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The Profitability of Momentum and Contrarian Strategies

in the Foreign Exchange Market

ABSTRACT

This paper reexamines market inefficiency in the foreign exchange market and investigates the sources of inefficiency. Using weekly currency returns of G7 countries and the European Union from 1971-2007, I find that both momentum and contrarian strategies generate significant abnormal profits. It casts doubt on the Efficient Market Hypothesis. The evidence appears to be stronger when using interest-adjusted returns. After decomposing the sources of profits, I find that the time serial autocorrelation is the predominant source of gains to both momentum and contrarian strategies. It also attributes to market inefficiency in the foreign exchange market. The profitability remains significant even with the presence of transaction costs.

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Introduction

The Efficient Market Hypothesis (thereafter EMH, Fama, 1970) suggests that since prices are theoretically unpredictable, there should be no abnormal profit existing in the market. However, both contrarian and momentum trading strategies have been found profitable in the stock market (De Bondt and Thaler, 1985; Jegadeesh and Titman, 1993). Similar evidence is observed in the foreign exchange market (thereafter FOREX) as well. Taylor (1992), for example, finds that exchange rates do not follow a random walk, but possess some degree of serial correlation. Sweeney (1986), using filter rules, confirms that investors earn abnormal returns when trading from a risk-free Dollar asset to a risk-free Deutsche Mark (DM) asset. Kho (1996) also reports significant excess returns to the buy-and-hold strategy. Okunev and White (2003) examine the profitability of momentum strategies and find that the well-documented profitability holds for currencies throughout 1990s. Bianchi et al. (2004) report similar results using a different sample (G7 countries – Canada, France, Germany, Italy, Japan, the U.K., and the U.S.).

This evidence suggests that the foreign exchange market is not efficient. In other words, exchange rates do not truly reflect all the currently available information on domestic and international economic and political environments (Fama, 1965). This paper reexamines market inefficiency and investigates the sources of such inefficiency. The results are twofold.

First, using weekly returns of eight currencies (of G7 countries and the European Union) from 1971 - 2007, I find that both momentum and contrarian strategies generate substantial abnormal profits. Among all fourteen strategies evaluated, eight are significantly profitable – 5 are momentum and 3 are contrarian. This finding is consistent with the literature. More importantly, it implies that the FOREX market is not an efficient market. Interestingly, when conditional on the time horizon, momentum strategies are more likely to be profitable in medium- to long-term horizons, while contrarian strategies yield significant profits in short-term horizons. The results appear to be stronger when using the interest-adjusted returns.

Second, this paper decomposes the sources of profits into time-series autocorrelation and cross-sectional variation. After the decomposition, I find that both attributes make a contribution to the abnormal profits. However, it is the time serial autocorrelation that accounts for the vast majority of profits to both momentum and contrarian strategies. The results again indicate that currency returns do not follow a random walk. EMH is therefore evidently violated in the FOREX market. It also justifies that time-series autocorrelation is the exact attribute to the inefficiency of the foreign exchange market.

These results remain significant even when transaction costs come into effect. Transaction cost (usually commissions and bid-ask spreads) is one of the well-documented factors that make arbitrage (the effort to correct mispricing) risky and costly (Barberis & Thaler, 2003; Shleifer & Vishny, 1997; De Long et al., 1990a). To be specific, think of the market as a place that comprises of a massive number of tiny arbitrageurs. Each arbitrageur takes a very small position to correct the mispricing. The collective action of corrections indeed drives prices toward fundamental values, but it will be costly due to the substantial transaction fees (Shleifer & Vishny, 1997). With the same function acting in the opposite direction, transaction costs will dampen the excess returns as well. In this paper, however, it is shown that a one-way transaction cost $c = 0.0001$ (or a round-trip $c = 0.0002$) cannot rule out the profitability presented earlier.

This paper extends the literature in several ways. First, prior studies almost exclusively use filter rules or moving average rules to investigate the trading profits in FOREX market. Both methods presume that the autocorrelation solely accounts for abnormal returns, and overlook the cross-sectional dispersion (Sweeney, 1986; Okunev and White, 2003; Bianchi et al., 2004). Using the weighted relative strength strategy (WRSS), this paper is the first attempt to examine both time-series autocorrelation and cross-sectional dispersion and their impacts on trading profits.

To understand the rationale, suppose the FOREX market does follow random walks. If investors buy winners (outperformed currencies) and simultaneously sell losers (underperformed currencies), their movements equal to holding a high-mean-return asset and short a low-mean-return asset. The discrepancy in mean returns will consequently generate positive excess returns even in a world where prices do follow random walks. Similarly, a contrarian strategy (buying losers and selling winners) will lose money due to the movements of buying and holding low-mean-return assets and selling high-mean-return assets.

Second, the performance-based strategies facilitate a further anatomy of the sources of abnormal returns, and the breakdown provides deep insights into the market inefficiency (Lehmann, 1990; Lo and MacKinlay, 1990; Conrad and Kaul, 1998). In terms of percentage, both time-series profitability and the cross-sectional dispersion are responsible for the abnormal profits, but autocorrelation contributes 90% of the profits to both momentum and contrarian strategies. This finding provides the first empirical evidence of the exact source of market inefficiency in the FOREX market.

Two other noticeable differences from the literature are the appropriate data frequency and the longest data range.

