Market Efficiency in Foreign Exchange Market

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Abstract

The study examines foreign exchange market overreaction for various combinations of formation and testing periods over 30 years. We find, first, reversal is significant for longer test periods and longer formation periods. Second, we see no evidence of consistent momentum or reversal during the entire sample period, thus the results of overreaction studies should be sensitive to sample period. Third, we observe losers' outperformance for most of formation and test periods combinations except for short-term when sport rates are used to construct portfolios. We observe the evidence of overreaction become stronger with longer formation and test period.

Key Words: Overreaction, Reversal, Momentum, Foreign Exchange Rate, Efficient Market Hypothesis

JEL Classification: F31, G14, G15

1. Introduction

After De Bondt and Thaler (1985) report investors' overreaction in equity markets, a number of researchers examined market efficiency in equity markets.[1] Foreign exchange markets are more continuous and liquid than equity markets, and participants such as governments, multinational companies, banks, etc. are large and well informed. These characteristics should contribute to the foreign exchange market efficiency, but researchers reported mixed evidence about foreign exchange market efficiency. Dornbush (1976) suggests a theoretical explanation about foreign exchange market overreaction and Bilson (1981) explained the market overreaction using speculator's behavior. Park (1984) found USD/CAD is consistent with market efficiency theory if term structure is considered. MacDonald and Taylor (1989) examined the market efficiency based on cointegration analysis. Anusakumar and Abdullar (2014) report foreign exchange market overreaction for 21 currencies. Dao et. al. (2016) show overreaction weekend gap for most currencies. Caporale et al. (2018) and Caporale et al. (2019) report the presence of overreactions and inertia anomaly which is similar to momentum in major currency pairs. Barroso and Santa-Clara (2015) show that carry, momentum, and reversal strategies contributed to their optimal currency portfolio performance. Raza et al. (2014) argue that momentum strategy dominant in short-term and the performance of momentum strategy depends on formation and testing period. In addition, some researchers find stronger market inefficiency in minor currencies. (e.g., Larson et. al., 2001; Parikakis and Syriopoulos, 2008.) Menkhoff et. al. (2012) find that minor currencies

[1] Conrad and Kaul (1993) point out upward bias of the results of De Bondt and Thaler (1985), and Baytas and Cakci (1999) find mixed performance of contrarian strategies. Wang and Yu (2004) find significant return of contrarian strategies in US futures markets.

with high transaction costs contribute to the momentum portfolio returns. Baek et al. (2001) discovered that yield curve risk factors contribute to the carry trade gains.

In this paper, we investigate foreign exchange market overreaction for various combinations of formation and testing periods using 23 currencies, including Euro, over 30 years period. In particular, we examine long-term formation and testing periods up to 36 months to see the long-term overreaction. Prior studies report market overreaction using a less than 12-month test period (e.g., Menkhoff et al., 2012; Raza et al., 2014). In addition, we consider other important aspect of overreaction such as transaction costs, excess return vs. nominal return, temporal changes of phenomenon. Our empirical study finds a few interesting results. First, we find reversal is significant for longer test periods and longer formation periods. Consistent with prior studies, we find momentum in short-term and reversal in long-term. Second, we do not observe any combination of formation and test period that shows consistent momentum or reversal during the entire sample period, thus the results of overreaction studies should vary by sample period which is consistent with Ligeralde (1994). Third, it is surprising to observe losers' outperformance for most of formation and test periods combinations except for three-month formation period when portfolios are formed based on spot returns.

2. Data & Methodology

This study extracts end-of-month spot exchange rates and interest rates between January 1986 and April 2017 from International Financial Statistics (IFS). The sample consists of currencies from the following countries: Austria, Belgium, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal, Spain, Australia, Canada, Denmark, Japan, Mexico, New Zealand, Singapore, South

Africa, Sweden, Switzerland, United Kingdom, United States, and Euro. There are 22 currencies before 1999, and 13 currencies from January 1999 due to the introduction of Euro. The study uses USD as a measurement currency and all excess returns are converted in USD percentage returns following Daniel (2017).

Following De Bondt and Thaler (1985), we test overreaction with various combinations of formation and test periods; 3-, 6-, 9-, 12-, 15-, 18-, 21-, 24-, 27-, 30-, 33- and 36-month. Each winner (loser) portfolio consists of top (bottom) 20% of all currency pairs based on the cumulative returns during the formation periods. There are 231 currency pairs before the introduction of Euro and 78 pairs after the Euro, that is top (bottom) 46 pairs before the Euro and 16 top (bottom) pairs after the Euro are winner (loser). Portfolios are equally weighted and reconstructed every month with round-trip transaction cost of 2%.[2] Cumulative returns (*cr*) during the formation periods are computed as below from currency excess return(*cer*) from the exchange rate swap,

$$cr_t^{i,j} = \prod_{t=1}^{T}(1 + cer_t^{i,j}) \tag{1}$$

$$cer_t^{i,j} = R_t^{i,j}\left(1 + r_{t-1}^{i}\right) + \left(r_{t-1}^{i} - r_{t-1}^{j}\right) \tag{2}$$

$$R_t^{i,j} = \frac{S_t^{i,j} - S_{t-1}^{i,j}}{S_{t-1}^{i,j}} \tag{3}$$

where, $R_t^{i,j}$ represents spot exchange rate return, $S_t^{i,j}$ is the price of one unit of currency *i* in terms of currency *j* at time *t*, r_t^i and r_t^j are interest rates of currency *i* and *j* at time *t*, respectively.

[2] Round trip 2% transaction cost is larger than estimate in the literature such as Aliber et. al (2000), Kuang et. al. (2014) and Raza et. al. (2014).

