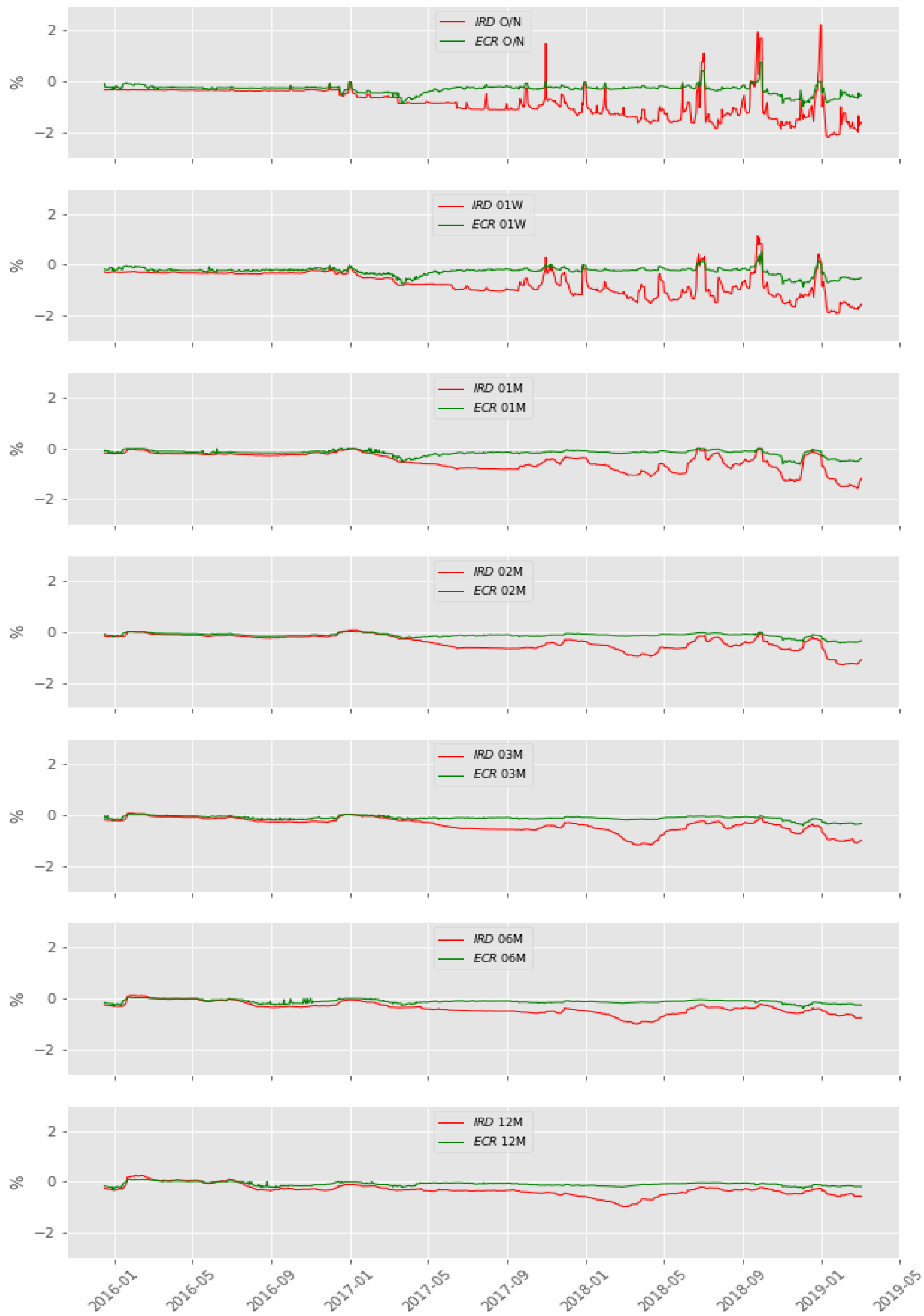


Figure 5: Nominal HKD-USD interest rate differentials vs. effective carry-to-risk ratio