1) This paper uses weekly exchange returns instead of daily or monthly data for two reasons. First, weekly data helps establish a reasonably long period of time to evaluate the past performance. Monthly evaluation seems to be more informative, but it is impractical in reality – according to Taylor and Allen's (1992) survey of chief foreign exchange dealers, about 90% of respondents report that trading rules are evaluated in the horizons ranging from intraday to one week. Second, weekly data provides a substantial number of trading strategies (1922 weeks in total, each representing one possible trading strategy). Prior studies that use moving average rules or filter rules on a daily basis, however, often suffer from the limited number of selected trading rules (Okunev and White, 2003).

2) The sample period ranges from January 1971 to October 2007. This is the longest period that has been used to examine the exchange rate movement after the Bretton Woods System. It not only avoids the world-wide fixed exchange rate system before 1971, but incorporates the post-Euro era, making this study more practical.

The remainder of this paper is organized as follows. Section I describes the data. Section II presents the profitability of all trading strategies, and Section III decomposes the sources of profits. Section IV takes transaction costs into account. Section V concludes.

I. Data Description

This paper analyzes eight major exchange rates in the world, including G7 countries (Canada, France, Germany, Italy, Japan, the U.K., and the U.S.) and the European Union. The data ranges from January 1971 to October 2007. U.S. dollars are used as the base currency. The daily exchange rates of Canada Dollar, Deutsche Mark, Japanese Yen, Pound and Euro are obtained from the Federal Reserve Bank of St. Louis, and the rates of French Franc and Italian Lira are downloaded from www. oanda.com/convert/fxhistory. Wednesday-to-Wednesday continuously compounded weekly returns are computed by accumulating daily returns, i.e. computed as a first difference in daily rates. Whenever the daily rate is missing on Wednesday, I replace it with Tuesday rates. The replacement ensures me to be able to construct a continuous weekly-return data set. The final sample consists of 1922 trading weeks.

I also construct a continuously compounded weekly return series that is adjusted for interest rate differentials under the covered interest rate parity. Risk-free three-month-government-bond interest rates are used for five countries, Canada, France, German, the U.S., and the U.K. For France, Italy, and Japan, as their short-term government bond rates are not available, the closest matching alternatives are chosen: three-month interbank interest rates are used for Italy and the European Union, and the bank discount rate is selected for Japan. All the interest rates are obtained from the Global Insight Inc. database.

Because the Euro was launched as a “single currency” for all the European Union Member States on December 31st, 1998, I divided the whole sample into two subperiods: January 1971 to December 1998, and January 1999 to October 2007. The Euro is not included in the first subperiod, but replaces Deutsche Mark, French Franc, and Italian Lira in the second subperiod. This replacement is necessary because after January 1st, 1999, old European currencies were irrevocably converted to the Euro in terms of the last day conversion rate[1]. Since then, the Deutsche Mark, French Franc, and Italian Lira are perfectly correlated with the Euro. The perfect correlation may result in upward biases in the weight put on the Euro in the equal-weighted trading strategies though.

A. Returns

The base currency returns from week t-1 to t are computed as follows:

$$R_t = \frac{S_t}{S_{t-1}} - 1, \qquad (1)$$

where R_t is the weekly return, S_t is the spot exchange rate at week t, and S_{t-1} is the spot rate at week t-1. All exchange rates are the ratio of foreign currencies to the U.S. Dollar.

I also compute the interest-adjusted currency returns under the covered interest rate parity (IRP). Investors that borrow money from foreign countries and invest in the United States, or vice versa, would actually experience these returns. The forward rate in week t-1 is denoted as F_{t-1}. The interest-adjusted returns from week t-1 to t are computed as follows:

$$R_{I,t} = \frac{S_t}{F_{t-1}} - 1, \qquad (2)$$

where

$$F_{t-1} = S_{t-1} Exp\left[\left(r - r_f\right)_t\right], \qquad (3)$$

$R_{I,t}$ is the interest-adjusted return, r is the domestic interest rate, r_f is the foreign interest rate, and t is the current week. Approximately, the equation can be written as follows:

[1] The Euro was adopted as the single currency of the European Union on January 1st, 1999. But old currencies were officially changed to Euro at different points of time. For example, Deutsche Mark was permanently converted to Euro on December 31st, 2001 along with the last day rate at 1.95583 DEM/EURO; French Franc was converted on February 17th, 2002 at 6.55957 FRF/EURO; and Italian Lira was converted on February 28th, 2002 at 1936.27 ITL/EURO. The daily exchange rates I use in this paper, however, have been officially adjusted according to the last day conversion rate back to the time before the last conversion date but after January 1st, 1999.

$$R_{I,t} = \frac{1}{52}(r_f - r_d) + \frac{S_t}{S_{t-1}} - 1. \qquad (4)$$

where $R_{I,t}$ is again the interest-adjusted return, $\frac{1}{52}(r_f - r_d)$ is the weekly interest rate differential between the U.S. (i.e. domestic country) and foreign countries, and $\frac{S_t}{S_{t-1}} - 1$ is the currency return shown in Equation (1).

B. Summary statistics

Table 1 presents the summary statistics for the Wednesday-to-Wednesday currency returns from January 1971 to October 2007. Panel A reports the base returns. It is shown that Italy and the U.K. have experienced the greatest depreciation (the Italian Lira has a mean return of 4.26% and the Pound is 3.43%). In contrast, Japan and the European Union have had the greatest appreciation (the Japanese Yen has a mean return of -2.53% and the Euro is -1.11%).

The first-order autocorrelation is positive and significant for all the currency returns, indicating strong linear dependence over time. In other words, positive (negative) changes in returns tend to be followed by positive (negative) changes. The Jarque-Bera tests are highly rejected too, showing that no returns are normally distributed. Therefore, the independently identically distribution assumption is not plausible in this analysis.