We hypothesize that overreaction in foreign exchange market exists.

$$H_0: apr_L - apr_W \leq 0$$

$$H_1: apr_L - apr_W > 0$$

where,

$$apr_{L,t} = \sum_{n=1}^{N1} \frac{cer_t^n}{N}, \; apr_{W,t} = \sum_{n=1}^{N2} \frac{cer_t^n}{N} \quad (4)$$

$$apr_L = \sum_{n=1}^{T} \frac{apr_{L,t}}{T}, \; apr_W = \sum_{n=1}^{T} \frac{apr_{W,t}}{T} \quad (5)$$

N is number of top (bottom) 20% of the currency pairs based on a ranking of the excess returns, *T* is the length of test period, *apr* represents average portfolio return, and subscript *W* and *L* represent winner and loser portfolios, respectively. To test the hypotheses, we subtract winner portfolio returns from loser portfolio returns each period, $r_t = apr_{L,t} - apr_{W,t}$.

For a portfolio with 6-month formation and 12-month test period (*f6 t12*), first formation period starts from January 1986 to June 1986, and all 231 currency pairs are ranked by the cumulative returns (*cr*) from the highest to lowest. The currency pairs in top 20% of cumulative returns are winner portfolio and pairs in the bottom 20% cumulative returns are loser portfolio for the first test period. The first test period for 12-month starts from July 1986 to June 1987 and monthly returns for each winner and loser portfolios are recorded. Second formation period starts from 6-month before the second test period, that is January 1987 to June 1987, and test period from July 1987 to June 1988. The returns for loser and winner portfolios from 2nd test period are recorded after the first test period. Construction of winner and loser portfolios follow this procedure for each formation and test periods until April 2017.

If long-term foreign exchange market overreaction exists, we expect to find the significant momentum followed by reversal. To save space, we report the results of 6-, 12-, 24-, and 36-month of test periods for each 6-, 12-, 24-, and 36-month of formation periods, total of 16 combinations. Additional statistical tests for overreaction effect along with risk assessment are reported.

3. Empirical results

Table 1 reports excess return difference between loser and winner portfolios for all formation and test periods including 2% assumed transaction cost. The result confirms overreaction hypothesis for all portfolios but short-term formation and test periods. These short-term periods (e.g., *f3 t3* and *f3 t6*) show winner portfolios outperform loser portfolios implying momentum strategy generates positive return. This is consistent with Menkhoff et. al. (2012) that reports stronger momentum effect for short-term test periods. Jegadeesh and Titman (2001) suggest the momentum return is associated with slow information diffusion causing delayed overreaction that will be eventually reversed and this is confirmed in the increasing averages of differences (last column and last row).

[Table 1]

We form quintile portfolios from the currency pairs based on a ranking of the excess returns. Table 2 reports the result of 6-, 12-, 24-, 36-month formation and test period and loser minus winner portfolio on the right column. As it is seen in the table, most of the formation and test periods show

returns in decreasing pattern from loser to winner supporting that overreaction effect in the forex market is significant.[3]

[Table 2]

[Table 3]

In Table 3, we examine 5-year rolling average differences between loser and winner portfolios. Overreaction is often observed in particular periods and it is not persistent over the entire sample period. It is notable to observe overreaction effect between 2008 and 2012 when the global economy was in recession and interest rates were record low. In the absence of the benefit from interest rate differential, the exchange rate market might have acted like equity markets that show strong overreaction effect (De Bondt and Thaler, 1985; Baytas and Cakci, 1999). In the table, negative return difference is observed for short-term formation and test periods in general that is consistent with the result in Table 1. Though we do not tabulate here, we find that there is overreaction effect clustering in 30- and 36-month test periods for all formation periods, and in all test periods for formation periods longer than 12-month.

We investigate risk factors contribute to differences in average returns between loser and winner portfolios in different sample periods. We construct a regression model following Clarida et al. (2009) and use the U.S. equity return volatility (*VIX*), 10-year U.S. Treasury yield (*Level*) and the difference between 10-year and 2-year U.S. treasury yield (*Slope*) as key risk factors.

[3] Though not reported, we test entire formation and test periods for robustness and this decreasing pattern is shown in most of the periods with overreaction effect in the experiment.

Prior studies report the loadings of major risk factors change before and after financial crisis in 2008 (e.g., Clarida et al., 2009; Raza et al., 2014). Euro's introduction may have contributed to the changes in risk factors' loadings as well (Menkhoff et al., 2012). Table 4 reports the regression for three sub periods around Euro's introduction and the financial crisis with year fixed effect based on Hausman test with the null of difference in coefficients not systematic. Regression analyses cover the period between January 1990 and April 2017.

$$r_t = \alpha_t + \sum \beta_s f_{st} + \varepsilon_t$$

where r_t is return difference, average portfolio return of losers less average portfolio return of winner, at time *t*, *f* is a risk factor, and *β* is a loading on each risk factor, *s*, that can be changed over time and regime. *VIX* has a positive coefficient across all models; it has a positive loading on average excess returns, although its loadings are gradually decrease. The coefficients of *Level* and *Slope* are negative in general; their loadings on average excess returns are changed depending on the periods. The coefficients of *Level* are changed to positive from negative since 2008. It is the period 10-year U.S. Treasury yield continuously falls after the most recent financial crisis. The coefficients of *Slope* are changed from negative to positive and changed back to negative between 1997 and 2007. In this study, we do not test what drives changes in the loadings of key risk factors, but it could be explained by the official adoption of Euro and the recent changes in interest rates across most of countries. Although we do not report here, we construct sub-samples with these two events and conduct regression analyses with the same model, and obtain same result; the loadings on key risk factors are changed in the specific period.