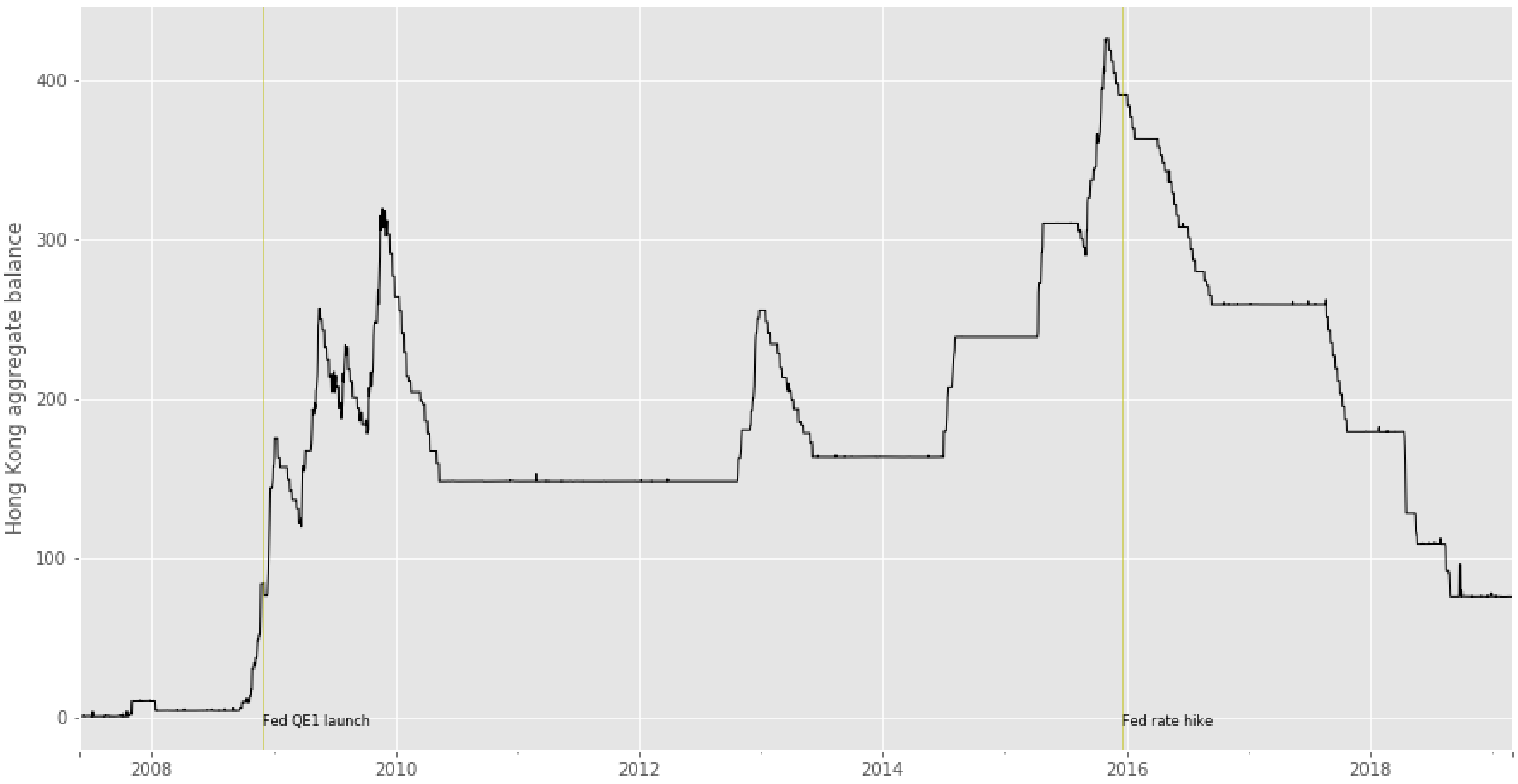


Figure 6: Hong Kong aggregate balance

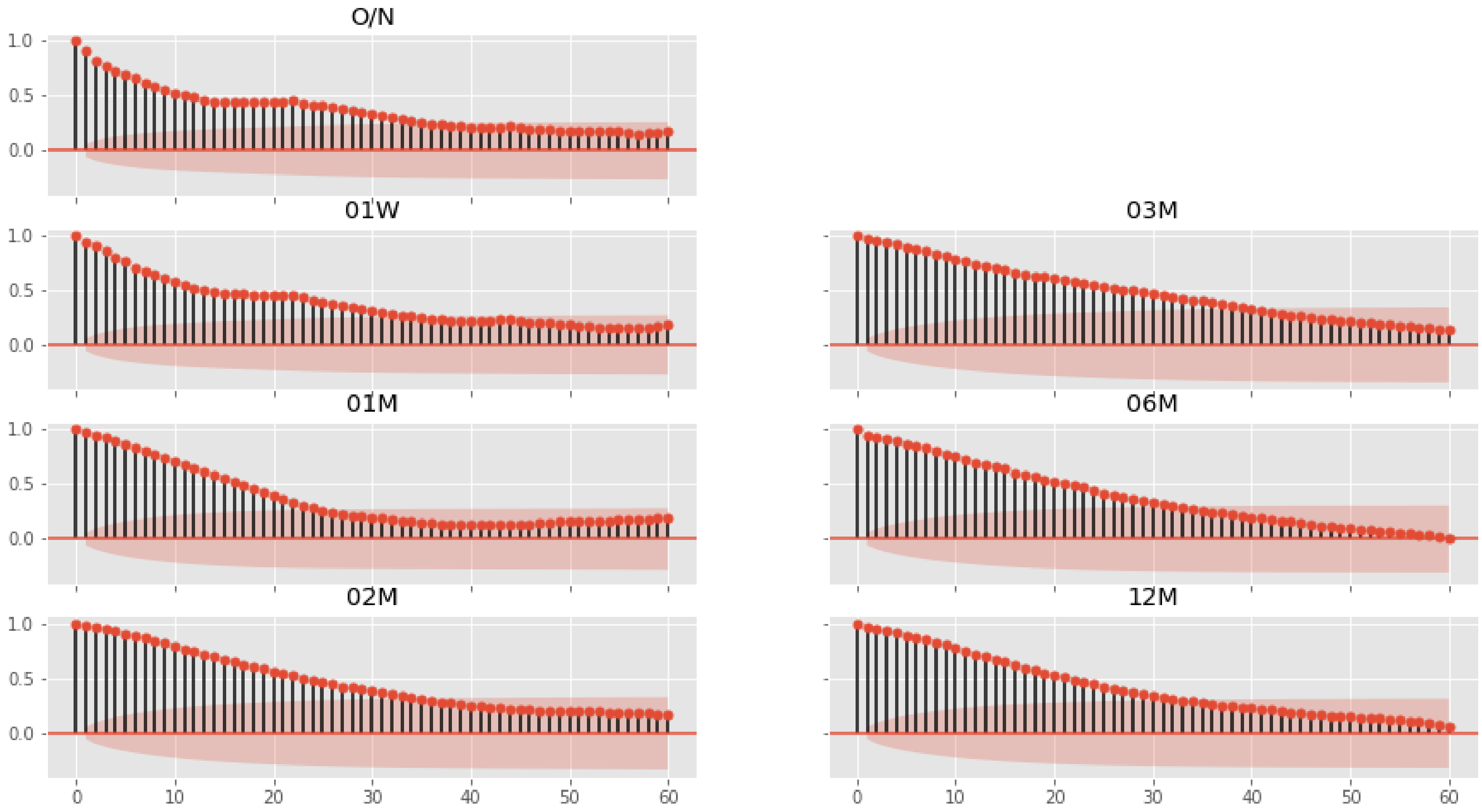


Figure 7: Autocorrelations of effective carry-to-risk ratios since normalization

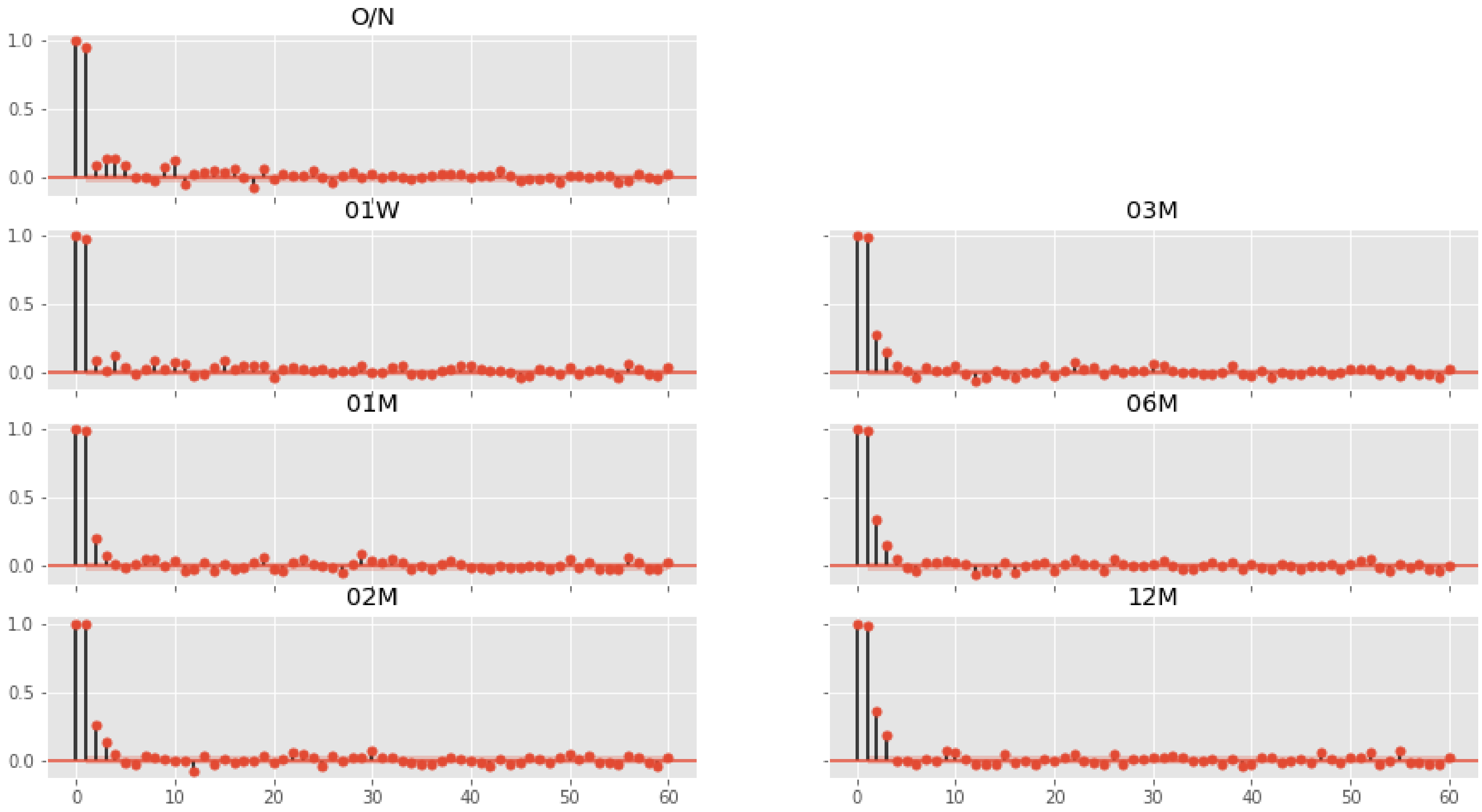


Figure 8: Partial autocorrelations of effective carry-to-risk ratios since normalization

Table 1: Nominal HKD-USD interest rate differentials

N is the number of observations, Avg is the sample mean, t-stat is the Student's t statistic. Post QE refers to period after the first Fed rate hike, i.e., since 17 December 2015. This period is the main focus of our analysis. QE refers to the quantitative easing period. Pre QE refers to the period before quantitative easing, i.e., before 26 November 2008. All refers to the period from 03 January 2006 to 04 Mar 2019.

