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Seasonal Equity Carry Trades between the US and Japan

Supervisor
Ch. Prof. Eric Girardin

Graduand
Giulia Zanusso
Matriculation Number 867232

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Contents

1. Introduction

During the 1980s, 1990s, and over the last 15 years, new findings on the existence of irregularities in stock prices have emerged, contradicting the "*Efficient Market Hypothesis"* (EMH) introduced by *Eugene Fama* in 1970. Up to some decades ago, the idea that "market prices fully incorporate all available information" was widely accepted, neglecting the possibility for investors to earn higher profits due to return unpredictability. EMH questions the ability of investors to detect mispriced securities, so scholars started looking for evidence against EMH: different behaviors in stock prices at a specific time of the day, the week, the month, or the year have been observed, showing the presence of calendar anomalies in the financial markets. Therefore, the growing academic research supporting "markets' inefficiency" and the clear evidence of investors' ability to gain profits from active portfolio management, looking for mispriced securities, and exploiting arbitrage opportunities, violate information efficiency.

Calendar anomalies have received abundant attention during the last 20 years, literature supporting the presence of monthly seasonality in the stock markets is copious, while there are contradictory findings about seasonality in the foreign exchange markets. Just a few studies have jointly analyzed the seasonal patterns in both stock and foreign currency markets, and even less have focused on their transmission channel, namely the equity capital flows. They are the base of equity carry trade strategies, according to which people should invest in stock markets with the highest expected returns and short those with the lowest returns (*Cenedese et al., 2016)*; they differ from currency carry trades, which look for risk-free profit opportunities using currency or forex arbitrages. The relationship between stock and foreign exchange markets has been examined not long ago under a new parity condition known as Uncovered Equity Parity (UEP) (*Hau and Rey, 2006*), but only *Girardin and Salimi (2019)* have recently analyzed its seasonal character, pointing out the necessity of considering the bilateral equity flows as the intrinsic connection between the two markets.

In this study we investigate monthly seasonality in the foreign exchange returns, looking for evidence that a seasonal outperformance of a country's stock market over another is associated with similar seasonal patterns in both foreign exchange returns and the bilateral capital flows, suggesting the existence of equity carry trades opportunities. Our analysis focuses on two leading world economies, US and Japan over a 40-year sample. The S&P500 and the NIKKE225 are taken respectively as representative of the US and the Japanese stock markets the USD/JPY currency pair and the bilateral equity flows between the US and Japan are considered to examine the seasonal anomalies documented by past literature, and to look for new evidence on the seasonal synchronicity among the analyzed variables, considering the bilateral equity flows as the engine of equity carry trades.

Inconclusive and contradictory findings about seasonality in the US and Japanese stock markets have been abundantly provided over the years: *Bouman and Jacobsen (2002)* show the presence of a significant *Sell in May effect* in both countries' stock markets, *Lucey and Zhao (2008)* and *Haggard and Witte (2010)* argue that the *Halloween Effect*[1] detected in the S&P500 was simply a reflection of the *January effect*; however, according to more recent literature *(Plastun A., Plastun V., 2018)*, no anomalous increases of stock prices during the month of January have been observed in the US stock market since the middle of the 20th century, suggesting that the *January effect* may have vanished during recent years. *Shingeki, Tkashi, and Katsuhiko (2013)* point out the existence of a new calendar effect in the Japanese stock market, the *Dekansho-bushi effect*; it should be distinguished from the previously found *Sell in May effect* since "Japanese stocks perform well in June and poorly in November and December". On the other hand, academic studies on seasonality in the foreign exchange market are limited and inconclusive, many of them do not find significant monthly effects on the USD/JPY currency pair.

The main drawback of past literature findings is the use of parametric and non-parametric tests of the equality of monthly means and variances and linear models. While, as shown by *Girardin and Salimi* (2019), a nonlinear framework could be

[1] According to *Bouman and Jacobsen* (2002) investors should sell their stock in May and "buy them back on St. Leger Day" (the date of a classic horse race run at Doncaster in England every September). However, *Michael O'Higgins and John Downes* (1990) report a similar US strategy related to market timing: the Halloween indicator. It is "so named because it would have you in the stock market starting October 31 and through April 30 and out of the market for the other half of the year".

preferable in detecting non-linear patterns, typical of seasonality in the financial markets.

The relation between stock and foreign exchange returns through capital flows has been investigated by *Hau and Rey (2006)*, who provided the first empirical evidence on Uncovered Equity Parity (UEP). According to UEP, when returns on foreign equity holdings outperform returns on domestic holdings, investors repatriate their foreign equity capital due to the desire to reduce their FX exposure, inducing a foreign currency depreciation[2]. Therefore, based on portfolio-rebalancing theory[3], UEP asserts the existence of a negative relation between stock and foreign exchange returns. Over the years UEP has been hotly debated: it received complete support from *Cappiello et al.* (2005, 2007) and *Kim* (2011), while *Cenedese et al*. (2016) totally rejected it, arguing that "the failure of UEP is primarily due to investors' return chasing behavior". *Curcuru et al. (2014)* claim that portfolio shifts are mainly due to equity carry trade strategies rather than risk reduction behaviors of investors.

Even if this literature focuses on the relation between stock and foreign exchange returns, no attention has been put on its seasonal character; *Girardin and Salimi (2019)* have shown for the first time the presence of a matching seasonality between stock returns differentials and foreign exchange returns. This result has been achieved using a regime-dependent methodology, showing the necessity to use a non-linear framework to capture seasonality in the financial markets.

Following *Girardin and Salimi (2019)*, in this study we deal with a seasonal adjustment analysis based on moving average filters, focusing on the seasonal components extracted from the observed series. The seasonal adjustment analysis is run with the X-

[2] Curcuru, S.E., Thomas, C.P., Warnock, F.E., Wongswan, J., 2014. Uncovered equity parity and rebalancing in international portfolios. Journal of International Money and Finance, Vol. 47, pp. 86–99. https://doi.org/10.1016/j.jimonfin.2014.04.009.

[3] According to portfolio-rebalancing theory, risk-averse investors systemically rebalance their portfolio changing allocations to stock, bonds, and other investment, since the optimal portfolio at the beginning of the period is not necessary the optimal one in the following period. International equity portfolio returns are exposed to both market and currency risks, so given the limited hedging opportunities, a risk-averse investor try to avoid over-exposure to foreign exchange risk, reallocating his equity capital.

13ARIMA-SEATS software[4], which allows to investigate the non-stable seasonal patterns in the stock returns differentials, the foreign exchange returns, and the net equity flows. It enables us to compare the seasonal shifts detected over the years in the three variables and to investigate the presence of any seasonal overlaps between the stock returns differentials, the foreign exchange returns, and the net equity flows.

Our research provides four main results. First, we confirm the presence of the *Dekansho-bushi effect* in the Japanese stock market as shown by *Shingeki, Tkashi, and Katsuhiko* (2013), underlying the difference with the well-known *Sell in May effect* documented by *Bouman and Jacobsen (2002);* we support recent studies about the disappearance of the *January effect* from the US stock market confirming only the existence of a significant *Sell in May* effect, as shown by *Bouman and Jacobsen (2002).* Second, we provide new evidence about seasonal patterns in the USD/JPY currency pair: the Bank of Japan's campaigns of purchases and sales of US dollars to affect the yen value in specific times over our 40-year sample, are found to be the main driver of seasonality in the USD/JPY exchange rate. Third, analyzing the stock returns differentials and the foreign exchange returns in five different sub-periods from December 1980 to December 2019, we find some significant overlaps in the seasonal patterns of the US-Japan stock returns differentials and the USD/JPY returns. We get evidence supporting *Hau and Rey's* (2006) theory only from December 1980 to December 1998, while during more recent years we observe a positive correlation between equity and currency returns, showing the presence of seasonal equity carry trade opportunities between the US and Japan, at least from December 2011 to December 2019. An investor, who during this period would have moved her capital to the US in Februarys and in Julys, would have gained respectively an overall gross return in excess of 2.8 and 2.6 percentage points, benefiting not only from the higher stock returns in the US than in the Japanese stock market but also from a USD appreciation in the same months. While, for the same reasons, investing in the Japanese stock market in Octobers would have provided an overall gross return

[4] The X-13ARIMA-SEATS software is an extension of the well-known Census X-11, produced, distributed, and maintained by the US Bureau of Census. It decomposes a time series into a trend, a seasonal and an irregular component, removing the seasonal component from the data. For the purpose of this study, we focus on the seasonal component, which is modeled as a periodic spline with time-varying parameters, assuring no data distortion.

in excess of 1.7 percentage points. Forth, the inconclusive results obtained in our analysis of the net equity flows between the US and Japan, as the transmission channel of seasonality between stock returns differentials and foreign exchange returns, may support previous literature findings about the uncharacteristic behavior of Japanese equity capital flows[5], but they can also pave the way toward further investigations, focusing not only on the direct equity flows between the US and Japan, but also on the bilateral indirect flows that may take place through third countries or offshore financial centers.

Finally, we contribute to the literature in three ways. Differently from previous papers, we use a non-linear framework, showing the limits of linear models and of the usual parametric and non-parametric tests of the equality of means in capturing seasonality in financial markets. We provide new evidence about seasonality in the USD/JPY currency pair, underlying the role of the Bank of Japan as the main driver of the seasonal movements detected in the USD/JPY exchange rate. Looking for overlaps between the seasonal patterns in the stock returns differentials and in the foreign exchange returns, we contribute to study the seasonal relation between equity and currency returns. *Hau and Rey's (2006)* theory is not completely contradicted by our results, since evidence in favor of UEP is found in the first 20 years of our sample. However, we support *Curcuru et al. (2014)* claiming that carry trades and return-chasing behaviors drive equity capital flows, even if some exceptions can be observed during turmoil periods when investors are found to be more risk-averse. On the other hand, evidence of seasonal equity carry trades is found during the last 10 years of analysis, showing that in specific months investors can not only benefit from the outperformance of a stock market over another but they can also gain from a simultaneous currency appreciation or depreciation. Finally, our results let us remark that "equity carry trades may be a seasonal phenomenon that can be present for decades", supporting *Girardin and Salimi's (2019)* recent findings.

This study is organized as follows: section 2 reviews previous literature; section 3 presents the data and the method used to analyze seasonality. The empirical results of

[5] See *Brennan and Cao (1997), Brooks et al. (2004)* and *Hau and Rey (2006)* and *section 4.3.2* about net equity flows.

the parametric and non-parametric tests of seasonality on the stock returns differentials, the USD/JPY returns, and the net equity flows are presented at the beginning of section 4, followed by the X-13ARIMA-SEATS estimation results about seasonality in the two countries' stock markets and on the seasonal relation between stock returns differentials, foreign exchange returns, and net equity flows. Section 5 concludes.

2. Review of Literature

The Efficient Market Hypothesis (EMH), also known as the Random Walk Theory[6] (*Kendal*, 1953), was introduced by *Eugene Fama* in 1970. Financial academics widely accepted it, and for many years the shared view was that "stock markets are extremely efficient in reflecting information about individual securities and the stock market as a whole." Thus, according to EMH, neither technical nor fundamental analysis would enable an investor to get higher returns than those achieved by holding a randomly selected portfolio of stocks, since new information is instantaneously reflected in actual prices. By the late 1980s, many financial economists and statisticians began to believe in stock prices' return predictability, starting to investigate more the possible "markets' inefficiency". During the 1990s and through the last 15 years, many academic studies proved the existence of irregularities in stock prices such as calendar anomalies and return predictability *(Rossi, 2016).* Therefore, returns from active portfolio management, arbitrage opportunities, or profits associated with markets' different behaviors at a specific time of the day, the week, the month, or the year, violate information efficiency.