In Figure 1, we present how major risk factors are changed during the sample period. Most importantly, we find *Level* continues to fall over the three decades and *Slope* remains in a range.

VIX does not appear to have a clear pattern over time, except for the most recent financial crisis in 2008.

[Table 4]

[Figure 1]

This study also examines foreign exchange market using an alternative portfolio construction. In Tables 5, 6, and 7, portfolio formation is built based on spot exchange rate return, but portfolios are evaluated with excess returns. The result is very interesting as the test periods show clear outperformance of losers for almost all combinations of formation and test periods at 1% significance level as in Table 5. Quintile portfolios show a consistent decreasing pattern in each portfolio return from loser to winner in Table 6. The differences in loser and winner portfolios are more significant in Table 7 than those in Table 3 that use excess returns to construct loser and winner portfolios. As excess returns in foreign exchange rates are associated with interest rates of two currencies besides the spot rates, interest rate differentials affect the portfolio to reach its short-term equilibrium as the overreaction result of formation periods with excess return weaker than that of alternative formation.

4. Conclusion

We examine the overreaction hypothesis in foreign exchange markets using 23 currency pairs over the last three decades. We find that overreaction is sensitive to formation and test periods. We observe meaningful reversal for longer-term formation and test periods. In other words, results

from the longer formation and the longer test periods provide strong evidence for foreign exchange market inefficiency. Further, we do not observe any formation and test period that consistently show momentum or reversal during the entire sample period and thus results of overreaction studies may vary depending on sample period.

It is interesting and surprising that losers' outperformance is more clearly observed if portfolios are formed based on spot currency return instead of excess return, except for very short formation and testing periods. There are certain combinations of formation and test periods that the phenomenon exists during the entire sample period. Thus, traders have had enough opportunity to exploit the market inefficiency over the last three decades.

Table1.Excess return difference - Formation and test with Excess return (Loser-Winner)

Formation Period	***Test Period***												
	t3	***t6***	***t9***	***t12***	***t15***	***t18***	***t21***	***t24***	***t27***	***t30***	***t33***	***t36***	***Ave***
f3	-0.039**	-0.048**	-0.013	-0.079**	0.012	0.010	0.036**	-0.056**	0.043**	0.032**	0.012	0.051**	-0.003
	(-6.38)	(-5.93)	(-1.77)	(-10.79)	(1.6)	(1.34)	(4.91)	(-7.53)	(5.59)	(3.99)	(1.79)	(6.74)	
f6	-0.027**	-0.008	-0.009	-0.007	0.028**	0.048**	0.027**	-0.028**	0.034**	0.019**	-0.014*	0.051**	0.01
	(-3.78)	(-.99)	(-1.27)	(-1.01)	(3.15)	(6.32)	(3.78)	(-4.03)	(4.38)	(2.87)	(-2.13)	(7.76)	
f9	-0.059**	-0.071**	-0.046**	-0.033**	0.002	0.009	0.012	-0.012	-0.004	0.030**	0.011	0.043**	-0.01
	(-7.66)	(-9.07)	(-6.65)	(-4.04)	(.35)	(1.24)	(1.71)	(-1.58)	(-.48)	(3.97)	(1.39)	(5.37)	
f12	-0.053**	-0.006	-0.023**	-0.009	-0.031**	0.009	-0.006	0.001	0.009	0.032**	0.041**	0.033**	-0.000
	(-7.48)	(-.9)	(-3.23)	(-1.24)	(-4.99)	(1.27)	(-.83)	(.06)	(1.28)	(4.27)	(5.13)	(4.39)	
f15	-0.020**	-0.013	-0.005	-0.017*	-0.022**	-0.005	0.001	0.026**	-0.001	0.026**	0.043**	0.023**	0.003
	(-2.85)	(-1.9)	(-.73)	(-2.51)	(-3.14)	(-.68)	(.13)	(3.03)	(-.09)	(3.39)	(5.29)	(2.99)	
f18	-0.006	0.005	-0.018**	-0.003	0.014*	-0.025**	0.008	0.017*	-0.001	0.029**	0.025**	0.007	0.004
	(-.86)	(.74)	(-2.72)	(-.46)	(2.28)	(-3.67)	(1.08)	(2.02)	(-.1)	(4.31)	(3.45)	(1.1)	
f21	-0.019**	-0.009	0.002	-0.001	0.044**	0.008	-0.010	0.022**	-0.006	0.032**	0.024**	0.011*	0.008
	(-3.16)	(-1.53)	(.36)	(-.19)	(6.21)	(1.22)	(-1.62)	(2.85)	(-.88)	(4.63)	(3.51)	(1.99)	
f24	-0.014*	0.009	0.027**	0.019*	0.028**	0.051**	0.038**	0.049**	0.026**	0.035**	0.035**	0.034**	0.028
	(-2.21)	(1.28)	(3.77)	(2.45)	(3.75)	(6.34)	(4.69)	(5.93)	(3.39)	(4.55)	(4.38)	(4.57)	
f27	-0.005	0.015*	0.001	0.014*	0.010	0.029**	0.037**	0.033**	0.029**	0.025**	0.018*	0.017**	0.019
	(-.67)	(2.09)	(.15)	(2.10)	(1.47)	(4.05)	(4.93)	(4.52)	(3.8)	(3.69)	(2.45)	(2.74)	
f30	0.000	0.008	-0.003	0.010	0.004	0.011	0.022**	0.028**	0.036**	0.021**	0.027**	-0.002	0.014
	(-.04)	(1.20)	(-.46)	(1.45)	(.65)	(1.47)	(2.9)	(4.21)	(4.87)	(2.88)	(3.95)	(-.32)	
f33	-0.010	0.000	0.014*	0.009	0.013*	0.016*	0.016*	0.028**	0.051**	0.010	0.025**	0.008	0.015
	(-1.54)	(.03)	(2.08)	(1.34)	(2.05)	(2.33)	(2.18)	(4.43)	(6.68)	(1.6)	(3.74)	(1.27)	
f36	0.000	0.010	0.012	0.028**	0.062**	0.013	0.019**	0.038**	0.037**	0.036**	0.034**	0.010	0.025
	(.01)	(1.38)	(1.69)	(3.51)	(7.05)	(1.76)	(2.59)	(4.93)	(5.01)	(4.74)	(5.03)	(1.26)	
Ave	-0.021	-0.009	-0.005	-0.006	0.014	0.015	0.017	0.012	0.021	0.027	0.023	0.024	