Panel A: Raw differentials (%)

| | | | Post QE | | | QE | | | Pre QE | | | All |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | Avg | t-stat | N | Avg | t-stat | N | Avg | t-stat | N | Avg | t-stat |
| O/N | 838 | -0.82 | -41.64 | 1841 | -0.09 | -53.65 | 391 | -1.23 | -28.22 | 3070 | -0.44 | -39.33 |
| 01W | 838 | -0.71 | -44.35 | 1841 | -0.09 | -45.05 | 391 | -1.02 | -29.14 | 3070 | -0.38 | -41.77 |
| 01M | 838 | -0.52 | -41.60 | 1841 | -0.02 | -7.83 | 391 | -0.77 | -29.90 | 3070 | -0.25 | -34.67 |
| 02M | 838 | -0.42 | -39.74 | 1841 | -0.02 | -4.96 | 391 | -0.71 | -33.45 | 3070 | -0.21 | -33.47 |
| 03M | 838 | -0.39 | -38.85 | 1841 | -0.02 | -4.93 | 391 | -0.69 | -36.85 | 3070 | -0.20 | -33.52 |
| 06M | 838 | -0.38 | -45.82 | 1841 | -0.06 | -11.37 | 391 | -0.64 | -43.79 | 3070 | -0.22 | -38.60 |
| 12M | 838 | -0.32 | -40.22 | 1841 | -0.06 | -10.69 | 391 | -0.46 | -41.63 | 3070 | -0.18 | -35.53 |

Panel B: Average absolute nominal differentials (%)

| | Post QE | QE | Pre QE | All |
|---|---|---|---|---|
| O/N | 0.87 | 0.10 | 1.24 | 0.45 |
| 01W | 0.74 | 0.10 | 1.10 | 0.40 |
| 01M | 0.52 | 0.08 | 0.83 | 0.29 |
| 02M | 0.42 | 0.11 | 0.73 | 0.27 |
| 03M | 0.39 | 0.12 | 0.70 | 0.27 |
| 06M | 0.38 | 0.18 | 0.65 | 0.29 |
| 12M | 0.34 | 0.22 | 0.47 | 0.28 |

Panel C: Count of positive nominal differentials

| | Post QE | QE | Pre QE | All |
|---|---|---|---|---|
| O/N | 16 | 34 | 18 | 68 |
| 01W | 19 | 219 | 31 | 269 |
| 01M | 2 | 1104 | 38 | 1144 |
| 02M | 29 | 1087 | 30 | 1146 |
| 03M | 38 | 931 | 21 | 990 |
| 06M | 36 | 787 | 15 | 838 |
| 12M | 104 | 767 | 10 | 881 |

Panel D: Count of negative nominal differentials

| | Post QE | QE | Pre QE | All |
|---|---|---|---|---|
| O/N | 822 | 1807 | 735 | 3364 |
| 01W | 819 | 1622 | 723 | 3164 |
| 01M | 836 | 737 | 718 | 2291 |
| 02M | 809 | 754 | 726 | 2289 |
| 03M | 800 | 909 | 735 | 2444 |
| 06M | 802 | 1054 | 741 | 2597 |
| 12M | 734 | 1074 | 746 | 2554 |

Table 2: Interest rate ask quotes to bid quotes

| Panel A: Average HKD ask/bid | | | | |
|---|---|---|---|---|
| | Post QE | QE | Pre QE | All |
| O/N | 1.41 | 2.25 | 1.65 | 1.94 |
| 01W | 1.30 | 1.69 | 1.06 | 1.50 |
| 01M | 1.12 | 1.42 | 1.02 | 1.29 |
| 02M | 1.08 | 1.37 | 1.03 | 1.25 |
| 03M | 1.03 | 1.18 | 1.01 | 1.12 |
| 06M | 1.06 | 1.21 | 1.02 | 1.14 |
| 12M | 1.02 | 1.05 | 1.01 | 1.04 |
| Panel B: Average USD ask/bid | | | | |
| | Post QE | QE | Pre QE | All |
| O/N | 1.00 | 1.08 | 1.05 | 1.05 |
| 01W | 1.04 | 1.06 | 1.03 | 1.05 |
| 01M | 1.02 | 1.07 | 1.01 | 1.05 |
| 02M | 1.01 | 1.09 | 1.00 | 1.06 |
| 03M | 1.03 | 1.12 | 1.01 | 1.08 |
| 06M | 1.03 | 1.15 | 1.01 | 1.10 |
| 12M | 1.03 | 1.11 | 1.00 | 1.07 |