Numerous studies have been conducted on calendar anomalies in the stock markets, while literature about seasonality in the foreign exchange market is more limited. Concerning the US stock market, *Bouman and Jacobsen (2002)* show that on average, returns in the US stock market were more than five percent higher between November

[6] EFM is linked to the concept of "random walk," which is a term used in finance to describe the pattern of a price series, considering all price changes as random deviations from previous prices. The Random Walk Theory is based on the idea that since information are immediately incorporated in stock prices, tomorrow price change will reflect only tomorrow news and it will be independent of today price.

and April than they were during the remainder of the year, proving the existence of a significant *Sell in May effect* in the S&P500 between January 1970 and August 1998. *Lucey and Zhao (2008)* and *Haggard and Witte* (*2010*) confirm previous findings, suggesting that the *Halloween effect* was a reflection of the *January effect*. However, the anomalous increase of US stock prices during the month of January, following the drop that typically happens in December, was documented in the past, while recent literature has shown that the *January effect* has not been present any more in the US stock market since the middle of the 20th century *(Plastun A., Plastun V., 2018). Kato and Schallheim (1985)* prove the existence of the *January effect* also in value and equally weighted Japanese indexes, but in a distant period. *Shigeyuki Hamori (2001)* reports that seasonality in the TOPIX between January 1971 and December 1997 "was found to be deterministic but not stochastic"; a significant *Sell in May effect* is documented by *Bouman and Jacobsen (2002),* analyzing the value-weighted Japanese index from January 1970 to August 1998, while a more recent study has pointed out a new seasonal pattern in the Japanese stock market: the *Dekansho-bushi effect*. According to *Shingeki, Tkashi, and Katsuhiko (2013),* this new calendar anomaly should be distinguished both from the *January* and the *Sell in May effects,* claiming that "Japanese monthly stock returns are significantly higher during the January to June versus the July to December periods". The *Dekansho-Bushi effect* is found to be independent of previously reported seasonal patterns: results didn't change when January was excluded from the sample months, and even if it can be similar to the calendar anomaly reported by *Bouman and Jacobsen (2002*), most Japanese stocks perform well until June but less so from July to the end of the year, suggesting a different behavior from the one supposed by the *Sell in May effect,* especially in October. On the other hand, past literature on seasonality in the USD/JPY exchange market is limited and contradictory: *Celini and Cuccia (2011)* analyzed the JPY/USD currency pair from 1974 to 1990 and from 1991 to 2010, concluding that JPY/USD data were not seasonal over both periods.

The relation between stock and foreign exchange markets has been recently examined by *Hau and Rey (2006)*, who have provided the first empirical evidence supporting the existence of a new parity condition known as Uncovered Equity Parity (UEP). Based on portfolio-rebalancing theory, UEP predicts that "local-currency equity return appreciation is offset by currency depreciation." This implies that when foreign equity holdings outperform domestic holdings, investors repatriate their foreign equity capital due to the desire to reduce their FX exposure, inducing a foreign currency depreciation. Indeed, UEP is founded on two different pillars: on one side it asserts that there is a negative correlation between equity returns and currency returns, on the other hand, it assumes investors' portfolio-rebalancing and repatriation of investment behaviors. This new parity condition has been hotly debated: evidence supporting the relation between stock returns differentials and exchange rate returns is abundant, while there are contradictory findings about the rationale behind portfolio rebalancing. UEP has received complete support from *Cappiello et al. (2005, 2007)* and *Kim (2011)*, partial support by *Curcuru et al. (2014),* while Cenedese *et al*. *(2016)* have totally rejected it. *Curcuru et al. (2014)* found that "portfolio shifts are related to past returns in the underlying equity market" supporting UEP, but they argued that carry trade strategies or the return-chasing behavior of investors may provide a better explanation for this rebalancing. Examining US investors' portfolio reallocations and returns, they observed that "US investors tend to rebalance away from equity markets that recently performed well and move into equity markets just before relatively strong performance", suggesting tactical reallocations to increase returns rather than reduce risk. This evidence partially contradicts UEP, supporting findings about the existence of equity carry trades strategies, as suggested by *Cenedese et al*. *(2016).*

A large literature[7] provides evidence about the presence of a positive correlation between stock returns and currency returns, showing that investors often increase their holding in markets that have recently outperformed, inducing an increase in the demand for currencies of countries with strong equity markets, causing their appreciation. On the other side, *Cho (2016)* and *Fuertes et al*. *(2018)* show that stock returns are generally negatively correlated with currency returns both in the US and in Japan as well as in all developed countries, supporting the UEP condition, while it is not the same for the emerging markets. Furthermore, analyzing the connection between stock markets and currency markets through capital flows, *Hau and Rey (2006)* and *Curcuru et al. (2014)*

[7] See *Froot, Scharfstein, and Stein* (1992); *Bohn and Tesar* (1996); *Griffin, Nadari, and Stulz* (2004); *Chabot, Ghysels, and Jagannathan* (2014).

find no positive correlation between net bilateral capital outflows and domestic currency depreciation for several countries, including Japan. However, according to *Brennan and Cao (1997), Brooks et al. (2004),* and *Hau and Rey (2006)*, Japanese capital flows behave differently from other developed countries. *Brennan and Cao (1997)* argue that “capital moves out of Japan when the yen appreciates”, *Brooks et al. (2004)* find no correlation between the foreign exchange market and the Japanese capital flows, and *Hau and Rey (2006)* claim that Japanese equity capital flows have an uncharacteristic behavior as a consequence of yen-carry trades: investors tend to exploit extremely low-interest rates generating significant capital flows in and out the Japanese bond market, “obscuring” equity capital flows.

With respect to the seasonal character of the relation between stock and foreign exchange markets, *Girardin and Salimi (2019)* for the first time linked the literature on seasonality in the equity market and in the foreign exchange market, showing the necessity to study their connection. Differently from previous academic papers, they used a non-linear framework, dealing with Markov-switching regressions for the exchange rate returns, stock returns differentials, and the net bilateral equity flows, identifying different seasonal patterns through the various regimes for four decades in the US - Germany case. They support the presence of equity carry trades, showing that they not only exist but have also been exploited by investors, as proved by the observed matching seasonality between the net equity flows, the stock returns differentials, and the foreign exchange returns in specific months of the year.

3. Data and Methodology

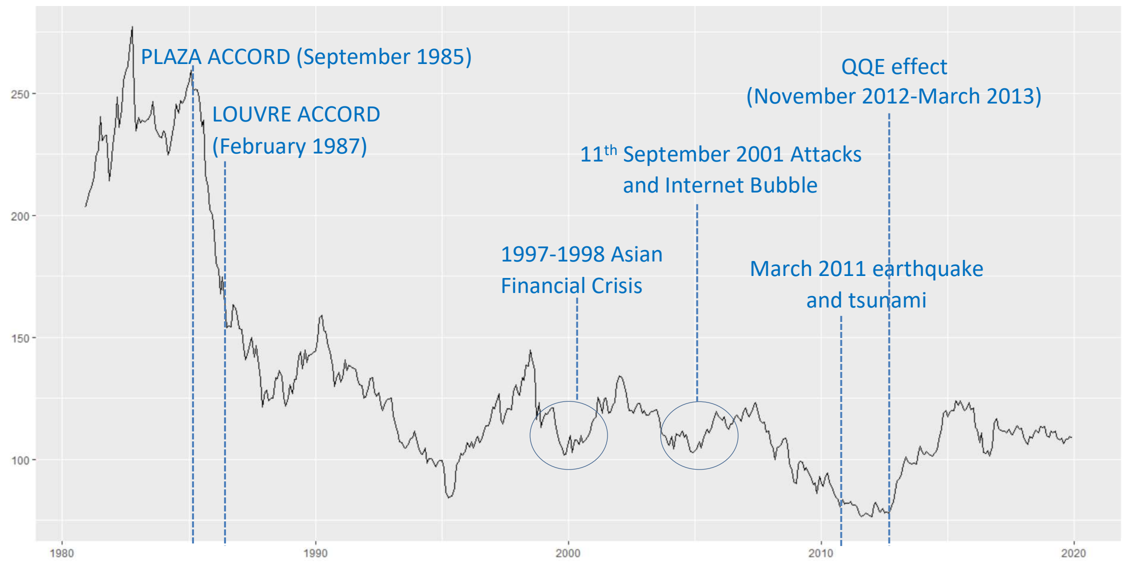
3.1 Data

To assess the existence of seasonal equity carry trades between the US and Japan, four different contexts are analyzed: the foreign exchange market, the two countries’ stock markets, and the bilateral equity flows between the US and Japan. The analysis is run over 40 years, considering all transformations in the seasonal patterns generated by government interventions, policy, and cultural changes. The studied period goes from

December 1980 to December 2019, starting just after the official easing of Japan's capital controls[8], and ending on the eve of the covid-19 pandemic.

To analyze seasonality in the USD/JPY exchange market, the Japanese yen to US dollar spot prices have been downloaded from the Pacific Exchange Rate service[9]. We use end-of-month quotes of the USD/JPY exchange rate from December 1980 to January 2019.

Figure 1: USD/JPY spot prices from December 1980 to December 2019



USD/JPY end-of-month quotes have been retrieved from the Pacific Exchange Rate service: https://fx.sauder.ubc.ca/data.html

USD/JPY monthly closing quotes show how many Japanese yen are needed to purchase one US dollar (the base currency).

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[8] At the end of 1949, the Foreign Exchange and Foreign Trade Law prohibited foreign exchange transactions with only a few exceptions; under this system, there were no restrictions for exports, but imports of goods and services and international financial transactions were heavily regulated. No significant liberalizations from capital controls were conducted until 1980, isolating Japan's financial markets from external influences. In December 1980, the Foreign Exchange and the Foreign Trade Control Law were revised: they established that "external transactions were free unless otherwise legislated", reversing the principle of 1949. However, this new condition did not immediately force Japan to complete freedom of capital movements, surely arbitrage between domestic and international markets was facilitated after 1980, both inflows and outflows started to rise to new levels, but investment opportunities sharply increased especially after the ending of limits on the conversion of foreign currencies into yen. Until June 1984, the "swap limit rule" restricted the amount of yen that could be obtained by selling foreign currencies borrowed in the markets abroad.
The Liberalization of Japan's Financial Markets: some major themes. BIS Economic Paper No. 34, pp. 15-21. https://www.bis.org/publ/econ34.htm

[9] https://fx.sauder.ubc.ca/data.html

As shown in *Figure 1*, the first ten years of our sample were characterized by huge government interventions in the currency market: from the beginning of 1980 to March 1985 the US dollar appreciated by over 47.9%, dropping sharply just after the Plaza Accord. The Plaza Accord was an agreement between the G5 nations (the United States, the United Kingdom, West Germany, France, and Japan) to induce a depreciation of the USD against the other four currencies over a two-year period. In September 1985, the Japanese yen was pushed up and the USD down, trying to reduce America's trade deficits and Japan's trade surpluses. In February 1987 the Louvre Accord stopped the continuing decline of the dollar and stabilized exchange rates, but the strong yen led to a major short-term shock to Japanese export-based industries. To offset the effects of this shock, the Japanese government began a massive campaign of expansionary monetary and fiscal policy trying to boost the domestic economy, but it gave rise to asset price bubbles in Japan's financial and real estate markets through the late 1980s. Low growth and deflation characterized the 1990s, after a period of zero interest rate policy during 1999 and 2000, the Bank of Japan introduced quantitative easing in March 2001. The BoJ purchased Japanese Government Bonds trying to restrain the Japanese economy from deflation and exited quantitative easing in March 2006. In October 2010, the impact of the Great Financial Crisis forced the Bank of Japan to introduce the Comprehensive Monetary Easing[10] (CME) to fight again against deflation and low growth. In April 2013, the Bank of Japan, pressured by Shinzo Abe (the President of Japan's Liberal Democratic Party and Prime Minister), announced the "Quantitative and Qualitative Easing" (QQE): under this policy, BoJ purchased a huge amount of long-dated Japanese government bonds and ETFs, to increase base money by 100% and aim at achieving a 2% inflation target in two years. Consequently, the yen weakened by 25% from November 2012 to May 2013.

As already shown, the USD/JPY currency pair has been strongly affected by the monetary policy measures adopted by the Bank of Japan over the years, but it was even more influenced by BoJ interventions in the foreign exchange market: it bought and sold US dollars in specific moments from 1985 to 2011 aiming to affect the yen value.

[10] One key measure in the Comprehensive Monetary Easing was an asset purchase program of government securities and private assets.

Figure A1 in Appendix A shows the Bank of Japan's purchases of the US dollar against the Japanese yen from April 1991 to March 2022[11]. It intervened for the first time in the foreign exchange market between 1985 and 1988 because of the Plaza and the Louvre Accords. A second round of interventions took place from 1991: in 1997 and 1998 the Asian financial crisis made the yen drop to nearly 148 to the dollar, requiring the help of the US authorities, who jointly with the Bank of Japan bought the yen to strengthen it. Interventions continued during the early 2000s; both the 11th of September 2001 attacks in the United States and the Internet Bubble made the Bank of Japan intervene in the USD/JPY exchange market up to April 2004. In September 2010 Japan intervened in the currency market for the first time after six years, and in March 2011 the G7 jointly agreed to stop the yen strength, which sharply increased just after the Tōhoku earthquake as a consequence of the speculation pursued by Japanese firms, which would repatriate foreign assets to pay for reconstruction. The last interventions of the Bank of Japan in the foreign exchange rate were in August and in October 2011, to help the economy recover from the slump triggered by the March earthquake and the tsunami.

To compare the seasonal patterns detected in the foreign exchange market with those observed in the two countries' stock markets, the NIKKEI225 and the S&P500 closing prices have been downloaded as the representative of respectively the Japanese and the US stock markets.