** and * indicate 1% and 5% significance level, respectively. HAC t-statistics based on Newey-West (1987) in parentheses.
All periods are in month, and returns are annualized.

Table 2. Quintile Portfolios - Formation and test with Excess return

f	*t*	Loser	2	3	4	Winner	L-W
6	**6**	0.005	-0.002	-0.006**	0.005	0.013**	-0.008
		(1.06)	(-.91)	(-2.71)	(1.76)	(3.01)	(-.99)
6	**12**	0.005	-0.001	-0.004	0.004	0.013**	-0.007
		(1.29)	(-.33)	(-1.75)	(1.53)	(3.05)	(-1.01)
6	**24**	-0.006	-0.008**	-0.004	0.013**	0.022**	-0.028**
		(-1.36)	(-3.74)	(-1.63)	(5.9)	(5.71)	(-4.03)
6	**36**	0.033**	0.011**	-0.006*	-0.002	-0.018**	0.051**
		(7.85)	(4.28)	(-2.27)	(-.87)	(-5.33)	(7.76)
12	**6**	0.007	0.001	-0.009**	0.005*	0.014**	-0.006
		(1.72)	(.66)	(-4.07)	(2.21)	(3.43)	(-.9)
12	**12**	0.008	-0.002	-0.006**	0.003	0.017**	-0.009
		(1.8)	(-1.28)	(-2.79)	(1.28)	(3.89)	(-1.24)
12	**24**	0.011*	0.005*	0.000	-0.003	0.010*	0.001
		(2.16)	(2.21)	(-.21)	(-1.24)	(2.32)	(.06)
12	**36**	0.027**	0.004	-0.005**	0.001	-0.005	0.033**
		(5.86)	(1.81)	(-2.57)	(.31)	(-1.28)	(4.39)
24	**6**	0.020**	-0.001	-0.004*	-0.006*	0.011**	0.009
		(4.29)	(-.63)	(-2.14)	(-2.33)	(2.68)	(1.28)
24	**12**	0.022**	0.001	0.007**	-0.013**	0.004	0.019*
		(4.42)	(.59)	(3.83)	(-5.62)	(.9)	(2.45)
24	**24**	0.039**	0.007*	0.003	-0.017**	-0.010**	0.049**
		(7.)	(2.36)	(1.34)	(-7.43)	(-2.58)	(5.93)
24	**36**	0.029**	0.012**	0.004*	-0.017**	-0.005	0.034**
		(5.56)	(4.78)	(2.17)	(-7.59)	(-1.27)	(4.57)
36	**6**	0.011*	0.003	0.002	-0.011**	0.001	0.01
		(2.42)	(1.18)	(1.1)	(-4.73)	(.14)	(1.38)
36	**12**	0.019**	0.005	-0.002	-0.007**	-0.009	0.028**
		(4.12)	(1.87)	(-.99)	(-3.33)	(-1.95)	(3.51)
36	**24**	0.020**	0.018**	-0.004	-0.011**	-0.017**	0.038**
		(4.56)	(7.05)	(-1.72)	(-5.13)	(-3.85)	(4.93)
36	**36**	0.009*	0.010**	-0.004	-0.008**	0.000	0.01
		(2.08)	(3.32)	(-1.89)	(-3.87)	(-.09)	(1.26)

Note: Each decile portfolio consists of 22 currency pairs before 1999 and 13 from 1999; there are 231 currency excess returns each month until 1998 and 78 returns from 1999. The first decile portfolio(Loser) is the annualized cumulative return during the test period (T) for the highest cumulative return group (upper 10%) during the formation period (F) and Winner is the lowest return group. ** and * indicate 1% and 5% significance level, respectively. HAC t-statistics based on Newey-West (1987) in parentheses.

Table 3. 5-year rolling average of Foreign Exchange Rate Overreaction - Formation and test with Excess return