Table 3: Adjusted HKD-USD interest rate differentials

Panel A: Average absolute adjusted differentials (%)

| | Post QE | QE | Pre QE | All |
|---|---|---|---|---|
| O/N | 0.85 | 0.08 | 1.11 | 0.42 |
| 01W | 0.70 | 0.09 | 1.02 | 0.37 |
| 01M | 0.50 | 0.05 | 0.81 | 0.27 |
| 02M | 0.41 | 0.08 | 0.72 | 0.25 |
| 03M | 0.36 | 0.09 | 0.67 | 0.24 |
| 06M | 0.35 | 0.11 | 0.62 | 0.24 |
| 12M | 0.29 | 0.16 | 0.45 | 0.23 |

Panel B: Count of positive adjusted differentials

| | Post QE | QE | Pre QE | All |
|---|---|---|---|---|
| O/N | 7 | 5 | 1 | 13 |
| 01W | 16 | 11 | 24 | 51 |
| 01M | 1 | 602 | 34 | 637 |
| 02M | 11 | 627 | 18 | 656 |
| 03M | 34 | 805 | 17 | 856 |
| 06M | 27 | 576 | 7 | 610 |
| 12M | 97 | 667 | 6 | 770 |

Panel C: Count of negative adjusted differentials

| | Post QE | QE | Pre QE | All |
|---|---|---|---|---|
| O/N | 823 | 1801 | 368 | 2992 |
| 01W | 819 | 1580 | 351 | 2750 |
| 01M | 832 | 624 | 345 | 1801 |
| 02M | 797 | 629 | 361 | 1787 |
| 03M | 780 | 665 | 369 | 1814 |
| 06M | 733 | 821 | 376 | 1930 |
| 12M | 716 | 833 | 380 | 1929 |

Table 4: Average absolute effective carry-to-risk ratios

| | Post QE | QE | Pre QE | All |
|---|---|---|---|---|
| O/N | 0.31 | 0.06 | 0.50 | 0.18 |
| 01W | 0.26 | 0.06 | 0.45 | 0.16 |
| 01M | 0.18 | 0.04 | 0.34 | 0.11 |
| 02M | 0.14 | 0.05 | 0.30 | 0.11 |
| 03M | 0.12 | 0.06 | 0.28 | 0.11 |
| 06M | 0.12 | 0.08 | 0.27 | 0.11 |
| 12M | 0.10 | 0.11 | 0.20 | 0.12 |

Table 5: 95% credible intervals of latent parameters and the implied statistics of effective carry-to-risk ratios

Stdev is the standard deviation.