Panel B reports the interest-adjusted returns. The results are similar: the Japanese Yen has been greatest appreciated (-7.47%), while the Italian Lira had the greatest depreciation (12.61%). However, all the interest-adjusted mean returns are larger in magnitude than the base returns. Also, all the returns but Japanese Yen are significantly different from zero (back to the case of base returns, only the Euro, Deutsche Mark, and Japanese Yen have significant non-zero mean returns). It indicates that the interest rate differential compensates for the gain (loss) of currency appreciation (depreciation) under the interest rate parity. For example, the profit of holding the appreciated Japanese Yen will be offset by the negative interest rate differential between Japan and the U.S. Conversely, the loss of investing in the depreciated Italian Lira will be offset by the positive interest rate earnings between Italy and the U.S. This result is consistent with Bianchi et al. (2004), who use three-month interbank rates as the proxy for interest rates. Again, the first order autocorrelation is significantly positive, and the normality hypothesis is rejected in all cases.

III. The Profitability of Trading Strategies

Prior studies extensively use filter rules or moving average rules to measure price movements. However, these technical trading rules are problematic because they exclusively rely on the time-series pattern in returns. To be specific, when employing such rules, investors supposedly believe that the FOREX market does not follow random walks and that the time serial autocorrelation in prices solely accounts for excess returns (Sweeney, 1986; Okunev and White, 2003; Bianchi et al., 2004).

To overcome the drawback, I adopt the weighted relative strength strategy (WRSS) in this paper. This method calculates average profits to zero-cost trading strategies that buy winners and sell losers (or buy losers and sell winners) based on their past performance (Lehmann, 1990; Lo and MacKinlay, 1990; Conrad and Kaul, 1998). Also, the WRSS examines the impact of both time serial autocorrelation and cross-sectional dispersion on the profitability of trading strategies. It also provides deeper insight into the market inefficiency.

Seven basic strategies with holding periods are implemented within each of two subperiods. The results provide fourteen profits based on various holding periods from short-term (e.g. 1-week), medium-term (e.g. 4- to 13-week), to long-term horizons (e.g. up to 104 weeks). For simplicity, the one-week return is used to evaluate the past performance.

Consider buying or selling currencies at time t+1 based on their performance from time t-1 to t. The time period {t-1, t} is the week I use to evaluate past performance, and {t, t+1} spans any time interval k for holding (k = 1, 4, 8, 13, 26, 52, and 104 weeks). The past performance is then computed relative to the market performance (i.e. the average return of an equal-weighted portfolio that contains all the currencies). A currency that outperforms the market portfolio will be labeled as a “winner”, whereas a currency that underperforms the market portfolio will be labeled as a “loser.” The expected profits, eventually, are sum of the product of i) the return of each currency at time *t*+1, and ii) the weight $w_{it}(k)$ that is put on each currency. In specific, the weights are computed as follows:

$$w_{it}(k) = \pm \frac{1}{N}[R_{it}(k) - R_{mt}(k)], \qquad (5)$$

where $w_{it}(k)$ denotes the faction of the portfolio devoted to currency *i* at time *t*, $R_{it}(k)$ is the return on currency *i* at time *t*, *t* = 1, 2, 3 …N, $R_{mt}(k)$ is the return on the equal-weighted portfolio of all N currencies ($R_{mt} = \frac{1}{N}\sum_{i=1}^{N} R_{it}$), and k is the length of time interval {*t*, *t*+1}.

This expression essentially captures the universal nature of all trading strategies:

First, the positive or negative sign preceding the expression on the right-hand side reflects an investor’s belief. Specifically, if the investor believes in price reversal, (s)he will follow a contrarian strategy, and it is shown with a negative sign in the equation; if (s)he believes in price continuation, (s)he will follow a momentum strategy, and it is shown with a positive sign in the equation.

Second, the past performance of a currency relative to the market performance (i.e. the average return of all currencies) is supposed to be informative about future pattern in returns. In other words, no matter if a strategy is contrarian or momentum, its success is based on the time-series behavior of currency returns. This is not consistent with the EMH however, which implies that future returns be completely unpredictable.

Third, by construction, the dollar weights in Equation (5) lead to an arbitrage (zero-cost) portfolio. The investment in dollars is given by

$$I_t(k) = \frac{1}{2}\sum_{i=1}^{N} |w_{it}(k)|, \qquad (6)$$

where long and short (currencies) are completely offset as follows:

$$\sum_{i=1}^{N} w_{it}(k) = 0 \;\; \forall\, k$$

Finally, and most importantly, this approach allows me to decompose the trading profits into time serial and cross-sectional sources for both contrarian and momentum strategies. The realized profits at time *t*+1 are given by

$$\pi_{t+1}(k) = \sum_{i=1}^{N} w_{it}(k) R_{i,t+1}. \qquad (7)$$

Notice that the profits measured in dollars can be arbitrarily scaled by any number. Again, the sign of the profits has no meaning of whether the strategy is favorable or unfavorable – the positive or negative sign of $\pi_{t+1}(k)$ only refers to a momentum or contrarian strategy. Most importantly, the gain (loss) of a momentum strategy is essentially equivalent to the loss (gain) of a contrarian strategy. This ensures me to rely on the sign and statistical significance of the average time-series $\pi_{t+1}(k)$ rather than the numeric figures. In other words, I mainly examine whether the expected profits are significantly positive or negative.