F	6	6	6	6	12	12	12	12	24	24	24	24	36	36	36	36
T	6	12	24	36	6	12	24	36	6	12	24	36	6	12	24	36
1991	0.110**	-0.036	-0.051**	0.071**	0.028	-0.017	0.032	0.044*								
1992	0.129**	0.011	0.002	0.137**	0.066**	0.000	0.080**	0.075**	0.018	0.042	0.091**	0.070**				
1993	0.045	0.05**	-0.021	0.080**	0.002	-0.103**	-0.049*	-0.053**	-0.049**	-0.065**	0.012	-0.007	-0.054**	-0.057**	-0.058**	-0.051**
1994	0.051*	0.058**	-0.029*	0.031	0.029	-0.036	0.022	-0.027*	0.009	0.005	0.031	0.012	-0.005	0.015	0.003	0.010
1995	0.112**	0.082**	-0.020	0.034*	0.068**	-0.029	0.006	-0.017	0.033*	0.016	0.034	0.038*	0.020	0.028	0.030	0.037*
1996	-0.045*	0.001	-0.026	0.074**	-0.047**	-0.028*	0.039*	-0.008	0.033*	0.064**	0.084**	0.04**	0.041**	0.070**	0.065**	0.070**
1997	-0.071**	-0.045*	-0.005**	0.066**	-0.077**	-0.024*	0.013	0.000	0.033*	0.056**	0.138**	0.032*	0.067**	0.107**	0.089**	0.103**
1998	-0.043*	-0.021	-0.054**	0.065**	-0.039**	0.012	0.055**	0.025	0.060**	0.086**	0.139**	0.025	0.085**	0.120**	0.092**	0.097**
1999	-0.025	-0.008	-0.004	0.084**	-0.036*	-0.012	0.027*	-0.002	-0.002	0.014	0.051**	-0.042**	0.002	0.025	0.008	0.031*
2000	-0.099**	-0.051**	-0.045**	0.037**	-0.064**	-0.021	0.012	-0.019	-0.031*	-0.024	0.021	-0.071**	-0.051**	-0.015	-0.043**	-0.02
2001	-0.081**	-0.066**	-0.076**	0.005	-0.088**	-0.087**	-0.086**	-0.052**	-0.080**	-0.101**	-0.042*	-0.089**	-0.084**	-0.083**	-0.103**	-0.08**
2002	-0.081**	-0.038	-0.049*	0.038**	-0.003	0.007	0.003	0.025	-0.005	-0.017	-0.021	-0.019	-0.026	-0.033	-0.068**	-0.041*
2003	-0.135**	-0.129**	-0.139**	0.068**	-0.083**	-0.076**	-0.086**	0.087**	-0.067**	-0.050**	0.028	-0.046**	-0.038	-0.013	-0.038	0.014
2004	-0.135**	-0.108**	-0.146**	0.051**	-0.102**	-0.122**	-0.136**	0.093**	-0.077**	-0.054**	0.041	-0.035*	-0.011	0.007	0.014	0.016
2005	-0.089**	-0.08**	-0.124**	0.066**	-0.084**	-0.118**	-0.126**	0.102**	-0.051**	-0.023	0.088**	-0.020	0.038	0.057**	0.074**	0.059**
2006	-0.008	-0.018	-0.025	0.089**	0.003	-0.04*	-0.049*	0.145**	0.007	0.029	0.126**	0.018	0.069**	0.102**	0.119**	0.086**
2007	0.001	-0.011	-0.030	0.059**	-0.063**	-0.118**	-0.123**	0.055**	-0.067**	-0.046**	0.044*	-0.05**	-0.030*	0.004	0.036**	0.003
2008	0.052**	0.069**	0.030*	0.104**	-0.005	0.017	0.001	0.054**	0.032	0.038	0.047*	0.051*	0.032	0.056*	0.102**	0.035
2009	0.077**	0.075**	0.057**	0.050	0.073**	0.117**	0.105**	-0.021	0.116**	0.122**	0.052*	0.115**	0.099**	0.141**	0.155**	0.006
2010	0.073**	0.081**	0.087**	0.084**	0.056**	0.093**	0.116**	-0.013	0.086**	0.080**	-0.006	0.123**	0.061**	0.094**	0.151**	-0.025
2011	0.028	0.067**	0.042**	0.072**	0.038	0.095**	0.12**	-0.009	0.082**	0.082**	-0.018	0.097**	0.061**	0.091**	0.149**	-0.017
2012	0.038*	0.042**	0.018	0.059*	0.066**	0.115**	0.123**	0.006	0.083**	0.089**	-0.005	0.110**	0.070**	0.097**	0.179**	0.017
2013	-0.008	0.010	0.035**	-0.044**	0.038	0.023	0.041*	-0.013	-0.007	-0.007	-0.045**	0.053**	-0.010	0.009	0.075**	-0.087**
2014	-0.033*	0.008	-0.005	0.011	-0.018	-0.048**	-0.034*	0.039**	-0.060**	-0.061**	-0.020*	0.007	-0.058**	-0.055**	0.018	-0.03**
2015	-0.037*	0.029**	-0.020	-0.016	0.014	-0.011	-0.033*	0.028*	-0.024*	-0.034**	0.009	0.000	-0.025*	-0.023	0.007	0.002
2016	-0.048**	0.010	-0.035**	0.007	0.019	0.011	-0.062**	0.068**	-0.028**	-0.024*	0.033**	0.048**	0.007	0.013	0.036**	0.047**

** and * indicate 1% and 5% significance level, respectively, based on Newey-West (1987)'s HAC t-statistics. Year indicates the last year of 5 year rolling average. For example, 1999 data is 5 year rolling average from January 1995 to December 1999.

Table 4. Regression analysis

Model:	(1)	(2)	(3)	(4)
Sample period:	Whole	1990~1996	1997~2007	2008~2017
VIX	0.008*	0.064**	0.030**	0.025**
	(0.004)	(0.015)	(0.007)	(0.006)
Level	-0.374**	-1.064**	-0.248**	1.116**
	(0.045)	(0.079)	(0.085)	(0.141)
Slope	-0.118*	-1.497**	0.385**	-1.562**
	(0.060)	(0.136)	(0.097)	(0.161)
Constant	0.021**	0.086**	0.008	-0.003
	(0.003)	(0.006)	(0.005)	(0.003)
Year Fixed effect	Yes	Yes	Yes	Yes
Number of Observations	47,232	12,096	19,008	16,128
Adj. R-Squared	0.0473	0.0306	0.0724	0.0470
Transaction cost	Yes	Yes	Yes	Yes

OLS results showing the relation between portfolio return and US equity volatility (*VIX*), 10-year Treasury yield (*Level*), and the difference between 10-year and 2-year Treasury yields (*Slope*). Dependent variable is a portfolio return difference, $r_t = apr_{L,t} - apr_{W,t}$. All models include year fixed effects base on Hausman test with the null of difference in coefficients not systematic. Numbers in parentheses are heteroskedasticity robust (i.e., White-Huber) standard errors. ** and * indicate 1% and 5% significance level, respectively.