Panel A: Distribution parameters

| | $\mu^{PostQE}$ | $\mu^{QE}$ | $\mu^{PostQE}$ | $\mu^{All}$ | $\beta^{PostQE}$ | $\beta^{QE}$ | $\beta^{PostQE}$ | $\beta^{All}$ |
|---|---|---|---|---|---|---|---|---|
| O/N | [-0.23, -0.20] | [-0.04, -0.04] | [-0.34, -0.28] | [-0.10, -0.09] | [0.23, 0.25] | [0.03, 0.03] | [0.26, 0.30] | [0.17, 0.18] |
| 01W | [-0.19, -0.16] | [-0.04, -0.03] | [-0.31, -0.25] | [-0.09, -0.08] | [0.17, 0.18] | [0.04, 0.04] | [0.26, 0.30] | [0.14, 0.14] |
| 01M | [-0.13, -0.12] | [-0.01, -0.00] | [-0.24, -0.19] | [-0.05, -0.04] | [0.08, 0.09] | [0.03, 0.04] | [0.20, 0.23] | [0.09, 0.10] |
| 02M | [-0.10, -0.09] | [ 0.00, 0.01] | [-0.23, -0.19] | [-0.04, -0.03] | [0.07, 0.07] | [0.05, 0.05] | [0.15, 0.18] | [0.09, 0.09] |
| 03M | [-0.09, -0.08] | [ 0.02, 0.02] | [-0.22, -0.19] | [-0.02, -0.02] | [0.06, 0.07] | [0.06, 0.06] | [0.14, 0.16] | [0.09, 0.10] |
| 06M | [-0.08, -0.07] | [ 0.02, 0.02] | [-0.22, -0.19] | [-0.03, -0.02] | [0.07, 0.07] | [0.08, 0.09] | [0.11, 0.13] | [0.10, 0.11] |
| 12M | [-0.06, -0.05] | [ 0.05, 0.06] | [-0.16, -0.14] | [ 0.01, 0.02] | [0.07, 0.08] | [0.12, 0.13] | [0.08, 0.10] | [0.13, 0.14] |

Panel B: Distribution statistics

| | $\text{Median}^{PostQE}$ | $\text{Median}^{QE}$ | $\text{Median}^{PostQE}$ | $\text{Median}^{All}$ | $\text{Stdev}^{PostQE}$ | $\text{Stdev}^{QE}$ | $\text{Stdev}^{PostQE}$ | $\text{Stdev}^{All}$ |
|---|---|---|---|---|---|---|---|---|
| O/N | [-0.31, -0.29] | [-0.05, -0.05] | [-0.44, -0.39] | [-0.16, -0.16] | [0.09, 0.10] | [0.00, 0.00] | [0.11, 0.15] | [0.22, 0.22] |
| 01W | [-0.25, -0.23] | [-0.05, -0.04] | [-0.41, -0.36] | [-0.14, -0.13] | [0.05, 0.06] | [0.00, 0.00] | [0.11, 0.15] | [0.17, 0.17] |
| 01M | [-0.16, -0.15] | [-0.02, -0.01] | [-0.31, -0.27] | [-0.08, -0.08] | [0.01, 0.01] | [0.00, 0.00] | [0.06, 0.09] | [0.10, 0.14] |
| 02M | [-0.13, -0.12] | [-0.02, -0.01] | [-0.28, -0.26] | [-0.07, -0.06] | [0.01, 0.01] | [0.00, 0.00] | [0.04, 0.05] | [0.10, 0.10] |
| 03M | [-0.11, -0.11] | [-0.00, -0.00] | [-0.27, -0.25] | [-0.06, -0.05] | [0.01, 0.01] | [0.01, 0.01] | [0.03, 0.04] | [0.10, 0.14] |
| 06M | [-0.11, -0.10] | [-0.01, -0.01] | [-0.26, -0.24] | [-0.07, -0.06] | [0.01, 0.01] | [0.01, 0.01] | [0.02, 0.03] | [0.14, 0.14] |
| 12M | [-0.09, -0.08] | [ 0.01, 0.01] | [-0.19, -0.18] | [-0.04, -0.03] | [0.01, 0.01] | [0.02, 0.03] | [0.01, 0.02] | [0.17, 0.17] |

Table 6: Correlations and principal components of macroeconomic factors

Panel A: Correlations

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| (1) HKAB | 1.00 | -0.33 | -0.94 | 0.84 | 0.25 | -0.74 | -0.91 | 0.02 |
| (2) HKMB | -0.33 | 1.00 | 0.34 | -0.04 | -0.10 | 0.78 | 0.56 | -0.33 |
| (3) FRate | -0.94 | 0.34 | 1.00 | -0.82 | -0.35 | 0.72 | 0.88 | 0.08 |
| (4) UECRes | 0.84 | -0.04 | -0.82 | 1.00 | 0.06 | -0.40 | -0.64 | -0.08 |
| (5) TED | 0.25 | -0.10 | -0.35 | 0.06 | 1.00 | -0.23 | -0.38 | 0.03 |
| (6) HSI | -0.74 | 0.78 | 0.72 | -0.40 | -0.23 | 1.00 | 0.89 | -0.28 |
| (7) SP500 | -0.91 | 0.56 | 0.88 | -0.64 | -0.38 | 0.89 | 1.00 | -0.19 |
| (8) VHSI | 0.02 | -0.33 | 0.08 | -0.08 | 0.03 | -0.28 | -0.19 | 1.00 |
| (9) VIX | 0.07 | -0.18 | 0.18 | -0.21 | 0.12 | -0.18 | -0.15 | 0.83 |