Table 2 reports the average expected profits to trading strategies for different holding periods (i.e. different *k*). To mitigate the small-sample bias in the estimation of the components of the realized profits, I implement trading strategies for overlapping holding periods on a weekly basis (Conrad and Kaul, 1998). Panel A shows the first subperiod (1971-1998) without the Euro, and Panel B shows the second subperiod (1999-2007), in which the Euro replaces the Deutsche Mark, French Franc, and Italian Lira as the single currency for all the European Union Member States.

Many interesting results are found in Table 2.

The first two columns report the results of base-return-based strategies. First, among all fourteen strategies, the number of positive and negative estimated profits is 9 versus 5. Therefore, unconditionally, momentum strategies are more likely to be successful than contrarian strategies. Second, eight strategies among the fourteen are statistically significant – 5 are momentum and 3 are contrarian. More than 50% of strategies generate significant profits. Third, once conditional on the time horizon, I find a systematic relation between successful strategies and holding periods. Momentum strategies are more likely to be profitable in the medium- and long-horizon: among twelve medium- and long-term strategies, eight are momentum, and five of the eight are statistically significant. In contrast, contrarian strategies tend to be significantly profitable at short-term horizons.

The pattern reported above is more obvious when using interest-adjusted returns. The last two columns of Table 2 show that the number of positive versus negative profits is 10:4. Momentum strategies still dominant in the medium- to long-term horizons: eight out of twelve medium- and long-horizon strategies are momentum, and two of them are significantly profitable. On the other hand, contrarian strategies appear to be profitable in the medium-term horizons (i.e. holding for 4- to 8-week): all four strategies are contrarian, and two out the four are statistically significant.

Overall, both contrarian and momentum strategies generate significant profits using base returns and interest-adjusted returns. The results cast doubt on the market efficiency hypothesis and lead further investigation for the inefficiency. Moreover, momentum strategies are more favorable than contrarian. This suggests that an extreme movement in returns will be followed by another extreme movement with the same sign. This finding is in line with the well-documented momentum profits in both the stock market (Jegadeesh and Titman, 1993; Jegadeesh and Titman, 2001; Fama and French, 1996) and the foreign exchange market (Okunev and White, 2003; Bianchi et al., 2004).

IV. Sources of Profits to Trading Strategies

In this section I decompose the sources of abnormal profits to both the contrarian and momentum strategies. This exercise is important because expected profits are comprised of two components: profits that result from time serial autocorrelation and profits that are generated by cross-sectional variation in mean returns. To preview, both are found to be responsible for the above-reported abnormal profits, but the time-series autocorrelation accounts for majority part of profits to both the momentum and contrarian strategies.

I follow the analysis of Conrad and Kaul (1998), Lehmann (1990), and Lo and MacKinlay (1990), and decompose the expected profits by:

$$E[\pi_{t+1}(k)] = -Cov\left[R_{m,t+1}(k), R_{mt}(k)\right] + \frac{1}{N}\sum_{i=1}^{N} Cov\left[R_{i,t+1}(k), R_{it}(k)\right]$$

$$+\frac{1}{N}\sum_{i=1}^{N}[\mu_{it}(k) - \mu_{mi}(k)]^2$$

$$= -C_k + O_k + \sigma^2[\mu(k)]$$

$$= P(k) + \sigma^2[\mu(k)] \qquad (8)$$

where $P(k) = -C_k + O_k$ is the predictability-profitability index, $\mu_{it}(k)$ is the unconditional mean return of currency i, and $\mu_{mi}(k) = \frac{1}{\mathrm{N}}\sum_{\mathrm{i=1}}^{\mathrm{N}} \mu_{it}(k)$ is the unconditional mean return of the equal-weighted market portfolio at time *t*.

Equation (8) shows that the total expected profits result from two parts: the time serial autocorrelation, $P(k)$, and the cross-sectional variance in mean returns, $\sigma^2[\mu(k)]$. $P(k)$ contains two components: C_k is the negative of *k*th-order autocovariance of the equal-weighted market portfolio return, and O_k is the average *k*th-order autocovariance of all N currencies.

More specifically,

$$C_k = R_{m,t+1}(k)R_{mt}(k) - \hat{\mu}_{mt}^2(k) - \frac{1}{N^2}\sum_{i=1}^{N}[R_{i,t+1}(k)R_{it}(k) - \hat{\mu}_{it}^2(k)] \qquad (10)$$

$$O_k = \frac{N-1}{N^2}\sum_{i=1}^{N}[R_{i,t+1}(k)R_{it}(k) - \hat{\mu}_{it}^2(k)] \qquad (11)$$

and

$$\sigma^2[\mu(k)] = \frac{1}{N}\sum_{i=1}^{N}[\hat{\mu}_{it}(k) - \hat{\mu}_{mt}(k)]^2. \qquad (12)$$

In the calculation of the components of expected profits, I assume that individual currency returns are mean stationary. Therefore, each individual currency has a mean return of $\hat{\mu}_{it}(k)$, and the mean return of the market portfolio (i.e. the portfolio that contains all N currencies) is given by $\hat{\mu}_{mt}(k)$. The subscript *t* refers to time *t*.

My purpose is to see which part, the time-series predictability in currency returns (i.e. $P(k) = -C_k + O_k$), or the cross-sectional dispersion in mean returns (i.e. $\sigma^2[\mu(k)]$), or the combination of the two, determine the trading profits. Put in another way, I hope to see the answer to this question: which part has made the major contribution to the market inefficiency?