Table5. Excess return difference – Formation with spot return and test with Excess return (Loser-Winner)

Formation	***Test Period***												
Period	***t3***	***t6***	***t9***	***t12***	***t15***	***t18***	***t21***	***t24***	***t27***	***t30***	***t33***	***t36***	***Ave***
f3	-0.018**	-0.029**	0.019**	-0.053**	0.043**	0.057**	0.050**	-0.033**	0.064**	0.047**	0.048**	0.080**	0.023
	(-3.31)	(-4.11)	(2.63)	(-7.65)	(6.34)	(8.45)	(6.59)	(-4.43)	(8.65)	(5.95)	(6.75)	(10.14)	
f6	0.010	0.025**	0.025**	0.035**	0.077**	0.084**	0.064**	0.001	0.068**	0.065**	0.020**	0.090**	0.047
	(1.45)	(3.08)	(3.44)	(4.92)	(11.15)	(10.97)	(9.51)	(0.07)	(8.84)	(9.43)	(2.72)	(12.93)	
f9	-0.004	-0.014	0.011	0.013	0.049**	0.071**	0.060**	0.010	0.047**	0.074**	0.035**	0.079**	0.036
	(-0.52)	(-1.71)	(1.48)	(1.66)	(6.92)	(9.99)	(8.60)	(1.16)	(6.47)	(9.98)	(4.42)	(10.60)	
f12	0.001	0.041**	0.038**	0.027**	0.037**	0.073**	0.047**	0.036**	0.062**	0.078**	0.062**	0.085**	0.049
	(0.12)	(5.25)	(5.04)	(3.6)	(5.58)	(9.67)	(7.02)	(4.59)	(8.68)	(11.58)	(7.88)	(11.73)	
f15	0.036**	0.051**	0.051**	0.044**	0.027**	0.066**	0.051**	0.064**	0.054**	0.068**	0.067**	0.084**	0.055
	(4.92)	(6.88)	(7.26)	(6.32)	(3.56)	(9.90)	(6.81)	(8.72)	(7.22)	(9.61)	(7.97)	(11.65)	
f18	0.051**	0.049**	0.039**	0.049**	0.069**	0.032**	0.061**	0.063**	0.046**	0.056**	0.062**	0.062**	0.053
	(7.32)	(6.49)	(5.68)	(6.99)	(9.88)	(4.96)	(8.13)	(8.22)	(5.85)	(9.16)	(7.99)	(9.60)	
f21	0.041**	0.049**	0.065**	0.064**	0.093**	0.069**	0.047**	0.068**	0.048**	0.054**	0.079**	0.073**	0.063
	(5.68)	(6.81)	(9.12)	(8.87)	(13.91)	(9.82)	(6.13)	(9.16)	(6.33)	(8.24)	(10.19)	(10.23)	
f24	0.051**	0.066**	0.085**	0.074**	0.081**	0.107**	0.072**	0.094**	0.085**	0.063**	0.089**	0.101**	0.081
	(6.99)	(8.33)	(11.68)	(9.34)	(10.75)	(13.47)	(9.16)	(11.89)	(11.00)	(8.61)	(10.94)	(13.17)	
f27	0.061**	0.077**	0.059**	0.068**	0.066**	0.084**	0.092**	0.081**	0.083**	0.075**	0.074**	0.083**	0.075
	(9.50)	(12.00)	(9.30)	(10.03)	(9.47)	(13.01)	(12.80)	(11.10)	(12.38)	(11.04)	(9.58)	(13.04)	
f30	0.063**	0.076**	0.064**	0.077**	0.063**	0.085**	0.074**	0.075**	0.082**	0.073**	0.087**	0.063**	0.073
	(10.28)	(12.20)	(10.69)	(13.67)	(9.22)	(13.74)	(11.67)	(13.93)	(12.72)	(10.64)	(12.06)	(12.39)	
f33	0.051**	0.050**	0.063**	0.051**	0.063**	0.066**	0.072**	0.077**	0.096**	0.072**	0.068**	0.069**	0.066
	(8.01)	(7.36)	(10.02)	(7.63)	(10.39)	(10.19)	(11.32)	(12.15)	(13.41)	(10.80)	(10.78)	(10.98)	
f36	0.053**	0.064**	0.059**	0.075**	0.105**	0.06**	0.062**	0.083**	0.088**	0.093**	0.081**	0.062**	0.074
	(8.33)	(9.70)	(8.87)	(10.39)	(15.61)	(9.22)	(9.48)	(12.43)	(13.55)	(15.37)	(11.94)	(8.82)	
Ave	0.033	0.042	0.048	0.044	0.064	0.071	0.063	0.052	0.068	0.068	0.064	0.078	

** and * indicate 1% and 5% significance level, respectively. HAC t-statistics based on Newey-West (1987) in parentheses.
All periods are in month, and the differences are on an annualized basis.