Monthly closing quotes of the NIKKEI225 from December 1980 to December 2019 have been obtained from Investing.com[12] and are reported in *Figure 2.* We can see that after the Plaza Accord, the Japanese stock market started an upward trend reaching a peak on the 29th of December 1989, and then precipitously declined in the early 1990s, when the Japanese recession was contrasting with the US bull market. A few Japanese economists talked about "Japan's wild asset-price bubble" concerning what happened in the Japanese stock market between the late 1980s and the early 1990s; one of them

[11] Japanese Bank purchases of USD against JPY have been downloaded from the FRED database. https://fred.stlouisfed.org/series/JPINTDUSDJPY
[12] https://www.investing.com/

was Kazuo Ueda[13], who activated the alarm about overvalued stocks in the late 1980s. Many Japanese shares were traded at price-to-earnings ratios of well over 60, compared with the global norm of 14 to 16. Only by the mid-2000s, P/E ratios had retreated to international norms. Tax incentives, the Nippon Individual Savings Account[14], and the defined-contribution pension plans were introduced to revive investors' confidence in the Japanese stock market, even if the long bear market reduced Japanese investors' faith in stocks as an asset. The rebound in the NIKKEI225 from 2003 to 2007 brought hopes about Japan's recovery, but by late 2008 it started falling again and in March 2009 it hit its lowest point since October 1982. Finally, the most recent crisis was in March 2011, a byproduct of the Tōhoku earthquake and tsunami that caused the Fukushima nuclear disaster. The Japanese government succeeded with four supplemental fiscal packages and with the introduction of the "Quantitative and Qualitative Easing" in April 2013 to arrest deflation, making the NIKKEI225 rise by 80% between November 2012 and May 2013.

To analyze seasonality in the US stock market, monthly closing quotes of the S&P500 have been downloaded from the FRED database[15] and are reported in *Figure 3*.

In addition, to investigate the presence of equity carry trade opportunities between the US and Japan, we will investigate monthly seasonality in the foreign exchange returns, looking for evidence that a seasonal outperformance of a country's stock market over another is associated with similar seasonal patterns in the bilateral equity flows. For this purpose, USD/JPY returns are calculated from the Japanese yen to US dollar spot prices, the stock returns differentials are computed as the returns of the S&P500 minus the returns of the NIKKEI225[16], and the net equity flows from the US to Japan are computed

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[13] Kazuo Ueda was a professor in the faculty of Economics at the University of Tokyo and at the Massachusetts Institute of Technology. In 1985 he also became Senior Economist at the Institute of Fiscal and Monetary Policy. During his life he dealt with several studies and publications in the following fields: Monetary Economics, Macroeconomics, International Finance.

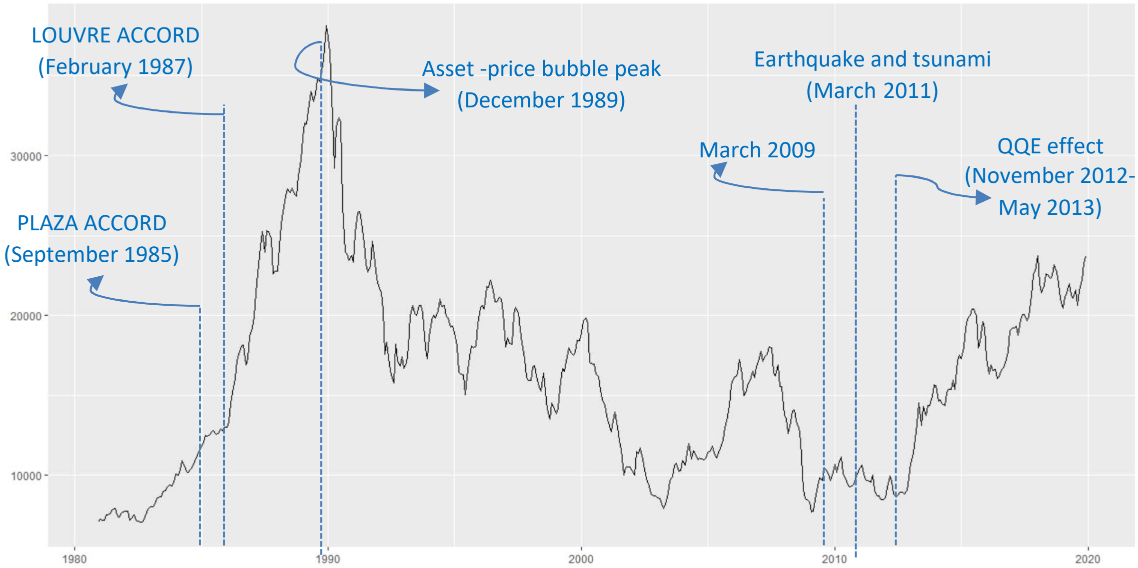
[14] The Nippon Individual Savings Account (NISA), was a newly introduced type of tax exemption program for small investments, proposed to help individuals' mid-to-long term asset accumulation functional to prompt businesses and relaunch the Japanese economy.

[15] https://fred.stlouisfed.org/

[16] Returns have been computed as followed: $R_{l,t} = \ln\left(\frac{P_{l,t}}{P_{l,t-1}}\right)$. l is the financial asset (foreign currencies or stocks) and $P_{l,t}$ is the spot price. Stock returns differentials have been computed as followed: $M_{SRD,t} = R_{S\&P500,t} - R_{NIKKEI225,t}$.

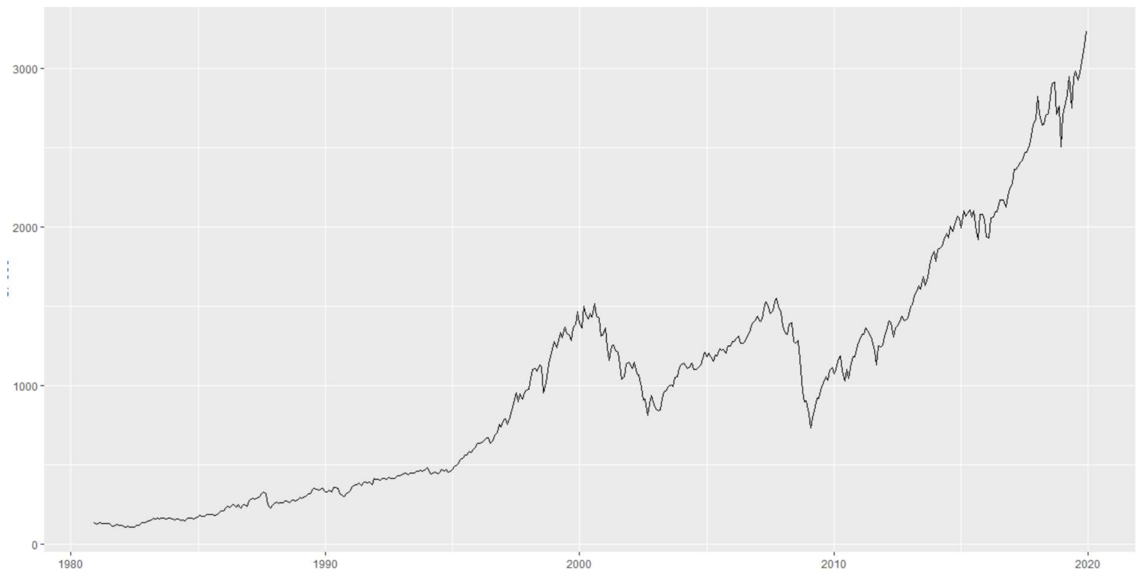
as the difference between the net purchases of Japanese stocks by US residents and the net purchases of US stocks by Japanese residents[17], normalized on the average of the absolute value of net equity flows from the US to Japan during the previous 12 months.

Figure 2: NIKKEI225 closing prices from December 1980 to December 2019



NIKKEI225 monthly closing prices have been retrieved from Investing.com: https://www.investing.com/

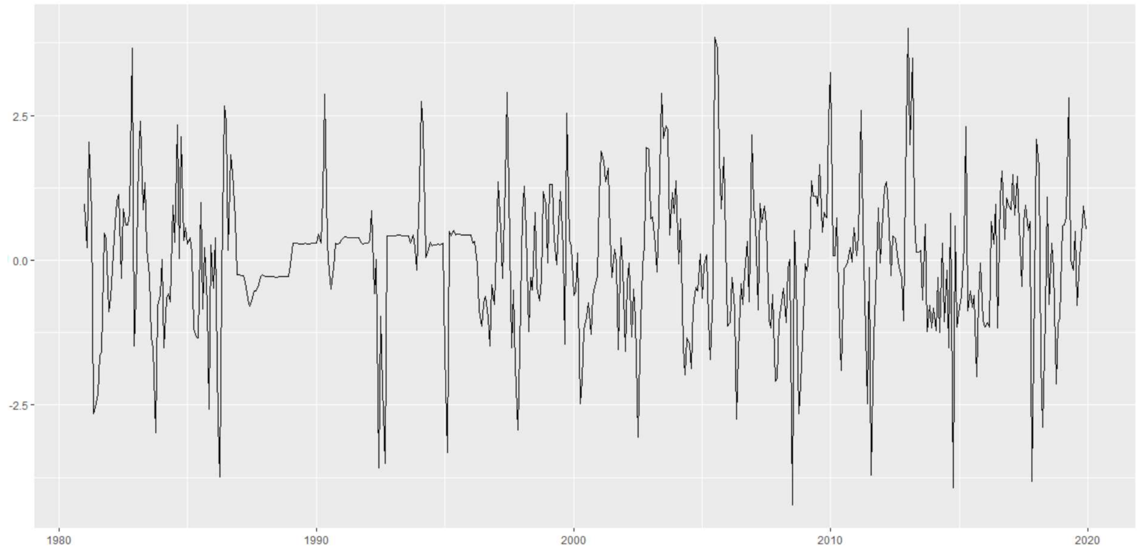
Figure 3: S&P500 closing prices from December 1980 to December 2019



S&P500 monthly closing prices have been retrieved from the FRED database: https://fred.stlouisfed.org/

[17] Gross foreign purchases and sales of US and foreign securities from December 1980 to January 2019 have been retrieved from the Treasury International Capital System (TIC). https://ticdata.treasury.gov/

Figure 4: NEF from the US to Japan



All amounts are expressed in millions of dollars.

Gross foreign purchases and sales of US and foreign securities from December 1980 to January 2019 have been retrieved from the Treasury International Capital System (TIC): https://ticdata.treasury.gov/

The net equity flows from the US to Japan are computed as the difference between the net purchases of Japanese stocks by US residents and the net purchases of US stocks by Japanese residents, normalized on the average of the absolute value of net equity flows from the US to Japan during the previous 12 months. Several outliers have been identified in the net equity flows during the first two decades of our sample; outliers have been replaced by values estimated through a linear interpolation used in the NEF seasonal adjusted series.

Figure 4 shows the net equity flows between the US and Japan from December 1980 to December 2019. They are a specific equity variable, but they may behave differently from the foreign exchange returns and the stock market returns differentials, due to missing data problems and potential influences from external sources. Some cross-border transactions may not be captured: the TIC reporting systems retrieves US cross-border activities and positions from a specific group of custodians, banks, and other institutions, but there are some minimum levels of cross-border transactions that must be reached before reporting is required. Furthermore, there may be some missed TIC data including for example cross-border flows resulting from stock swaps or asset-backed securities[18]. In addition, we are dealing with a two countries portfolio,

[18] https://home.treasury.gov/data/treasury-international-capital-tic-system-home-page/frequently-asked-questions-regarding/ticfaq2#q4

considering only the direct transactions between the US and Japan, while nowadays investors may move their equity capital from one country to another using also indirect channels. One of the determinants of international capital flows is globalization, financial market integration allows investors to move their equity capital from the US to Japan or vice versa, through third countries such as the UK or using offshore financial centers[19]. Despite the missing data problem, the discrepancies in the seasonality of the net equity flows with respect to the foreign exchange market and the stock returns differentials during more recent years, may be explained by the influence of other types of bilateral capital flows (government or corporate bonds, as well as bank flows, etc.) on the foreign exchange returns. They are a broader variable compared to the stock returns differentials and the net equity flows, which are essentially equity variables.

Looking at *Figure 4* we can see that the net equity flows from the US to Japan have been highly volatile during the analyzed 40-year period. In the 1980s Japan was called the "world-beating economy", concerning the huge Japanese exports and overseas investments: it became the largest source of FDI in the United States. The long period of low growth and deflation that characterized the Japanese economy through the 1990s and 2000s, as well as the establishment in 1995 of the World Trade Organization (WTO), may have reduce the scope for US unilateral trade pressures, starting a durable economic relation with Japan, which is still solid nowadays. However, a shift in the investment priority related to the rise of China as a trade power started in the 2000s: the US bilateral trade deficit with China increased and by September 2008 China became the largest foreign holders of US Treasury securities, and the major economic competitor for Japan. Nevertheless, US and Japan are still important economic partners, even if both of them over the years have established commercial and investment relationships with third countries.