Panel A in Table 3 reports the results within the first subperiod (1971-1998). The first striking finding is that the contribution of $\sigma^2[\mu(k)]$ to the profits is not constantly equal to 100%. This indicates that currency returns do not follow a random walk. The EMH is therefore evidently violated in the FOREX market.

A benchmark return-generation process (Conrad and Kaul, 1998) will be helpful to understand the underlying logic in interpreting the market efficiency and the components of the profit potential. Assume that all the currency returns follow a random walk:

$$R_{it}(k) = \mu_i(k) + \varepsilon_{it}(k), i = 1, 2, \dots N, \qquad (13)$$

where

$$E[\varepsilon_{it}(k)] = 0 \ \forall i, k \text{ and } E[\varepsilon_{it}(k)\varepsilon_{j,t-1}(k)] = 0 \ \forall \ i, j, k.$$

Also by construction,

$$Cov[R_{it}(k), R_{j,t-1}(k)] = 0 \ \forall \ i, j, k.$$

This essentially implies that there is no either time serial autocorrelation for individual currencies or mean return dispersion across different currencies. All profit potentials are therefore ruled out. However, when combined with Equation (8), it demonstrates that momentum (contrarian) strategies will be profitable (unprofitable) under the assumption of random walks. In this case, $P(k)$ is equal to zero since the exchange rates follow a random walk, and therefore the expected profits are exclusively determined by the cross-sectional dispersion, $\sigma^2[\mu(k)]$. In specific,

$$E[\pi_{t+1}(k)] = \frac{1}{N}\sum_{i=1}^{N}[\mu_{it}(k) - \mu_{mi}(k)]^2 = \sigma^2[\mu(k)], \qquad (14)$$

According to the result in Table 3, the cross-sectional variation in mean returns does not fully account for the expected profits. Therefore, the EMH is violated with convincing evidence in the FOREX market. However, it is surprising that the cross-sectional mean return dispersion only works for the paucity of statistically profitable strategies, which is found by Conrad and Kaul (1998) as well: "… the role of $\sigma^2[\mu(k)]$ has a small effect on profits to trading strategies that use weekly returns."

Second, and more importantly, the time serial autocorrelation accounts for the vast majority of profits to both momentum and contrarian strategies. The contribution percentages of autocorrelation in most of cases are beyond 90%. Some are even over 100% because the reversed effect of mean return variance. The result suggests that the profitability of trading strategies is primarily based on the time-series pattern in returns. Since the time-series effect only occurs in a world where prices do not follow random walks, again we are convinced that the EMH does not hold in the FOREX market.

The evidence of interest-adjusted currency returns is even stronger (Table 4). The time serial profitability is again the predominant source of gains to both momentum and contrarian strategies, while the cross-sectional variation in mean returns makes marginal contributions.

In short, the results suggest that it is the time serial autocorrelation that determines the profits to trading strategies. It is also the exact attribute to the market inefficiency. However, the autocorrelation does not simply work as an implied assumption in the literature. This is consistent with the findings of Okunev and White (2003) and Bianchi et al. (2004).

V. Transaction Costs Consideration

Many researchers believe that transaction costs will virtually eliminate all the profit potentials documented in the literature. For example, Conrad, Gultekin, and Kaul (1997) suggest that a typical 0.2% level of transaction costs is enough to remove any extra profit in the stock market. In the FOREX market, Neely and Weller (1999) find that there is no positive excess returns once a reasonable transaction cost (e.g. one-way transaction cost c = 0.0001 or 0.0002) is taken into account on a daily basis. In this paper, I examine the effect of transaction costs on the profitability on a weekly basis.

Transaction costs in the FOREX market are far less explicit than in the security or commodity market, however. Usually, foreign exchange investors place their orders through a broker, who in turn routes the order to a market maker (dealer) or exchange where the order is actually executed. As a result, two parties charge fees: the broker charges a commission, and the market maker who executes the order on the exchange charges a spread. The spread charge is always a round-trip transaction cost. For example, assume that a broker has a EUR/USD spread of 1.2173/75 from a bank. If the broker widens the spread to 1.2170/78 for his customers, the broker has marked up the spread by 0.0003 on each side. The spread generally accounts for a major part of transaction costs in the FOREX market.

I follow the framework of Lehmann (1990) and calculate the transaction costs per currency per week as

$$tc = 2c\left|w_{it} - w_{i,t-1}\right|, \qquad (13)$$

where c is the one-way transaction cost per dollar transaction (c = 0.0001), w_{it} is the number of dollars invested in currency *i* at time *t*, and $w_{i,t-1}$ is the number of dollars invested in currency *i* at time *t*-1. Using the multiplier 2 preceding c is because the transaction costs in the FOREX market is usually a round-trip cost.

The break-even percentage of transaction costs are computed by dividing the total average profits by the respective transaction costs. The results are reported in the last columns in Table 3 and Table 4. Overall, the percentages of transaction costs required to make the profits zero are substantially large, and much larger than the real market charges. For instance, a large institutional trader in the FOREX market typically faces a 2 to 3 basis points spread charge per one-way trade (Neely and Weller, 1999). Plus a reasonable commission fee, say 1-2% per transaction, the total transaction costs will be no more than 5% per transaction. Even if the institution use all the seven currencies in this paper to form a portfolio on a weekly basis (or it can manipulate a much larger number of currencies in the market), the transaction costs still cannot rule out the profitability that is presented earlier. Therefore, the weekly-return-based trading strategies will remain profitable even with the presence of transaction costs. It is interesting but possible because the weekly trading strategies commit less trading, and therefore are more likely to be profitable due to the fewer transaction costs.