Table 6. Decile Portfolios - Formation with spot return and test with Excess return

f	*t*	Loser	2	3	4	Winner	L-W
6	**6**	0.020**	-0.009**	0.006**	0.004	-0.005	0.025**
		(4.10)	(-3.79)	(2.81)	(1.49)	(-1.19)	(3.08)
6	**12**	0.029**	-0.004	0.000	-0.002	-0.006	0.035**
		(6.78)	(-1.54)	(0.19)	(-0.82)	(-1.49)	(4.92)
6	**24**	0.007	-0.011**	0.004	0.011**	0.007	0.001
		(1.71)	(-4.58)	(1.96)	(4.54)	(1.69)	(.07)
6	**36**	0.050**	0.014**	0.007**	-0.012**	-0.039**	0.09**
		(10.82)	(4.82)	(3.33)	(-6.04)	(-11.84)	(12.93)
12	**6**	0.032**	-0.001	-0.006**	0.003	-0.009*	0.041**
		(6.48)	(-0.33)	(-2.86)	(1.07)	(-2.31)	(5.25)
12	**12**	0.028**	-0.003	-0.007**	0.000	0.001	0.027**
		(6.16)	(-1.39)	(-3.56)	(-0.05)	(0.30)	(3.6)
12	**24**	0.029**	0.005*	-0.002	-0.004	-0.007	0.036**
		(6.04)	(2.49)	(-0.92)	(-1.63)	(-1.74)	(4.59)
12	**36**	0.058**	0.005*	-0.003	-0.012**	-0.027**	0.085**
		(12.03)	(2.02)	(-1.25)	(-5.07)	(-7.75)	(11.73)
24	**6**	0.046**	0.008**	-0.007**	-0.009**	-0.020**	0.066**
		(9.16)	(3.09)	(-3.17)	(-3.69)	(-4.70)	(8.33)
24	**12**	0.052**	0.002	0.004*	-0.015**	-0.023**	0.074**
		(9.92)	(1.01)	(2.28)	(-5.90)	(-5.71)	(9.34)
24	**24**	0.064**	0.006*	-0.001	-0.019**	-0.03**	0.094**
		(12.02)	(2.07)	(-0.37)	(-7.90)	(-8.67)	(11.89)
24	**36**	0.064**	0.006*	0.004*	-0.016**	-0.036**	0.101**
		(12.77)	(2.47)	(2.06)	(-6.77)	(-9.43)	(13.17)
36	**6**	0.043**	0.002	-0.007**	-0.012**	-0.021**	0.064**
		(10.11)	(0.66)	(-3.14)	(-4.91)	(-6.10)	(9.7)
36	**12**	0.047**	0.007**	-0.005**	-0.014**	-0.028**	0.075**
		(10.52)	(2.91)	(-2.61)	(-6.18)	(-7.30)	(10.39)
36	**24**	0.048**	0.008**	-0.002	-0.013**	-0.035**	0.083**
		(11.13)	(3.50)	(-0.83)	(-5.40)	(-9.39)	(12.43)
36	**36**	0.037**	0.005*	-0.007**	-0.004	-0.026**	0.062**
		(8.69)	(2.12)	(-3.05)	(-1.89)	(-6.21)	(8.82)

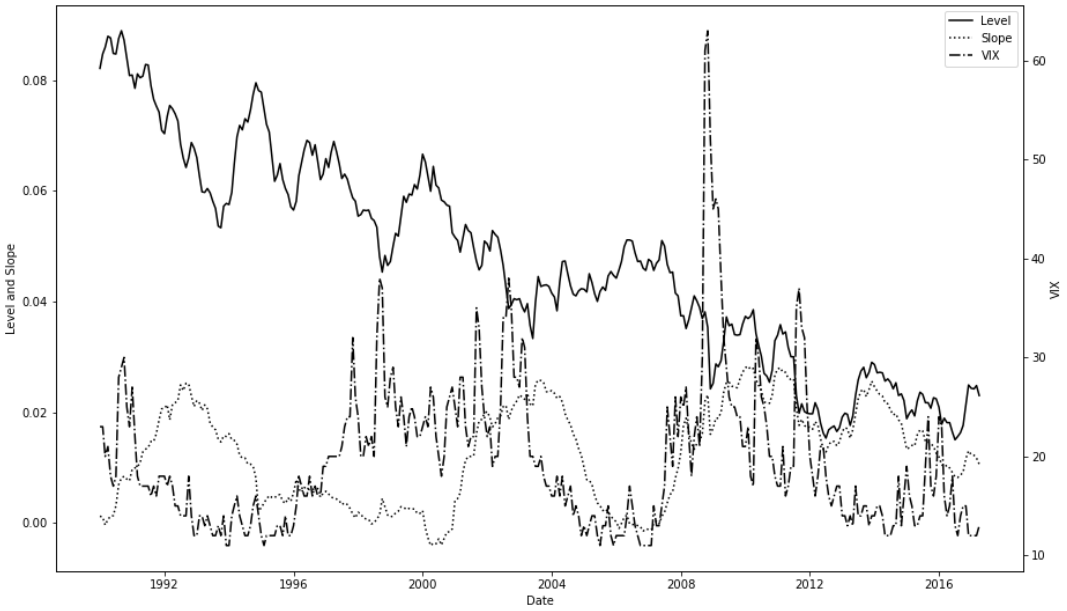
Note: Each decile portfolio consists of 22 currency pairs before 1999 and 13 from 1999; there are 231 currency excess returns each month until 1998 and 78 returns from 1999. The first decile portfolio(Loser) is the annualized cumulative return during the test period (T) for the highest cumulative return group (upper 10%) during the formation period (F) and Winner is the lowest return group. ** and * indicate 1% and 5% significance level, respectively. HAC t-statistics based on Newey-West (1987) in parentheses.