Panel B: Loadings of first four principal components

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| PC1 | 0.44 | -0.27 | -0.44 | 0.34 | 0.17 | -0.42 | -0.46 | 0.07 | 0.02 |
| PC2 | -0.14 | -0.30 | 0.20 | -0.29 | 0.05 | -0.18 | -0.05 | 0.60 | 0.61 |
| PC3 | 0.00 | 0.41 | -0.08 | -0.02 | 0.86 | 0.21 | -0.04 | 0.01 | 0.19 |
| PC4 | 0.20 | 0.53 | -0.06 | 0.49 | -0.38 | 0.24 | 0.02 | 0.35 | 0.33 |

Table 7: Simulated 95% credible intervals of latent parameters of the dynamics of effective carry-to-risk ratios

| $ECR$ | O/N | 01W | 01M | 02M | 03M | 06M | 12M |
|---|---|---|---|---|---|---|---|
| $\mu_0$ | [ 0.03, 0.06] | [ 0.03, 0.05] | [ 0.01, -0.00] | [ -0.00, 0.00] | [-0.00, -0.00] | [-0.01, -0.01] | [-0.01, -0.00] |
| $\mu_1$ | [ 1.09, 1.28] | [ 0.47, 0.62] | [ 0.57, 0.73] | [ 0.86, 0.98] | [ 0.71, 0.85] | [ 0.61, 0.75] | [ 0.47, 0.66] |
| $\mu_2$ | [-0.28, -0.02] | [ 0.38, 0.64] | [ 0.03, 0.21] | [ 0.06, 0.23] | [ 0.17, 0.35] | [-0.19, -0.01] | [ 0.42, 0.66] |
| $\mu_3$ | [-0.10, 0.07] | [-0.14, 0.10] | [ 0.10, 0.22] | [-0.17, -0.05] | [-0.20, -0.09] | [ 0.14, 0.27] | [-0.40, -0.19] |
| $\gamma_1$ | [ 0.01, 0.02] | [ 0.01, 0.01] | [-0.00, -0.00] | [-0.00, 0.00] | [-0.00, -0.00] | [-0.01, -0.00] | [-0.01, -0.00] |
| $\gamma_2$ | [-0.02, -0.01] | [-0.02, -0.01] | [-0.00, 0.00] | [-0.00, -0.00] | [-0.00, 0.00] | [-0.01, -0.00] | [-0.01, -0.00] |
| $\gamma_3$ | [ 0.01, 0.02] | [ 0.00, 0.01] | [-0.00, 0.00] | [ 0.00, 0.00] | [-0.00, -0.00] | [-0.01, -0.00] | [-0.00, 0.00] |
| $\gamma_4$ | [ 0.02, 0.03] | [ 0.01, 0.02] | [ 0.00, 0.01] | [ 0.00, 0.00] | [ 0.00, 0.00] | [ 0.00, 0.01] | [-0.00, 0.00] |
| $\beta_0$ | [ 0.10, 0.11] | [ 0.07, 0.08] | [ 0.01, 0.02] | [ 0.01, 0.01] | [ 0.01, 0.01] | [ 0.01, 0.01] | [ 0.02, 0.02] |
| $\beta_1$ | [-0.05, -0.02] | [-0.01, 0.03] | [ 0.10, 0.13] | [ 0.06, 0.08] | [ 0.07, 0.10] | [ 0.13, 0.15] | [ 0.07, 0.09] |