VI. Conclusion

In this paper I analyze the profitability of trading strategies in the foreign exchange market from short-term to long-term by using a sample of weekly currency returns of eight countries (G7 countries, Canada, France, Germany, Italy, Japan, the U.K., and the U.S., plus the European Union). Seven past-performance-based strategies with holding periods ranging between 1 week and 104 weeks have been implemented as contrarian or momentum strategies.

First I find that both the momentum and contrarian strategies generate substantial abnormal profits. This implies that the FOREX market is not an efficient market. Interestingly, momentum strategies appear to be more likely to be successful than contrarian strategies. Once conditional on the time horizon of returns, momentum strategies appear to be profitable in the medium- to long-term while contrarian strategies yield significant profits only in short-term horizons.

To better understand the fundamental determinants to the abnormal profits of trading strategies as well as the exact attribute of the market inefficiency, I examine the relative importance of two components of the profitability: the time-series autocorrelation and cross-sectional dispersion in mean returns. I find that the cross-sectional variance does not fully account for the excess profits, which again indicates that the EMH does not hold in the FOREX market. More strikingly, the time serial autocorrelation is primarily responsible for the extra profits to both momentum and contrarian strategies. It suggests that it is the autocorrelation that causes the market inefficiency in the foreign exchange market. The mean return dispersion, on the other hand, only makes a marginal contribution to the abnormal returns and market inefficiency. Lastly, the profitability holds, even after taking transaction costs into consideration.

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Table 1
Summary Statistics
The data set consists of weekly returns of eight individual currencies for G7 countries, Canada, France, Germany, Italy, Japan, the U.K., and the U.S., plus the European Union from January, 1971 to October, 2007. US dollars are used as the base currency. The continuously compounded weekly returns (Wednesday-to-Wednesday) are computed by accumulating daily returns, which are computed as a first difference in daily rates. The final sample contains 1922 trading weeks. The Jarque-Bera test of normality is computed based on skewness and excess kurtosis with Chi-square distributed with two degrees of freedom. Panel A reports the descriptive statistics for the base returns, and Panel B reports for the interest-adjusted returns.

	Panel A: Base Returns						
	Canada	European Union	France	Germany	Italy	Japan	UK
N	1922	457	1921	1918	1922	1920	1922
Mean (%)	0.59	-1.11	2.09	1.13	4.26	-2.53	3.43
Median (%)	0.98	-4.50	0.00	-2.30	1.31	2.60	-0.70
Std Dev	0.007	0.012	0.014	0.013	0.010	0.013	0.013
t-stat	0.39	-0.19	0.66	0.37	1.82	-0.83	1.18
Skewness	0.21	0.25	0.44	0.19	1.27	-0.39	0.52
Kurtosis	3.71	0.30	3.47	3.58	12.32	3.64	4.11
Autocorrelation							
1	0.011	0.010	0.013	0.012	0.145	0.050	0.044
2	0.076	-0.008	0.031	0.064	0.172	0.059	0.014
3	-0.010	0.042	0.042	0.028	0.157	0.051	0.031
4	0.008	0.036	0.020	-0.028	0.049	0.014	0.016
5	-0.029	0.060	-0.005	0.028	0.079	0.016	0.056
6	0.038	-0.023	-0.036	-0.024	0.004	-0.030	0.004
7	0.003	-0.021	0.004	0.007	0.012	0.003	-0.004
8	-0.032	-0.022	0.043	0.029	0.022	0.015	0.016
9	0.027	-0.008	0.012	0.022	0.009	-0.039	-0.008
10	-0.010	0.059	-0.011	0.046	0.042	0.004	-0.009
Jarque-Bera	1115.6	6.445	1029.4	1034. 5	12670.1	1106.5	1442.0
	(0.00)	(0.04)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Panel B: Interest-adjusted Returns							
	Canada	European Union	France	Germany	Italy	Japan	UK
N	1922	457	1921	1918	1922	1920	1922
Mean (%)	3.82	-1.43	7.37	0.47	12.61	-7.47	8.00
Median (%)	3.56	-6.50	6.19	-1.80	10.35	0.70	2.51
Std Dev	0.007	0.012	0.014	0.013	0.010	0.013	0.013
t-stat	2.52	-0.25	2.34	0.16	5.36	-2.46	2.75
Skewness	0.20	0.26	0.45	0.19	1.30	-0.42	0.55
Kurtosis	3.76	0.31	3.51	3.63	12.69	3.70	4.21
Autocorrelation							
1	0.012	0.005	0.012	0.008	0.152	0.047	0.042
2	0.077	-0.013	0.030	0.060	0.179	0.055	0.012
3	-0.009	0.038	0.041	0.025	0.163	0.047	0.028
4	0.008	0.032	0.019	-0.031	0.056	0.010	0.014
5	-0.029	0.056	-0.005	0.025	0.086	0.013	0.054
6	0.039	-0.027	-0.036	-0.027	0.011	-0.034	0.002
7	0.005	-0.025	0.004	0.005	0.019	-0.001	-0.006
8	-0.031	-0.026	0.043	0.026	0.029	0.011	0.014
9	0.028	-0.012	0.012	0.019	0.017	-0.043	-0.010
10	-0.009	0.055	-0.011	0.043	0.050	0.000	-0.010
Jarque-Bera	1146.8	6.898	1048.1	1066.4	13443.2	1154.4	1517.3
	(0.00)	(0.03)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Table 2