Table 7. 5-year rolling average of Foreign Exchange Rate Overreaction - Formation with spot return and test with Excess return

F	6	6	6	6	12	12	12	12	24	24	24	24	36	36	36	36
T	6	12	24	36	6	12	24	36	6	12	24	36	6	12	24	36
1991	0.201**	0.100**	0.048*	0.135**	0.165**	0.086**	0.124**	0.134**								
1992	0.229**	0.154**	0.098**	0.195**	0.202**	0.103**	0.167**	0.166**	0.178**	0.196**	0.176**	0.153**				
1993	0.116**	0.103**	0.035*	0.104**	0.075**	-0.034	0.017	0.017	0.046*	0.056**	0.084**	0.068**	0.056**	0.059**	0.072**	0.089**
1994	0.075**	0.087**	-0.005	0.015	0.058**	-0.022	0.037	0.008	0.016	0.038	0.076**	0.059**	0.014	0.038*	0.017	0.009
1995	0.121**	0.103**	-0.004	0.021	0.084**	-0.019	0.016	0.019	0.045*	0.038	0.075**	0.097**	0.043*	0.060**	0.045**	0.038
1996	-0.016	0.026	-0.020	0.090**	-0.003	0.025	0.041*	0.058**	0.045*	0.071**	0.118**	0.095**	0.06**	0.091**	0.068**	0.058**
1997	-0.018	-0.002	-0.032	0.105**	-0.009	0.043**	0.034**	0.09**	0.085**	0.102**	0.167**	0.119**	0.108**	0.14**	0.097**	0.081**
1998	0.002	0.026	-0.04*	0.107**	0.025	0.075**	0.073**	0.115**	0.112**	0.135**	0.153**	0.093**	0.135**	0.146**	0.098**	0.053**
1999	0.054**	0.078**	0.047**	0.183**	0.084**	0.111**	0.100**	0.143**	0.142**	0.153**	0.114**	0.122**	0.147**	0.147**	0.134**	0.141**
2000	0.000	0.050**	0.021	0.148**	0.068**	0.108**	0.112**	0.146**	0.134**	0.155**	0.116**	0.124**	0.111**	0.112**	0.094**	0.117**
2001	-0.002	0.024	-0.023	0.101**	-0.001	-0.011	0.011	0.081**	0.043*	0.052**	0.072**	0.115**	0.056**	0.040*	0.031*	0.054**
2002	-0.022	0.051*	-0.011	0.121**	0.049**	0.048*	0.082**	0.111**	0.068**	0.091**	0.092**	0.106**	0.078**	0.070**	0.042*	0.091**
2003	-0.070**	-0.034	-0.082**	0.175**	-0.022	-0.025	0.002	0.179**	0.042*	0.084**	0.158**	0.106**	0.088**	0.114**	0.090**	0.148**
2004	-0.092**	-0.044*	-0.108**	0.132**	-0.065**	-0.098**	-0.08**	0.153**	-0.033	0.011	0.142**	0.066**	0.061**	0.078**	0.091**	0.086**
2005	-0.054**	-0.027	-0.095**	0.130**	-0.037	-0.080**	-0.076**	0.157**	-0.016	0.011	0.149**	0.061**	0.09**	0.115**	0.133**	0.117**
2006	0.018	0.005	0.003	0.139**	0.054**	0.000	0.005	0.183**	0.090**	0.087**	0.167**	0.078**	0.136**	0.146**	0.170**	0.135**
2007	0.020	-0.007	-0.006	0.094**	-0.001	-0.069**	-0.076**	0.098**	0.010	0.000	0.074**	0.034**	0.032*	0.038**	0.081**	0.047**
2008	0.038*	0.034**	0.022	0.099**	0.025	0.015	0.011	0.047**	0.036*	0.000	0.001	0.094**	0.021	0.038*	0.094**	0.046**
2009	0.059**	0.05**	0.058**	0.063**	0.101**	0.114**	0.118**	0.009	0.125**	0.092**	0.049**	0.142**	0.088**	0.112**	0.132**	0.05**
2010	0.049*	0.057**	0.088**	0.103**	0.062**	0.065**	0.108**	-0.004	0.091**	0.056**	0.006	0.133**	0.067**	0.084**	0.122**	0.015
2011	-0.002	0.049**	0.043*	0.086**	0.026	0.056**	0.099**	-0.013	0.048*	0.045*	-0.026	0.098**	0.039*	0.072**	0.104**	0.005
2012	0.010	0.031*	0.021	0.077**	0.045*	0.081**	0.100**	0.004	0.065**	0.065**	-0.001	0.123**	0.055**	0.087**	0.143**	0.048**
2013	-0.002	0.03*	0.053**	-0.001	0.035	0.023	0.039	0.034*	0.018	0.025	0.018	0.081**	0.024	0.035*	0.078**	-0.017
2014	-0.027	0.015	-0.006	0.033**	-0.029*	-0.052**	-0.040**	0.048**	-0.045**	-0.036**	0.002	0.026*	-0.034**	-0.031**	0.017	-0.008
2015	-0.042**	0.023*	-0.034**	-0.019	-0.018	-0.033*	-0.060**	0.023	-0.046**	-0.039**	0.005	0.000	-0.049**	-0.047**	-0.017	-0.022*
2016	-0.043**	0.012	-0.047**	0.002	0.001	0.000	-0.069**	0.067**	-0.029**	-0.021*	0.044**	0.055**	0.002	0.009	0.04**	0.044**

** and * indicate 1% and 5% significance level, respectively, based on Newey-West (1987)'s HAC t-statistics. Year indicates the last year of 5 year rolling average. For example, 1999 data is 5 year rolling average from January 1995 to December 1999

Figure 1:


Level
Slope
VIX
Level and Slope
VIX
Date
0.08
0.06
0.04
0.02
0.00
60
50
40
30
20
10
1992
1996
2000
2004
2008
2012
2016

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