[19] Richard Portes, Hélène Rey, 1999. The Determinants of Cross-Border Equity Flows. National Bureau of Economic Research, Working Paper 7336. https://www.nber.org/papers/w7336

Table 1: Descriptive statistics for foreign exchange returns, stock returns differentials, and net equity flows

	Min	Mean	Max	Standard Deviation	Skewness	Kurtosis
ΔL(USD-JPY)	-0,16	0,00	0,10	0,03	-0,46	4,64
SRD	-0,23	0,00	0,17	0,05	0,20	3,78
NEF	-1280,88	-6,24	852,66	104,20	-8,59	123,75

	Jarque-Bera Test	Boxe-Pierce Test	ADF
ΔL(USD-JPY)	X-squared: 68,997 p-value = 9,992e-16	X-squared = 0,83787 p-value = 0,36	Dickey-Fuller = -7,7393 p-value < 0,01
SRD	X-squared: 14,891 p-value = 0,000584	X-squared = 45,854 p-value = 1,274e-11	Dickey-Fuller = -6,942 p-value < 0,01
NEF	X-squared: 290082 p-value < 2,2e-16	X-squared = 0,0029273 p-value = 0,9569	Dickey-Fuller = -7,7191 p-value < 0,01

	Zivot and Andrews	Phillips and Perron	KPSS
ΔL(USD-JPY)	Test statistic: -21,0112 p-value = 0,02937; [22]	Z(alpha) = -466,94 p-value < 0,01	KPSS Level = 0,12933 p-value > 0,1
SRD	Test statistic is: -22,4424 p-value = 0,003328; [109]	Z(alpha) = -467,36 p-value < 0,01	KPSS Level = 0,18705 p-value > 0,1
NEF	Test statistic: -22.1104 p-value = 0,008835; [96]	Z(alpha) = -464,67 p-value < 0,01	KPSS Level = 0,21004 p-value > 0,1

ΔL(USD-JPY): USD/JPY exchange rate return, SRD=ΔLS&P500-ΔLNIKKEI225: stock returns differentials, NEF are the normalized net equity flows from the US to Japan.
For Zivot and Andrews test, potential breakpoints are indicated in the squared brackets.

Table 1 shows the descriptive statistics of the exchange rate returns, the stock returns differentials, and the net equity flows from the US to Japan. According to the *Jarque-Bera* test, the three variables are all non-normally distributed due to their excess kurtosis. The *Augmented Dickey-Fuller* [20], *KPSS* [21], and *Phillips-Perron* tests show that all the variables are stationary. However, many standard unit root tests are biased towards non-rejection of the unit root for stationary time series; therefore, we should also deal with tests that allow for structural breaks. *Zivot and Andrews (2002)* test states under the null that a given time series is a unit root series with drift, against the alternative hypothesis that the time series is a stationary process with one-time break in the level. Looking at its results we can see that for all our variables we reject the null, concluding that foreign exchange returns, stock returns differentials, and net equity flows are stationary processes with one potential breakpoint reported between squared brackets.

Monthly descriptive statistics of USD/JPY returns, stock returns differentials, and net equity flows are shown in *Table A1* in Appendix B. On average the USD has the lowest returns vis-à-vis the Japanese yen in Januarys and Mays and the highest in Augusts and Octobers. Like the foreign exchange returns, the average of the stock returns differentials has the highest value in Augusts and Octobers, while it has the lowest value in Decembers. Finally, the average of net equity flows from the US into Japan have their lowest value in Januarys, Augusts, and Septembers, and the highest one in Decembers. Looking at the values of skewness and kurtosis, we can conclude that the monthly data are non-normal distributed.

3.2 Methodology

Following past literature, the usual *ANOVA test* and the non-parametric *Kruskal-Wallis test* are run to assess the equality of means of several independent groups e.g., the monthly means of exchange rate returns, stock returns differentials and the net equity flows. Another common parametric test for the analysis of monthly seasonal patterns is the linear framework that relies on an ordinary least squares (OLS) estimation of a model

[20] The Augmented Dickey-Fuller (ADF) test belongs to the category of the "Unit Root Tests." It is one of the most common hypothesis tests that investigate whether or not a time series is stationary. The presence of a unit root makes a time series non-stationary. Given the following equation $Y_t = \alpha Y_{t-1} + \beta X_e + \varepsilon$, if $\alpha = 1$ it means that there is a unit root *(Dickey, Fuller, 1979)*.
[21] The KPSS test check the stationarity of a time series around a deterministic trend. It differs from the ADF test due to its capability to test for stationarity in the "presence of a deterministic trend," namely it may not necessarily reject the null of stationarity even if the series is steadily increasing or decreasing *(Kwiatkowski et al., 1992).*

including, in our case, eleven dummy variables and the intercept. The regression is computed as follows:

$$M_{i,t} = \alpha + \sum_{j=2}^{12} \beta_{i,j} \, D_{j,t} + u_{i,t}$$

where $M_{i,t}$ is a monthly series like the exchange rate returns, the stock returns differentials or the net equity flows; $D_{j,t}$ is the monthly dummy variable taking value of 1 in the j_{th} month and 0 in the other months, $u_{i,t}$ is an iid error term. We are considering only 11 monthly dummies (omitting one month e.g., January), since we include the intercept α. We must point out that the OLS regression is based on a linear framework and so for a long sample it relies on the stability of the parameters; since the seasonal patterns of both the exchange rate and the two countries' stock markets may change over time due to many factors as government policy changes, interventions in the market, cultural changes and holidays, the application of a non-linear framework may be preferred.

To capture the monthly seasonal variations in the stock returns differentials, the foreign exchange returns and the bilateral equity flows and to check if there are any similarities that may suggest the presence of monthly equity carry trades opportunities between the US and Japan, we deal with a seasonal adjustment analysis. It decomposes a time series into a trend, a seasonal and an irregular component, removing seasonal variations in the original series.

For the purpose of this thesis, we focus on the seasonal component extracted from the data. The most common seasonal adjustment methods are based on moving average filters applied sequentially by adding one observation at a time. We use the seasonal adjusted X-13ARIMA-SEATS software, produced, distributed, and maintained by the Census Bureau[22]. It offers two different seasonal adjustment procedures: SEATS and X-

[22] In 1954, the US Bureau of Census developed the "Method I" software, replacing the manual "ratio-to-moving-average-procedure" used by the US Federal Reserve Board. In 1955 US Census Bureau modified and enlarged its first software developing the "Census Method II". During the 60's and 70's other eleven versions (X1, X2, …, X11) were enhanced, the best known was Census X-11 that was extended in the 80's to the ARIMA-based methods such as the X11-ARIMA, X-12-ARIMA and the currently used X-13ARIMA-SEATS. The latest software uses linear filters of the X-

11. X-11 allows to specify which seasonal moving average will be used to estimate the seasonal factors (for default a 3x3 seasonal filter is applied), while the SEATS approach uses a stable seasonal filter. Empirical evaluations *(Tiller R., Chow D., Scott S., 2012)* show that SEATS identifies deterministic seasonality more often than X-11; it views seasonality as stochastic but still tends to produce more stable seasonal factors. In fact, applying the SEATS approach to our data quite unreliable results have been obtained: it shows the presence of stable seasonal components in both the S&P500 closing prices and the USD/JPY currency pair, while we will see below that both series are characterized by non-stable seasonality over the entire sample. On the other side, X-11 uses shorter filters that could cause the absorption of additional irregular variation by the seasonal component. Finally, comparing the results obtained by applying both methods to our data, we decided to use the X-11 adjustment procedure with a longer seasonal filter, namely a 3x15 seasonal filter, to reduce the variability in the X-11 seasonal component to an acceptable level, getting closer to SEATS results, but avoiding the production of stable seasonal factors.

Hereafter the decomposition and the adjustment procedure followed by X-11. Given a monthly time series X_t, X-11 first estimates the trend-cycle component using the default 2x12 moving average $TC_t^{(1)} = M_{2x12}(X_t)$; then it extracts the seasonal irregular component $(S_t + I_t)^{(1)} = X_t - TC_t^{(1)}$; and finally it estimates the seasonal component by a 3x15 moving average over each month: ${S_t}^{(1)} = M_{3x15}[(S_t + I_t)^{(1)}]$. As mentioned above, we focus our analysis on the seasonal component S_t of each time series, namely the monthly intra-year fluctuations that are repeated almost regularly year after year.

In our study, first we deal with an econometric analysis on the seasonal components of the Japanese yen to US dollar spot prices and the closing prices of the two countries' stock markets taken separately; then to investigate the presence of equity carry trades opportunities between the US and Japan, we examine whether the seasonal outperformance of a country's stock market over another is associated with similar

11 method combined with the ARIMA-model filters adjusted to the data. Handbook on Seasonal Adjustment (2018)

seasonal patterns in both the USD/JPY returns and the bilateral equity flows. Therefore, the seasonal adjustment is applied to the stock returns differentials, the foreign exchange returns, and the net equity flows over five sub-samples. For each sub-period, the X-11 adjustment procedure of the X-13ARIMA-SEATS software models the seasonal component as a periodic spline with time-varying parameters[23], assuring no data distortion.

4. Empirical Results: Seasonal Adjustment Analysis and evidence of Equity Carry Trades

4.1 Parametric and non-parametric test of seasonality

The results of the common parametric and non-parametric tests on the equality of means are reported in *Table A2* in Appendix B. According to the *ANOVA test,* only the average stock returns differentials are found to be not equal for all months. While, the *Kruskal-Wallis* non-parametric test shows that the mean ranks of the foreign exchange returns, the net equity flows and also the stock returns differentials are almost the same across months. Finally, these tests show no significant difference between monthly means for all the analyzed variables.

The results of the OLS regression are shown in *Table 2*. There are no significant coefficients in the USD/JPY returns as well as in the stock returns differentials and in the log returns of the two stock markets. Only the equity flows from the US to Japan have significant January and December coefficients. The opposite signs in the coefficients of December and January may suggest the existence of a consistent January effect, according to which in the first month of the year equity capital tends to flow from Japan to US, while the opposite happens in Decembers. Nevertheless, the OLS regression has been not so meaningful in detecting seasonality in both the exchange rate returns and

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[23] X-13ARIMA-SEATS uses RegARIMA models to detect seasonality and decompose the series: given the observed time series y_t, the program fit the following model $y_t = \mu + x_t'\beta + z_t$ where μ is a constant term, $x_t'\beta$ is the regression term, and z_t follows an ARIMA model identified by the program. Basing on the irregular component of the X-11 decomposition, *Zhang and Poskitt (2006)* suggested to split the time-varying seasonal effect into a constant and a stochastic parts: $S_t = n_t + \mu_t$ where n_t is the constant component and $\mu_t = S_t' y_t;\ y_t = y_{t-1} + k_t$ is the stochastic component.

the stock returns differentials. We must point out that the linearity assumption may not be suitable for the analyzed variables: as mentioned above, financial data may be affected by policy changes and other events, according to which a non-linear model may be preferable to detect persistent seasonal carry trade opportunities.

Table 2: OLS estimation for USD/JPY returns, stock returns differentials and NEF

Dependent Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ΔL(USD-JPY)	0,0005	-0,0032	-0,0015	-0,0067	-0,0003	-0,0031	-0,0046	-0,0084	-0,0074	-0,0083	-0,0030	-0,0037
	[0,9311]	[0,6544]	[0,8410]	[0,3567]	[0,9702]	[0,6714]	[0,5282]	[0,2500]	[0,3110]	[0,2553]	[0,6780]	[0,6080]
SRD	0,0061	-0,0087	-0,0041	-0,0081	-0,0059	-0,0012	-0,0027	0,0038	-0,0085	0,0106	0,0051	-0,0094
	[0,5162]	[0,4633]	[0,7278]	[0,4942]	[0,6185]	[0,9205]	[0,8203]	[0,7514]	[0,4757]	[0,3716]	[0,6702]	[0,4305]
ΔL(lnS&P)	0,0100	-0,0053	0,0042	0,0062	-0,0021	-0,0074	-0,0019	-0,0104	-0,0158	0,0005	0,0047	0,0042
	[0,1930]	[0,5835]	[0,6658]	[0,5204]	[0,8315]	[0,4460]	[0,8420]	[0,2850]	[0,1053]	[0,9571]	[0,6304]	[0,6622]
ΔL(lnNIK)	0,0039	0,0034	0,0083	0,0144	0,0039	-0,0062	0,0008	-0,0142	-0,0073	-0,0101	-0,0004	0,0136
	[0,6533]	[0,7549]	[0,4462]	[0,1894]	[0,7241]	[0,571]	[0,9441]	[0,1965]	[0,5081]	[0,3557]	[0,9708]	[0,2134]
NEF	-40,7356	33,0600	33,3010	32,6775	27,9435	32,5055	32,5985	0,6040	4,9176	32,2841	32,4225	54,3159
	[0,0288]**	[0,1622]	[0,1591]	[0,1671]	[0,2373]	[0,1693]	[0,1681]	[0,9796]	[0,8351]	[0,1723]	[0,1704]	[0,0219]**

Numbers in squared brackets are p-values; '**' significant coefficients at the 5% level.