Average profits to return-based trading strategies for different holding periods

The table reports average profits to zero-cost trading strategies that buy winners and sell losers based on their past performance relative to the performance of an equal-weighted index of all N currencies. One-week return is used to evaluate the past performance for individual currencies. The dollar profits are given by $\pi_{t+1}(k) = \sum_{i=1}^{N} w_{it}(k) R_{i,t+1}$, $i = 1, 2, 3, \ldots N$, where $w_{it}(k) = \pm\frac{1}{N}[R_{it}(k) - R_{mt}(k)]$, denoting the faction of the portfolio devoted to currency i at time t, $R_{it}(k)$ is the return on currency i at time t, $R_{mt}(k)$ is the return on the equal-weighted portfolio of all N currencies ($R_{mt} = \frac{1}{N}\sum_{i=1}^{N} R_{it}$), and k is the length of holding time interval (k = 1, 4, 8, 13, 26, 52, 104, 156, 208, and 260 weeks). The positive or negative sign of $\pi_{t+1}(k)$ refers to a momentum or contrarian strategy. The first two columns report the profits of base-return-based strategies; the last two columns report the profits of trading strategies that use interest-adjusted returns. t-statistics are shown in the parentheses. All profits are multiplied by 10^6.

Strategy	Base Returns		Interest-adjusted Returns	
Interval	1971-1998	1999-2007	1971-1998	1999-2007
1 week	0.23	-4.84	0.73	0.72
	(0.38)	(-7.85)	(0.80)	(0.78)
4 weeks	1.22	0.83	-0.59	-0.46
	(2.50)	(1.37)	(-0.64)	(-0.50)
8 weeks	2.40	-2.52	-1.90	-2.08
	(5.20)	(-4.53)	(-2.33)	(-2.54)
13 weeks	2.96	2.34	0.76	0.66
	(6.52)	(3.86)	(0.82)	(0.72)
26 weeks	-0.82	-0.80	0.87	0.90
	(-2.00)	(-1.41)	(0.98)	(1.01)
52 weeks	-0.07	0.51	1.91	1.83
	(-0.16)	(0.74)	(1.97)	(1.89)
104 weeks	0.17	3.02	4.11	4.03
	(0.42)	(4.55)	(3.85)	(3.81)

Table 3

The decomposition of average profits to trading strategies that use base returns

The table reports the components of extra profits to both contrarian and momentum strategies from short-term to long-term. All trading strategies are formed as zero-cost portfolios that buy winners and sell losers based on their past performance. One-week return is used to evaluate the past performance for individual currencies. The dollar profits are given by $\pi_{t+1}(k) = -C_k + O_k + \sigma^2[\mu(k)] = P(k) + \sigma^2[\mu(k)]$, where $P(k) = -C_k + O_k$ is the index of predictability-profitability, C_k is the negative of kth-order autocovariance of the equal-weighted market portfolio return, O_k is the average kth-order autocovariance of all the N currencies, and $\sigma^2[\mu(k)]$ is the cross-sectional variance in mean returns. $I_t(k)$ is the average dollar long (short) position in each strategy. Round-trip break-even transaction costs are calculated by dividing the total average profits by the respective transaction costs tc, where $tc = 2c|w_{it} - w_{i,t-1}|, c = 0.0002$. t-statistics are shown in the parentheses. All profits are multiplied by 10^6. All profitable momentum strategies are marked in bold, while all profitable contrarian strategies are in normal print.

Strategy Interval	$E[\pi_{t+1}(k)]$	$P(k) = -C_k + O_k$	$\sigma^2[\mu(k)]$	$\%P(k)$	$\%\sigma^2[\mu(k)]$	$I_t(k)$	Break-even transaction costs
Panel A:	*1971-1998*						
1 week	**0.23**	**0.13**	**0.10**	**55.5**	**44.5**	**3.52**	**13.9**
	(0.38)	**(0.21)**	**(66.72)**			**(136.45)**	
4 weeks	**1.22**	**1.12**	**0.10**	**91.8**	**8.2**	**3.52**	**73.6**
	(2.50)	**(2.29)**	**(67.75)**			**(136.50)**	
8 weeks	**2.40**	**2.31**	**0.10**	**96.0**	**4.0**	**3.52**	**144.9**
	(5.20)	**(4.99)**	**(68.24)**			**(136.56)**	
13 weeks	**2.96**	**2.86**	**0.10**	**96.6**	**3.4**	**3.52**	**178.7**
	(6.52)	**(6.30)**	**(67.28)**			**(136.65)**	
26 weeks	-0.82	-0.93	0.10	112.8	-12.8	3.53	-49.7
	(-2.00)	(-2.26)	(66.99)			(136.86)	
52 weeks	-0.07	-0.18	0.12	269.2	-169.2	3.54	-4.2
	(-0.16)	(-0.44)	(65.57)			(137.30)	
104 weeks	**0.17**	**0.03**	**0.13**	**20.3**	**79.7**	**3.56**	**10.2**
	(0.42)	**(0.09)**	**(64.55)**			**(138.20)**	