ΔL(USD-JPY): USD/JPY exchange rate return, SRD: stock returns differentials, ΔL(lnS&P): S&P500 log returns, ΔL(lnNIK): NIKKEI225 log returns, NEF: normalized net equity flow from the US to Japan.

The regression is computed as follows: $M_{i,t} = \alpha + \sum_{j=2}^{12} \beta_{i,j} D_{j,t} + u_{i,t}$. $M_{i,t}$ *is a monthly series like the exchange rate returns, the stock returns differentials or the net equity flows;* $D_{j,t}$ *is the monthly dummy variable taking value of 1 in the* j_{th} *month and 0 in the other months,* $u_{i,t}$ *is an iid error term. We are considering 11 monthly dummies (omitting one month e.g., January) and the intercept* α.

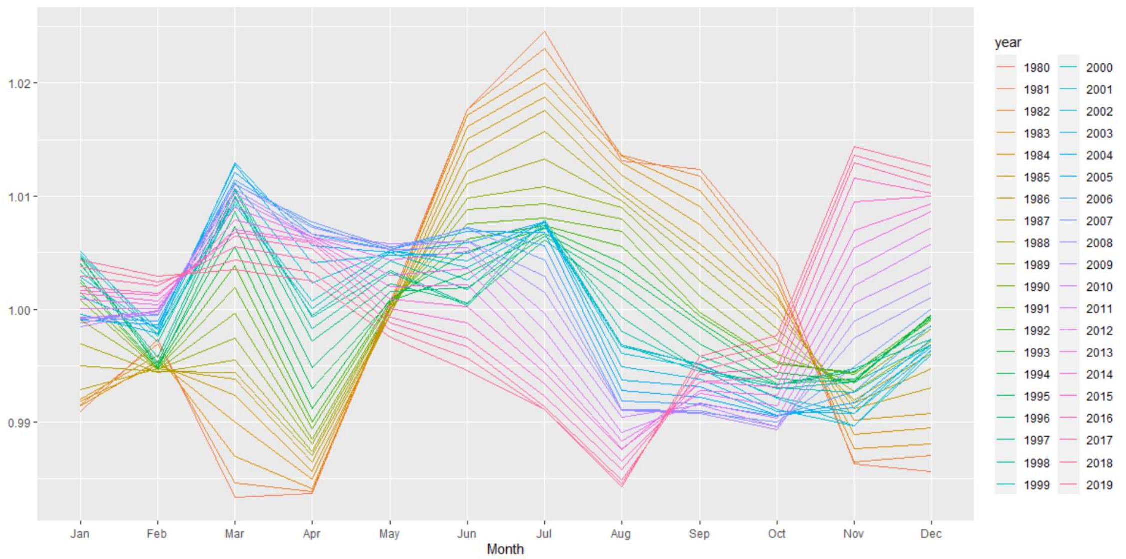
4.2 Seasonal Adjustment Analysis: X-13ARIMA-SEATS results

4.2.1 Foreign exchange market

To analyze seasonality in the foreign exchange market, the seasonal adjustment is performed on the Japanese yen to US dollar spot prices by fitting an ARIMA model of order (2 1 2): no significant estimated coefficients are found. The seasonal plot in *Figure 5* shows that seasonality in the USD/JPY exchange rate varied many times from December 1980 to December 2019. In the early 1990s there was a sharp change in seasonality that led to a reduction in the monthly seasonal fluctuations during the early 2000s. Furthermore, some variations in the seasonal behavior of the USD/JPY spot prices are detected in the years around the Great Financial Crisis, and a drastic shift is pointed out by the pink lines after 2011. Therefore, non-stable seasonality is found in the Japanese yen to US dollar spot prices over the 40-year period, but at least four different seasonal patterns are detected: during the 1980s, from the late 1980's to the early 2000s, until the Great Financial Crisis and after 2011.

The unique and tormented history of the USD/JPY currency pair (described in *section 3.1*) may have affected its seasonality, but the main driver of the seasonal fluctuations detected in the USD/JPY exchange rate is found to be the Bank of Japan. Appendix A shows in detail how both its campaigns of purchases and sales of USD and the adopted monetary policy measures have influenced seasonality in the foreign exchange market, causing drastic changes at specific times between December 1980 and December 2019.

Figure 5: Seasonal plot USD/JPY Seasonal Component



The USD/JPY seasonal plot has been computed with the ggseasonplot function of the Rstudio's seasonal package. USD/JPY spot prices are plotted against the individual "seasons" in which the data were observed: namely the years in which the pattern changes.

4.2.2 Stock Markets

Academic studies based on linear frameworks have provided inconclusive and contradictory findings on the presence of monthly seasonality in both the Japanese and the US stock markets. We study the NIKKEI225 and the S&P500 closing prices separately, dealing with a time varying parameter estimate analysis, to get some clear results about seasonality in the two countries' stock markets.

The seasonal adjustment on the NIKKEI225 closing prices is performed by fitting an ARIMA model of order (1 1 0)(1 0 1); the *QS statistic*[24] points out that there is no seasonality remaining in the final seasonal adjusted data, the *Box-Ljung test*[25] shows that there is no autocorrelation remaining in the residuals and according to the *Shapiro test* we reject the null hypothesis about the normality of the residuals. The estimated coefficients for the NIKKEI255 monthly closing prices are all significant with the only exceptions of March and August. The *F-test*[26] shows the presence of deterministic seasonality in the Japanese stock market, confirming the result achieved by *Shigeyuki Hamori (2001)*[27]. *Figure 6* shows the plot of the seasonal component of the Japanese stock closing prices, obtained by applying the X-11 adjustment procedure of the X-13ARIMA-SEATS program. Japanese stocks have higher returns from January to April than in the second part of the year, with a final increase in December. The start of a bear market in May could suggest the presence of the *Sell in May effect* in the NIKKEI225, as already showed by *Bouman and Jacobsen (2002)*[28]. However, the down market that starts in May continues until the end of the year, while according to the *Sell in May effect*, Japanese investors should then "come back in September" and benefit from the higher stock market returns during the last part of the year. Therefore, our evidence

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[24] QS statistic is a test on the autocorrelation at seasonal lags, which considers only positive autocorrelation coefficients.

[25] The Ljung-Box test investigate whether or not residuals are independently distributed, namely if they exhibit or not serial correlation.

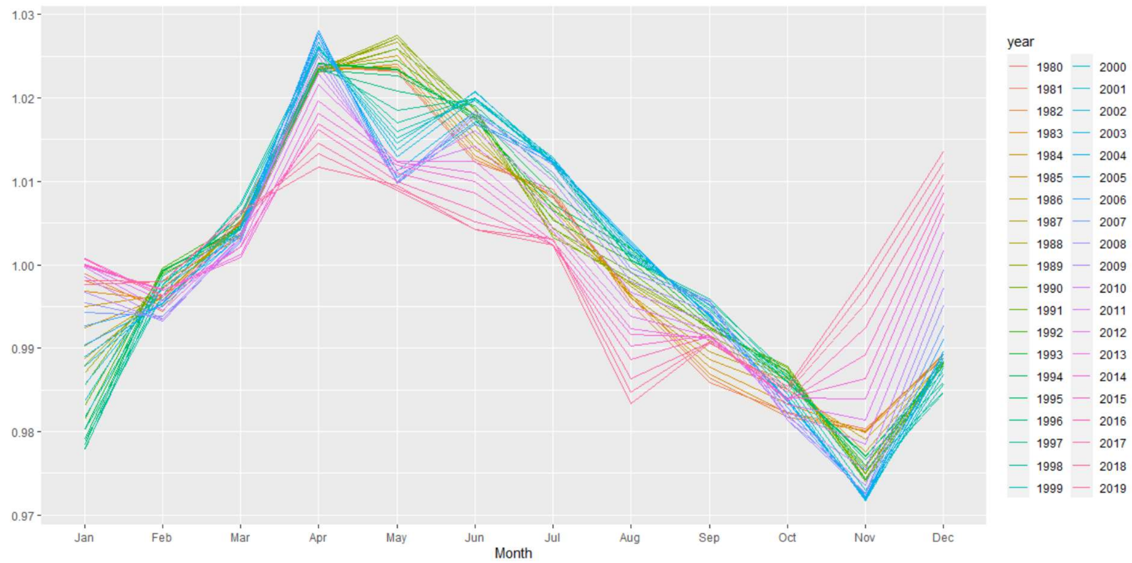
[26] The model proposed by *Lytras, D.P., Feldpausch, R.M., and Bell, W.R*. (2007) uses seasonal dummies to analyze a time series behavior. The null hypothesis states that seasonal dummies are all jointly not significant, while the alternative hypothesis assumes the presence of deterministic seasonality. Finally looking at the *p-value* of the *F-test* for seasonal regressors of the NIKKEI225, we can reject the null and conclude that the seasonal dummies are all jointly statistically significant and that the Japanese stock market has a deterministic seasonality.

[27] *Shigeyuki Hamori (2001)* analyzed the TOPIX large/medium/small-sized stock index in the period January 1971-December 1997. The ANOVA test, Van der Waerden test, a standard t-test and the Dickey-Fuller test led to conclude that seasonality in the Japanese stock market index was found to be deterministic but not stochastic. If there exist seasonal movements in stock returns, investors can take advantage of the patterns and gain profit. However, in this paper linear parametric test were used.

[28] *Bouman and Jacobsen (2002)* showed the presence of the Sell in May effect in the Japanese stock market by analyzing monthly stock returns of value-weighted market indices of 19 countries over January 1970 - August 1998. To evaluate the existence of a Sell in May effect a usual regression technique has been implemented with a seasonal dummy variable S_t as follow: $r_t = \mu + \alpha_1 S_t + \varepsilon_t$. Results regarding the Japanese stock market reported a strongly presence of the Sell in May effect.

supports the presence of the so called *Dekansho-bushi effect (Shigeki, Takashi, Katsuhiko, 2013)*[29] according to which Japanese monthly stock returns are simply higher in the first half of the year and lower in the second half.

Figure 6: Seasonal plot of NIKKEI225 Seasonal Component



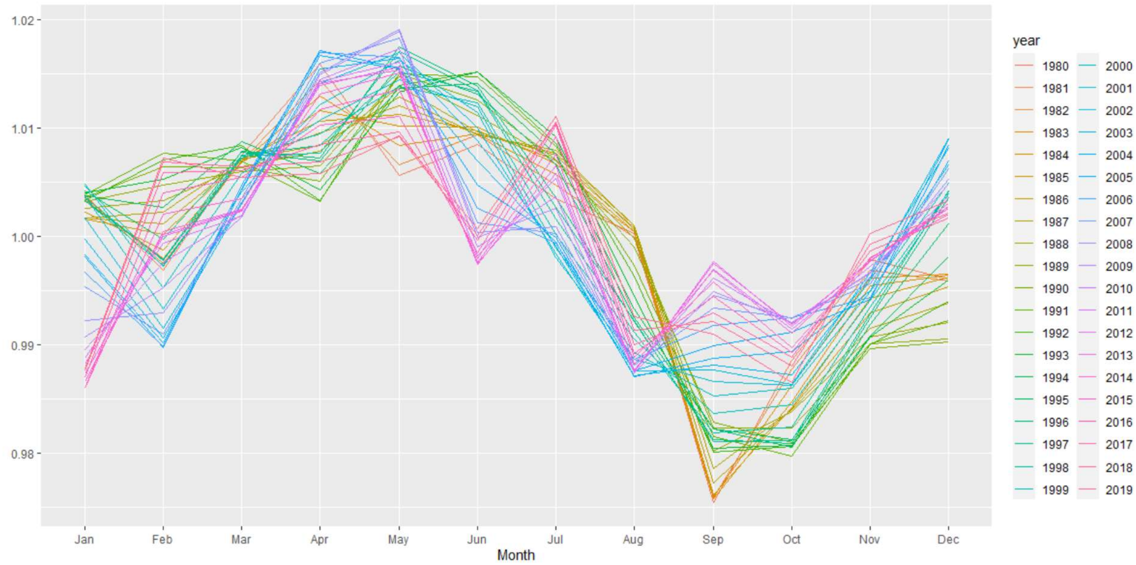
The NIKKEI225 seasonal plot has been computed with the ggseasonplot function of the Rstudio's seasonal package. NIKKEI225 closing prices present a stable seasonal pattern over the years, confirming the presence of a deterministic seasonality in the Japanese stock market.

The seasonal adjustment on the S&P500 closing prices is performed by fitting an ARIMA model of order (1 1 1). As for the NIKKEI225, the tests show no seasonality remaining in the final seasonal adjusted data, and no autocorrelation in the residuals which are normally distributed. Only the coefficients of April, May and December are statistically significant. The seasonal subseries plot in *Figure A4* in Appendix C, enables us to see an overall upward trend from January to May, followed by lower US stock returns from May to September, and a final increase from October to December. This seasonal pattern may suggest the presence of a significant *Sell in May effect* in the US stock market,

[29] *Shigeki, Takashi, Katsuhiko (2013)* first analyzed the mean monthly returns of five indexes (Nikkei Economic Electronic Database Systems Financial Quest. TOPIX, Tokyo Stock Price Index; TSE, Tokyo Stock Exchange) in the years 1950-2008. Then they dealt with a χ2 test and analyzed the impact of cumulative returns of the value-weighted TOPIX and the price-weighted Nikkei 225 between 1950 and 2008. Finally, they pointed out that Japanese stocks perform well until June, but lag from July to the end of the year. The financial impact of following *a Dekansho-bushi* strategy is that, holding stocks during the first half of each trading year and hedging the position by selling the index in the second half, is enormous.

according to which investors sell US stocks in Mays and buy them back in Octobers. It was already detected by *Bouman and Jacobsen* (2002), who show that on average returns in the US stock market were more than five percent higher between November and April than they were during the remainder of the year. Moreover, the seasonal adjustment analysis shows the presence of an overall non-stable seasonality in the US stock market over the long period: looking at *Figure 7,* we can see that many seasonal shifts characterized the period from December 1980 to December 2019. As for the USD/JPY spot prices we can detect four changes in the seasonal pattern of the S&P500: in the late 1980s, around the 2000s, during the Great Financial crisis and after 2011.

Figure 7: Seasonal plot of S&P500 Seasonal Component



The S&P500 seasonal plot has been computed with the ggseasonplot function of the Rstudio's seasonal package. It shows how the S&P500 closing prices have changed among the individual "seasons" in which the data were observed.

Finally applying X-13ARIMA-SEATS to the closing prices of the two countries' stock markets and to the USD/JPY spot prices, we found that only the NIKKEI225 has a deterministic seasonality, while both the S&P500 and the Japanese yen to US dollar spot prices are characterized by non-stable seasonal patterns, concluding that from an econometric point of view there are no significant seasonal overlaps between the closing prices of the two countries' stock markets and the USD/JPY spot prices over the 40 years period. However, the seasonal changes detected in the foreign exchange market took place in the same periods as the ones observed in the US stock market, suggesting the existence of similar seasonal patterns in the USD/JPY currency pair and the S&P500 over the identified sub-periods.

4.3 Stock Returns Differentials and Foreign Exchange Returns: X-13ARIMA-SEATS results and evidence of Seasonal Equity Carry Trades

Stock returns differentials are analyzed in order to investigate when investors have incentives to move their capital from a country to another and benefit from the excess returns of one stock market vis-à-vis to the other. In addition, to detect the existence of equity carry trade opportunities between the US and Japan, we should investigate the seasonality in the foreign exchange returns and assess if there are any similarities with the seasonal patterns detected in the stock returns differentials.

Our preliminary analysis has pointed out that the seasonal shifts detected over the 40 years period in the US stock market took place nearly at the same time as in the USD/JPY currency pair. So, we decided to divide the entire sample into five sub-periods characterized by almost stable-seasonal patterns in both the Japanese yen to US dollar spot prices and the S&P500 closing prices. Looking for the causes that may have prompted the lack of stability in the seasonality of the foreign exchange market and its potential relation with the US stock market, we figure out (as showed in more detail in Appendix A) that Bank of Japan interventions in the foreign exchange market are the main driver of the seasonal shifts observed in the USD/JPY currency pair. Furthermore, BoJ initiatives almost coincide with the seasonal changes detected in the US stock market since the Bank of Japan usually intervened during turmoil periods to affect the yen value with respect to the US dollar. Consequently, the overall sample is decomposed into five sub-periods: December 1980 - December 1988, January 1989 - December 1998, January 1999 - March 2004, April 2004 - August 2010, and December 2011 - December 2019. The seasonal adjustment analysis is now performed on the stock returns differentials and the USD/JPY returns for each of the five sub-samples, to investigate the seasonal relationship between the two variables and get evidence about the presence or not of seasonal equity carry trades in the different periods. *Table 3* reports the estimated coefficients obtained applying the X-11 adjustment procedure of the X-

13ARIMA-SEATS software to the foreign exchange returns and the stock returns differentials.

Table 3: X-13ARIMA estimated coefficients of USD/JPY returns and stock returns differentials over the five sub-periods

December 1980 - December 1988

Month	Δ L(USD-JPY) estimated coef.	SRD estimated coef.
Jan	0,01340 ***	-0,00360
Feb	0,00320	0,00870
March	-0,01000 **	-0,02660 *
Apr	-0,00910 *	-0,00720
May	0,02460 ***	0,00570
Jun	0,01380 ***	0,00500
Jul	0,00480	0,00490
Aug	0,00240	0,00840
Sep	-0,00590	-0,00280
Oct	0,00090	0,01780
Nov	-0,02900 ***	-0,01290
Dec	-0,00920	0,00270

January 1989 - December 1998

Month	Δ L(USD-JPY) estimated coef.	SRD estimated coef.
Jan	0,00130	-0,01370
Feb	-0,01040	0,00680
March	0,01460	0,00800
Apr	-0,00800	-0,01970
May	-0,00010	-0,00680
Jun	-0,00630	0,02050
Jul	0,00210	-0,01280
Aug	0,01220	-0,01090
Sep	-0,01050	0,01630
Oct	-0,01300	-0,01700
Nov	0,01820 *	0,02300 *
Dec	-0,00020	0,00630

January 1999 – March 2004

Month	Δ L(USD-JPY) estimated coef.	SRD estimated coef.
Jan	0,02230 ***	0,00040
Feb	0,00740 **	-0,04010 ***
March	-0,00440	-0,01160 *
Apr	-0,00090	0,00450
May	-0,01260 ***	0,01640 **
Jun	-0,00060	-0,02270 ***
Jul	0,00130	0,02030 ***
Aug	-0,03090 ***	0,00210
Sep	-0,00340	-0,02690 ***
Oct	0,00960 ***	0,04810 ***
Nov	0,00170	-0,01220
Dec	0,01040	0,02170

April 2004 – August 2010

Month	Δ L(USD-JPY) estimated coef.	SRD estimated coef.
Jan	-0,00800	0,00770
Feb	0,00630	-0,01970 **
March	0,00920 *	0,00730
Apr	0,00750	0,00540
May	0,00080	0,01180 **
Jun	0,01100 **	-0,02810 ***
Jul	-0,00230	0,01430 **
Aug	-0,00680	0,01020 *
Sep	-0,00070	0,01490 **
Oct	-0,00970 *	0,01630 **
Nov	-0,01620 ***	0,00380
Dec	0,00900	-0,04390

December 2011 – December 2019

Month	Δ L(USD-JPY) estimated coef.	SRD estimated coef.
Jan	0,00099	-0,00673
Feb	-0,01312 ***	0,01530 ***
March	-0,00567	0,01528 ***
Apr	-0,00047	-0,00170
May	-0,00668 *	-0,00688
Jun	0,00484	0,00219
Jul	-0,01388 ***	0,01179 **
Aug	-0,00341	0,00776
Sep	-0,00659 *	0,01267 **
Oct	0,00624 *	-0,01093 **
Nov	0,00906 **	-0,01552 ***
Dec	0,02870	-0,02320

'***' significant at 1% level, '**' significant at the 5% level, '*' significant at the 10% level

ΔL(USD-JPY): USD/JPY exchange rate return, SRD: stock returns differentials.

Coefficients in this table should be read as this example: 0.01340 in January means a 1.34% exchange rate return.

Monthly positive returns in the foreign exchange market correspond to a depreciation of the US dollar vis-à-vis the Japanese yen. While monthly positive values in the stock returns differentials show higher returns in the US stock market than in the NIKKEI225.

In the period from December 1980 to December 1988 no significant overlap is found in the coefficients of the two variables with the only exception of March. In Marchs US stocks have lower returns than the Japanese ones, and a USD appreciation is observed. Therefore, there is no evidence of equity carry trades opportunities between the US and Japan from December 1980 to December 1988, but quite the opposite, the higher returns of the NIKKEI225 in March were immediately compensated by a Japanese yen depreciation in the same month, vindicating UEP theory. The same happened in the opposite direction in Novembers from January 1989 to December 1998: in Novembers US stocks returns are higher than the Japanese ones, and a USD depreciation is observed. As in the previous period, there is no evidence of equity carry trade opportunities, but again the UEP condition is affirmed in Novembers between January 1989 and December 1998.

Looking at the estimated seasonal coefficients of both the foreign exchange returns and the stock returns differentials between January 1999 and March 2004, we can see an overlapping seasonality in February, May and October. In Februarys Japanese stock returns are 4.0 percentage points higher than US stock returns, while in Mays returns in the S&P500 are 1.64 percentage points higher that in the NIKKEI225. Futhermore, a US dollar depreciation is detected in February, while the opposite is observed in May. This double reversal can suggest the presence of equity carry trade opportuities for investors, who would have sold US (Japanese) equity in February (May) and used the proceeds to buy Japanese yen (US dollar) to invest in the NIKKEI225 (S&P500), generating a USD (Japnese Yen) depreciation in the same month. Therefore, adding up the returns from the USD/JPY exchange market and the stock returns differentials from January 1999 and March 2004, an investor who would have moved her capital to the Japanese (US) stock market in February (May) would have benefited from an overall gross return in excess of 4.8 (2.9) percentage points. This means that in Februarys and Mays UEP doesn’t hold at least for the short period, because stock returns differentials are not immediately compensated by a USD appreciation/depreciation. However, in Octobers higher US stock returns corrispond to a USD depreciation, providing evidence in favour of *Hau and Rey’s* (2006) theory.

Significant seasonal similarities are found also in June and October from April 2004 to August 2010. In Junes investors would have sold US equity to gain from the higher returns in the Japanese stock market, generating a USD depreciation, while the opposite is observed in Octobers. Adding up the stock returns differentials and the foreign exchange returns, an investor who would have moved her capital to the Japanese (US) stock market in June (October) would have benefited from an overall gross return in excess of 3.9 (2.6) percentage points. This shows that during these months UEP doesn’t hold between contemporaneous values of exchange rate returns and stock returns differentials. The outperformance of a stock market over the other is not immediately compensated by a USD appreciation or depreciation; however, in Junes this parity condition is vindicated in one month horizon. Given the high overall gross returns that an investor could have gained by moving her capital to Japan in Junes, we thus suggest that *Hau and Rey's (2006)* evidence in support of a depreciation of the Japanese yen subsequent to the outperformance of the NIKKEI225 over the S&P500, may not be due to risk aversion or repatriation of investment but to carry trades and return-chasing behavior of investors.

Looking at the significant seasonal coefficients from December 2011 to December 2019, an overlapping seasonality is detected in February, July and October. In Februarys and Julys investors could have benfited from a USD appreciation with an average return respectivelly of 1.13 (-0.013) and 1.14 (-0.01388) percentage points, and from a USD depreciation in Octobers with an average return of 0.6 (0.006) percentage points. To show that these month effects detected in the foreign exchange market can be exploited for trading, the transaction costs are taken into account. As showed in *Figure A4* in Appendix D, the bid-ask spread[30] from January 2012 to December 2019 was usually so small that it never exceeded the profit from the arbitrage transactions, making these seasonal opportunities in the foreign exchange market profitable also from the point of view of the net spread. Therefore, adding up the USD/JPY returns and the stock returns differentials, an investor who would have moved her capital to the US in February and in July would have benefited respectivelly of an overall gross return in excess of 2.8 and 2.6 percentage points; while investing in the Japanese stock market in October would have provided an overall gross return in excess of 1.7 percentage points. Therefore, we provide evidence of the presence of equity carry trades opportunities between the US and Japan also from December 2011 to December 2019, pointing out a different and inverse pattern than the one detected in the previous years: investors moved by return-

[30] The most common form of transaction costs is the bid-ask spread. Bid and ask quotes for the USD/JPY currency pair have been retrieved from DataStream from January 2012 to December 2019. Bid-ask spread quotes have been computed as follow: $Bid - Ask\ spread\ (\%) = \frac{Ask\ price - Bid\ price}{Ask\ price}$.

chasing purposes had incentives to invest in the US stock market from February to October and then move their equity capital to Japan from October to January.