Strategy Interval	$E[\pi_{t+1}(k)]$	$P(k) = -C_k + O_k$	$\sigma^2[\mu(k)]$	$\%P(k)$	$\%\sigma^2[\mu(k)]$	$I_t(k)$	Break-even transaction costs
Panel B:	*1999-2007*						
1 week	-4.84	-4.90	0.06	101.4	-1.4	1.44	-293.5
	(-7.85)	(-7.96)	(34.12)			(83.61)	
4 weeks	**0.83**	**0.77**	**0.06**	**92.5**	**7. 5**	**1.45**	**50.2**
	(1.37)	**(1.27)**	**(35.84)**			**(83.69)**	
8 weeks	-2.52	-2.57	0.05	102.0	-2.0	1.45	-152.7
	(-4.53)	(-4.62)	(38.55)			(83.81)	
13 weeks	**2.34**	**2.29**	**0.05**	**97.7**	**2.3**	**1.45**	**141.8**
	(3.86)	**(3.77)**	**(41.79)**			**(83.95)**	
26 weeks	-0.80	-0.85	0.05	106.4	-6.4	1.46	-47.6
	(-1.41)	(-1.50)	(42.27)			(84.33)	
52 weeks	**0.51**	**0.45**	**0.06**	**88.6**	**11.4**	**1.47**	**30.0**
	(0.74)	**(0.66)**	**(37.64)**			**(85.10)**	
104 weeks	**3.02**	**2.94**	**0.09**	**97. 2**	**2.8**	**1.49**	**175.3**
	(4.55)	**(4.43)**	**(27.97)**			**(86.77)**	

Table 4

The decomposition of average profits to trading strategies that use interest-adjusted returns

The table reports the components of extra profits to all the trading strategies, contrarian or momentum from short-term to long-term. The trading strategies are zero-cost strategies that buy winners and sell losers based on their past performance. One-week interest-adjusted return is used to evaluate the past performance for individual currencies. The dollar profits are given by $\pi_{t+1}(k) = -C_k + O_k + \sigma^2[\mu(k)] = P(k) + \sigma^2[\mu(k)]$, where $P(k) = -C_k + O_k$ is the index of predictability-profitability, C_k is the negative of kth-order autocovariance of the equal-weighted market portfolio return, O_k is the average kth-order autocovariance of all the N currencies, and $\sigma^2[\mu(k)]$ is the cross-sectional variance in mean returns. $I_t(k)$ is the average dollar long (short) position in each strategy. Round-trip break-even transaction costs are calculated by dividing the total average profits by the respective transaction costs tc, where $tc = 2c|w_{it} - w_{i,t-1}|, c = 0.0001$. t-statistics are shown in the parentheses. All profits are multiplied by 10^6. All profitable momentum strategies are marked in bold, while all profitable contrarian strategies are in normal print.

Strategy Interval	$E[\pi_{t+1}(k)]$	$P(k) = -C_k + O_k$	$\sigma^2[\mu(k)]$	$\%P(k)$	$\%\sigma^2[\mu(k)]$	$I_t(k)$	Break-even transaction costs
Panel A:	*1971-1998*						
1 week	**0.73**	**0.63**	**0.10**	**85.5**	**14.5**	**1.02**	**44. 5**
	(0.80)	**(0.68)**	**(43.80)**			**(42.39)**	
4 weeks	-0.59	-0.69	0.105	117.1	-17.1	1.02	-35.6
	(-0.64)	(-0.75)	(46.41)			(42.43)	
8 weeks	-1.90	-1.98	0.08	104.3	-4.3	1.02	-115.5
	(-2.33)	(-2.43)	(48.83)			(42.47)	
13 weeks	**0.76**	**0.67**	**0.09**	**88.1**	**11.9**	**1.02**	**46.0**
	(0.82)	**(0.73)**	**(51.62)**			**(42.53)**	
26 weeks	**0.87**	**0.79**	**0.08**	**90.3**	**9.7**	**1.03**	**52.3**
	(0.98)	**(0.89)**	**(52.39)**			**(42.68)**	
52 weeks	**1.91**	**1.83**	**0.08**	**95.6**	**4.4**	**1.05**	**113.3**
	(1.97)	**(1.89)**	**(54.59)**			**(42.99)**	
104 weeks	**4.11**	**3.99**	**0.13**	**97.0**	**3.0**	**1.08**	**239.5**
	(3.85)	**(3.74)**	**(37.66)**			**(43.67)**	

Strategy Interval	$E[\pi_{t+1}(k)]$	$P(k) = -C_k + O_k$	$\sigma^2[\mu(k)]$	$\%P(k)$	$\%\sigma^2[\mu(k)]$	$I_t(k)$	Break-even transaction costs
Panel B:	*1999-2007*						
1 week	**0.72**	**0.66**	**0.05**	**92.4**	**7.6**	**1.02**	**43.3**
	(0.78)	**(0.72)**	**(61.79)**			**(42.37)**	
4 weeks	-0.46	-0.51	0.05	111.5	-11.5	1.02	-27.8
	(-0.50)	(-0.55)	(69.08)			(42.40)	
8 weeks	-2.08	-2.12	0.04	101.9	-1. 9	1.02	-126.2
	(-2.54)	(-2.59)	(132.58)			(42.45)	
13 weeks	**0.66**	**0.62**	**0.03**	**95.0**	**5.0**	**1.02**	**40.0**
	(0.72)	**(0.69)**	**(110.87)**			**(42.50)**	
26 weeks	**0.90**	**0.87**	**0.03**	**97.0**	**3.0**	**1.03**	**53.9**
	(1.01)	**(0.97)**	**(164.58)**			**(42.65)**	
52 weeks	**1.83**	**1.78**	**0.05**	**97.3**	**2.7**	**1.04**	**108.8**
	(1.89)	**(1.84)**	**(192.75)**			**(42.96)**	
104 weeks	**4.03**	**3.94**	**0.10**	**97.6**	**2.4**	**1.08**	**235.0**
	(3.81)	**(3.72)**	**(150.19)**			**(43.64)**	