4.4 Net equity flows: X-13ARIMA-SEATS results and NEF uncharacteristic behavior

After having detected the presence of seasonal equity carry trades opportunities during more recent years, we would like to assess if investors have exploited in practice these seasonal chances by looking at the bilateral equity flows between the US and Japan. We investigate whether the similarities found in the foreign exchange returns and in the stock returns differentials are matched by the seasonal patterns of the bilateral US-Japan net equity flows.

We apply the X-11 adjustment procedure of the X-13ARIMA-SEATS software to the net equity flows from the US to Japan for each of the five sub-periods: the estimated coefficients are reported in *Table A3* in Appendix C. No overlapping seasonality is found in the stock market returns differentials, the foreign exchange returns and the bilateral net equity flows for any of the considered periods.

We cannot find any significant coefficients in the NEF or any overlaps with the seasonal patterns detected in the foreign exchange returns and in the stock returns differentials from December 1980 to December 1998: the absence of seasonality in the net equity flows may give evidence in favor of UEP theory since no significant monthly equity capital movements are detected. As shown above, in the period from December 1980 to December 1998 no seasonal equity carry trades opportunities are found, but quite the opposite a negative correlation between stock returns differentials and foreign exchange returns are observed in Marchs and Novembers. These results are not surprising: this period was full of government interventions, and as expected during turmoil years investors may be more risk-averse than in other periods. The Foreign Exchange and the Foreign Trade Control Law of December 1980 drove the Japanese transition to the freedom of capital movements, the Plaza and the Louvre Accords in 1985 and 1987 together with the Asian Financial Crisis of 1997 and 1998 and the huge campaign of interventions of the Bank of Japan, led to a period of instability in both the foreign exchange and the two countries' stock markets. Therefore, the rationale behind the capital movements observed in Marchs from December 1980 to December 1988 and in Novembers from January 1989 to December 1998, may be due to risk balancing and repatriation of investment rather than return-chasing behavior of investors, confirming what was suggested by UEP (*Hau and Rey, 2006*) as well as by the absence of any significant seasonal equity flows in the NEF.

Looking at the estimated coefficients of the net equity flows from January 1999 to August 2010, some similarities are detected between the US-Japan net equity flows and the stock returns differentials, but no matches are found with the USD/JPY returns. Finally, we don't find any seasonal overlaps between the three analyzed variables from December 2011 to December 2019: as mentioned above, seasonality has changed drastically after 2011 in both the foreign exchange market and the US stock market. *Kazuo Ueda (2013)* showed that the currency and the stock markets responded significantly to the strong pressure for the introduction of QQE measures put by Shinzo Abe (the President of Japan's Liberal Democratic Party) to the Bank of Japan from late 2012, as well as to the subsequent monetary easing. Concerning the trading activities observed during this period, only foreigners bought equities consistently after November 2012, while Japanese investors were afraid to exploit any opportunities. The absence of an upward trend in the interest rates amplified the impact of QQE in the USD/JPY currency pair and in the Japanese stock market; while the limited participation of Japanese investors in the trades suggests that the equity flows observed in these years were not driven by portfolio rebalancing purposes, but by speculative trades of foreigners motivated by high expectations of the effectiveness of the QQE measures. Even after April 2013, domestic investors did not become less risk-averse, they continued to not buy equities or foreign assets on an unhedged basis.

The discrepancies observed between the three analyzed variables may be legitimated by the fact that we are dealing with some specific equity variables like the stock returns differentials and the bilateral equity flows between the US and Japan, and some broader data like the foreign exchange returns, which are more exposed to external influences. The purchases and sales of US dollar by the Bank of Japan have strongly affected the USD/JPY currency pair in the years before 2004 and then in 2010 and 2011, while BoJ's monetary policy had unclear impacts on the foreign exchange market, but it certainly affected the bilateral equity flows between the US and Japan. Previous studies[31] found no evidence that the quantitative easing introduced in 2001, as well as the post-Lehman policy measures and the CME, started in 2010, had a direct impact on the exchange rate; however, they strongly affected the economic activities through portfolio rebalancing, commitment effects, expectations, or reduction in liquidity, term, or risk premia. As a consequence, the decrease of spreads and risk premia between 2001 and 2006, caused a reduction of the standard portfolio balancing trades; in 2010 the CME policy increased investors' risk appetite so that they were more prone to buying risky assets; then speculation by foreigners dominated the years before the introduction of QQE, and after the start of the aggressive monetary easing in April 2013, the substantial purchases of Japanese Government Bonds by the Bank of Japan significantly impacted also the foreign exchange market.

Moreover, the inconclusive results obtained in our analysis of the net equity flows between the US and Japan, as the transmission channel of seasonality between the stock returns differentials and the foreign exchange returns, may match some previous findings on Japanese equity flows. *Brennan and Cao (1997), Brooks et al. (2004),* and *Hau and Rey (2006)* all show that Japan behaves differently from other developed countries concerning capital flows. *Brennan and Cao (1997)* argue that "capital moves out of Japan when the yen appreciates", showing an opposite behavior than what should be expected under the assumption of equity carry trades; *Brooks et al. (2004)* prove that the USD/JPY exchange rate cannot be explained by the existing relationship between the capital flows and the stock markets, and *Hau and Rey (2006)* claim that ''Japan is special because international portfolio flows concern mostly bonds as opposed to equity''. According to previous literature, indeed, Japanese equity capital flows have an uncharacteristic behavior as a consequence of yen-carry trades: *Hau and Rey (2006)* point out that Japanese investors tend to exploit extremely low-interest rates, generating significant capital flows in and out of the Japanese bond market, "obscuring" equity capital flows. Furthermore, *Cho et al. (2006)* show the existence of different patterns in the capital flows between the US and Japan: the outperformance of the US stock market leads to both stocks and bond investments, while different signs between

[31] *Pelin Berkmen, S.,* 2012 and *Kazuo Ueda,* 2013.

the net equity flows and the net debt flows are observed in Japan. Finally considering the abovementioned interventions of the Bank of Japan, the numerous monetary policy measures adopted over the years, and supported by previous literature findings, we can consider that the contradictory results obtained from the seasonal adjustment analysis on the net equity flows between the US and Japan are not surprising. Moreover, we must recall that the missing data problem may affect the different behavior of the net equity flows: some cross-border transactions may not be captured by the TIC system, since we are considering only the direct flows from the US to Japan and vice versa. Possible indirect flows through third countries or offshore financial centers are not taken into consideration, and they may be potentially huge especially during more recent years due to financial markets integration.

5. Conclusions

We contributed to the study of the seasonal relation between equity and currency returns, providing novel findings about seasonality in the US and in the Japanese stock markets, and new results on the seasonal patterns that characterized the USD/JPY currency pair from December 1980 to December 2019. Our evidence of the presence of month effects in both stock and foreign exchange markets violates the Information Efficient Market hypothesis *(Fama, 1970)*, showing the possibility for investors to get higher returns by exploiting mispriced securities and arbitrage opportunities. The use of a non-linear framework enabled us to show that the USD/JPY currency pair was characterized by a non-stable seasonality over the entire sample; the seasonal shifts detected in the Japanese yen to US dollar spot prices were found to be driven by the Bank of Japan's campaigns of purchases and sales of USD carried out at specific times from the early 1980's to October 2011. These interventions almost coincided with the seasonal changes observed in the US stock market, so we decomposed the entire sample into five subperiods, during which we detected significant overlaps in the seasonality of the stock returns differentials and the foreign exchange returns. Evidence of the presence of seasonal equity carry trades was found from April 2004 to December 2019; different investment opportunities were identified in the two sub-periods due to the different seasonality that characterized the periods from April 2004 to August 2010 and from December 2011 to December 2019. The drastic change in seasonality detected after 2011, in both the stock returns differentials and the foreign exchange returns, generated a pattern reversal compared to the previous period: in Februarys and Julys a USD appreciation was observed immediately after the outperformance of the US over the Japanese stock market, while a yen appreciation was detected in Octobers as a consequence of higher returns in the NIKKEI225 vis-à-vis the S&P500; whereas from April 2004 to August 2010, investors had incentives to move their capital to Japan in Mays and to the US in Octobers.

We have pointed out the existence of a positive relationship between equity and currency returns during recent years, supporting *Cenedese et al.'s (2016)* findings that capital flows from one country to another are driven by equity carry trades strategies and return-chasing behaviors of investors. Furthermore, the different direction of the monthly investment opportunities identified from April 2004 to December 2019 confirms that for the US and Japan "seasonal equity carry trades are a seasonal phenomenon that can be present for decades", as *Girardin and Salimi's (2019)* have previously shown for Germany and US. Nevertheless, we cannot conclude that UEP does not hold at all: evidence in favor of a negative correlation between equity and currency returns was found both in Marchs and in Octobers from December 1980 to December 1998, ad in Octobers again from January 1999 to April 2004. The lack of significant seasonality in the net equity flows between the US and Japan may support *Hau and Rey's (2006)* theory according to which the depreciation of the USD after the outperformance of the US over the Japanese stock market may be due to investors' risk aversion rather than to carry trades. This assumption could be true considering the turbulent events that characterized the beginning of our sample, leading investors to be more risk-averse than during more recent years; but the inverse seasonal pattern detected after 2011 in both the USD/JPY returns and the US-Japan stock returns differentials provides no evidence in favor of UEP even during longer periods. We are not surprised that seasonality in the net equity flows doesn't match the seasonal overlaps observed between the stock returns differentials and the foreign exchange returns during the last sub-period: the influence of other types of bilateral capital flows on the foreign exchange returns, as well as the impact of the yen-carry trades on the Japanese equity flows, the consequences of CME and QQE for standard portfolio balancing trades and foreigners' speculation after 2012, may have affected this transmission channel. The inconclusive results obtained analyzing the net equity flows between the US and Japan as the engine of equity carry trades, may support previous literature findings about the uncharacteristic behavior of Japanese equity capital flows, but they can also pave the way toward further investigations focusing not only on the direct equity flows between the US and Japan, but also on the bilateral indirect flows that may take place through third countries or offshore financial centers.

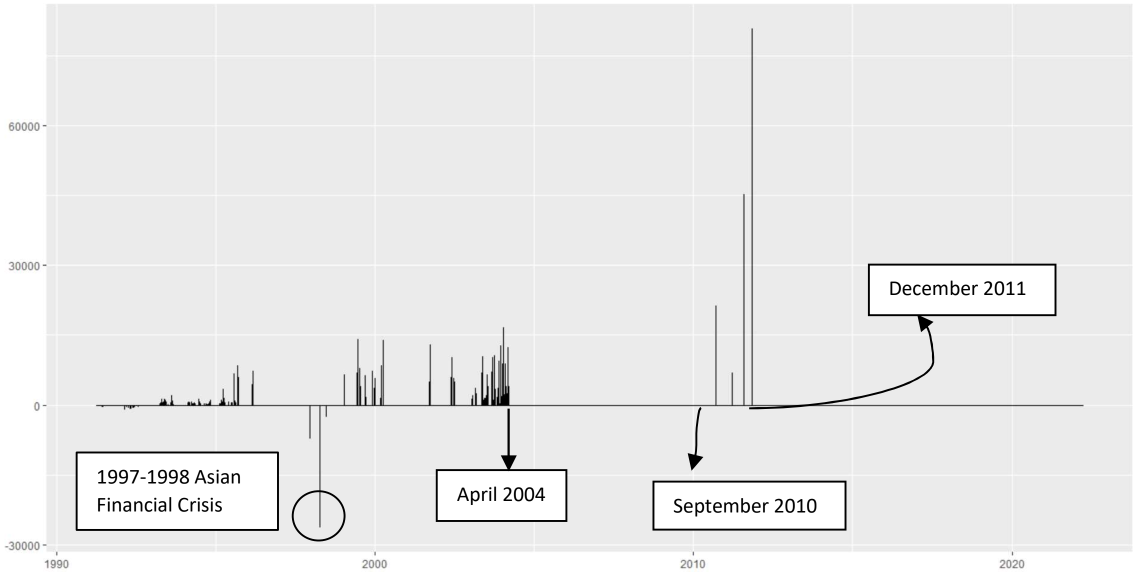
This study confirmed the limits of the usual parametric and non-parametric tests, and linear models to capture seasonality in the financial markets as *Girardin and Salimi (2019)* have pointed out for the first time, underlying the necessity to use a non-linear framework. Furthermore, a study on the causal relationship in the seasonality between equity and currency returns remains open for the future, and a related market econometric analysis to assess if seasonality in one stock market may originate from the seasonal patterns in another country's index may be worth pursuing.

Appendix

Appendix A

The Bank of Japan's interventions in the foreign exchange market and their consequences in the seasonal patterns of the USD/JPY currency pair

Figure A1: Japanese Bank purchases of USD against JPY

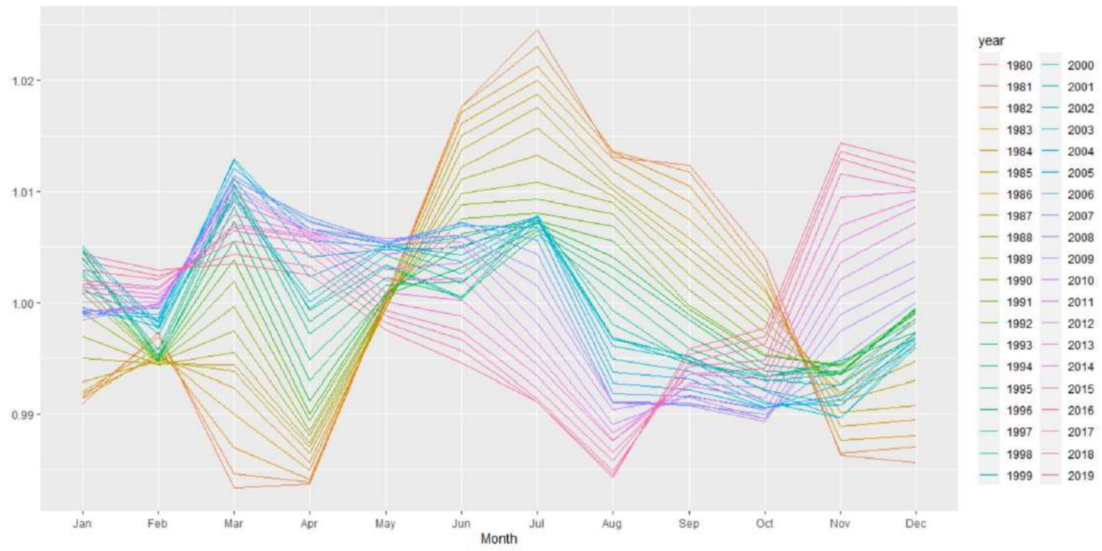


Japanese Bank purchases of USD against JPY have been downloaded from the FRED database: https://fred.stlouisfed.org/series/JPINTDUSDJPY.

Units: 100 million Yen; (+) numbers mean purchases of the USD (sell Yen), (-) numbers mean sales of USD (buy Yen)

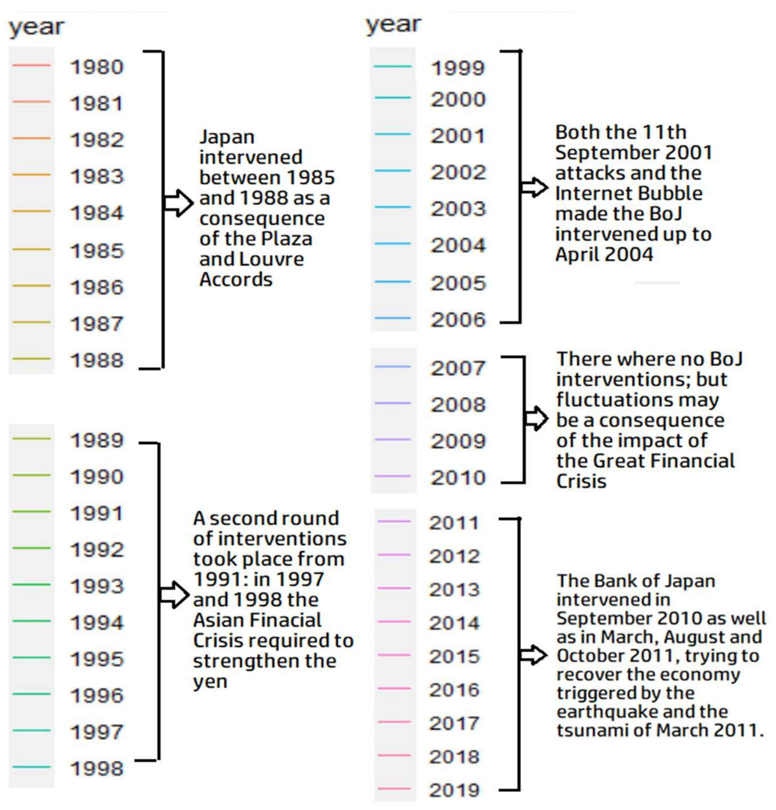
Sample: April 1991 to March 2022

Figure A2: Seasonal Plot of the USD/JPY Seasonal Component



The USD/JPY seasonal plot has been computed with the ggseasonplot function of the Rstudio's seasonal package. USD/JPY spot prices are plotted against the individual "seasons" in which the data were observed: namely the years in which the pattern changes.

Figure A3: Bank of Japan interventions in the foreign exchange market and their consequences in the seasonality of USD/JPY exchange rate



Applying the X-11 adjustment procedure used by the X-13ARIMA-SEATS software to the Japanese yen to US dollar spot prices, a non-stable seasonality is found in the USD/JPY currency pair from January 1981 to December 2019. *Figure A2* shows the succession of at least four different seasonal patterns in the USD/JPY exchange rate over the analyzed 40 years. In the early 1990s a sharp change in seasonality led to a reduction of the monthly seasonal fluctuations during the early 2000s; an additional seasonal shift can be detected in the years around the Great Financial Crisis, and the pink lines point out a drastic change in seasonality after 2011. Combining these findings with the history of the Bank of Japan's interventions in the USD/JPY exchange rate (shown in *Figure A1*), we conclude that the seasonal fluctuations observed in the Japanese yen to US dollar spot prices are strictly related to the Bank of Japan's campaigns of purchases and sales of USD undertaken from 1985 to 2011, in an attempt to affect the yen value.

The Bank of Japan established in 1882, as the central bank of the currently third-largest economy in the world has a direct impact on the foreign exchange market. Its main mission is to ensure the stability of prices and foreign exchange rates as well as the stability of the financial system. Eight times a year Monetary Policy Meetings (MPMs) discuss Japan's economic and financial conditions, providing the guidelines for money market operations that often affect the value of the yen and its interactions with other global currencies. BoJ's campaigns of purchases and sales of USD started in 1985 when the Group of Five industrial nations (France, Germany, Japan, the United Kingdom, and the United States) agreed to weaken the US dollar, that at the Plaza Accord was considered overvalued with respect to the other currencies including the yen. In 1988 after a drop of USD, the Bank of Japan intervened to buy dollars and sell yen. A second round of interventions took place in 1991, and in 1997-1998 the Asian financial crisis caused the yen to weaken to nearly 148 to the dollar in August, leading the US authorities together with the Bank of Japan to buy yen. Interventions continued during the early 2000s, both the 11th of September 2001 attacks in the United States and the Internet Bubble made the Bank of Japan intervene in the USD/JPY exchange market up to April 2004. In September 2010 the BoJ started a new campaign after six years of no interventions in the foreign exchange market, which ended in October 2011. In March 2011, the G7 jointly agreed to stop the increase of the yen as a consequence of the speculation generated by the repatriation of foreign assets by Japanese firms to pay for reconstruction. Finally, in August and October 2011, Japan intervened again trying to recover the economy triggered by the March earthquake and the tsunami.

The Bank of Japan may affect the USD/JPY currency pair also through indirect interventions as it did with the introduction of the Quantitative and Qualitative Easing (QQE) program in April 2013. Its goal was to encourage consumer spending to boost inflation, but in so doing it induced a depreciation of the yen, creating opportunities for traders to profit from price movements in the USD/JPY exchange rate.

Figure A3 schematizes how the five different seasonal patterns (shown by the colored lines in *Figure A2*) identified in the USD/JPY currency pair over the 40-year sample, almost coincide with BoJ's campaigns of purchases and sales of US dollars. Every time the Bank of Japan started a new campaign of interventions in the foreign exchange market, seasonality in the USD/JPY exchange market changed. A drastic shift can be observed after 2011: seasonality at the beginning of the analyzed period is found to be reversal to the seasonal pattern detected from 2011 to 2019.
This analysis provides robust evidence about the determinant role of the Bank of Japan in the foreign exchange market, and its relevance in the USD/JPY seasonal shifts.

Appendix B

Monthly descriptive statistics and empirical results of parametric and non-parametric tests

Table A1: Monthly descriptive statistics of the USD/JPY returns, stock returns differentials and net equity flows

January	Mean	Std. Dev.	Skewness	Kurtosis
ΔL(USD-JPY)	0,0028	0,0277	0,1290	2,0624
SRD	0,0066	0,0566	0,5605	3,2855
NEF	-32,8137	205,1259	-6,0007	37,0148

February	Mean	Std. Dev.	Skewness	Kurtosis
ΔL(USD-JPY)	-0,0005	0,0308	0,1069	3,7552
SRD	-0,0021	0,0429	0,3547	2,8532
NEF	0,2810	1,1258	-0,5265	4,3777

March	Mean	Std. Dev.	Skewness	Kurtosis
ΔL(USD-JPY)	0,0013	0,0371	-0,4902	3,4485
SRD	0,0025	0,0576	0,3562	2,7681
NEF	0,5569	1,5219	1,5064	7,8993

April	Mean	Std. Dev.	Skewness	Kurtosis
ΔL(USD-JPY)	-0,0039	0,0276	0,1536	2,6589
SRD	-0,0015	0,0574	0,4799	3,9906
NEF	-0,0319	1,3382	-0,5562	3,5476

May	Mean	Std. Dev.	Skewness	Kurtosis
ΔL(USD-JPY)	0,0025	0,0314	-0,4801	3,2651
SRD	0,0007	0,0398	0,6657	3,6377
NEF	-4,7312	28,5090	-5,9864	36,9036

June	Mean	Std. Dev.	Skewness	Kurtosis
ΔL(USD-JPY)	-0,0003	0,0278	-0,4928	4,2172
SRD	0,0054	0,0469	0,0425	2,4655
NEF	-0,1345	1,3746	0,0212	3,5385

July	Mean	Std. Dev.	Skewness	Kurtosis
ΔL(USD-JPY)	-0,0017	0,0290	-0,2538	2,4866
SRD	0,0039	0,0546	0,2427	2,1932
NEF	-0,0067	1,3928	-0,3498	5,1675

August	Mean	Std. Dev.	Skewness	Kurtosis
ΔL(USD-JPY)	-0,0055	0,0293	1,1704	6,0355
SRD	0,0104	0,0490	0,1976	2,7145
NEF	-31,9664	198,7643	-6,0018	37,0231

September	Mean	Std. Dev.	Skewness	Kurtosis
ΔL(USD-JPY)	-0,0045	0,0286	-0,8142	4,3677
SRD	-0,0019	0,0546	0,1949	3,2151
NEF	-27,6181	171,4630	-6,0018	37,0232

October	Mean	Std. Dev.	Skewness	Kurtosis
ΔL(USD-JPY)	-0,0054	0,0392	-1,7574	7,4558
SRD	0,0173	0,0656	-0,9740	6,3293
NEF	-0,2169	1,2965	-0,6981	3,9431

November	Mean	Std. Dev.	Skewness	Kurtosis
ΔL(USD-JPY)	-0,0001	0,0377	-0,3932	3,8204
SRD	0,0117	0,0499	0,2084	2,2101
NEF	-0,0437	1,3778	-0,4273	4,3235

December	Mean	Std. Dev.	Skewness	Kurtosis
ΔL(USD-JPY)	-0,0008	0,0350	-0,4734	3,5574
SRD	-0,0028	0,0500	0,7693	5,2222
NEF	21,8844	136,5355	6,0017	37,0224

ΔL(USD-JPY): USD/JPY exchange rate returns, SRD=ΔLS&P500-ΔLNIKKEI225: stock returns differentials, NEF are the normalized net equity flows from the US to Japan.

The sample period is from December 1980 to December 2019.

Positive USD/JPY returns correspond to a depreciation of the US dollar vis-à-vis the Japanese yen.

On average the USD has the lowest returns vis-à-vis the Japanese yen in Januarys and Mays, and the highest in Augusts and Octobers. The average stock returns differentials have the highest value in Augusts and Octobers, while it has the lowest value in Decembers. The average of net equity flows from the US into Japan has the lowest value in Januarys, Augusts, and Septembers and the highest one in Decembers. Finally looking at the values of skewness and kurtosis, we can conclude that the monthly distributions are non-normal distributed.

Table A2: Parametric and non-parametric tests of equality of means

Variable	ANOVA test	Kruskal-Wallis Test
M_FX	1,8097	4,9609
	[0,9808]	[0,9330]
M_SRD	1,8097	7,0244
	[0,0262]**	[0,7971]
M_NEF	1,8097	12,7106
	[0,4465]	[0,3126]

Numbers in squared brackets are p-values; '**' significant coefficients at the 5% level.

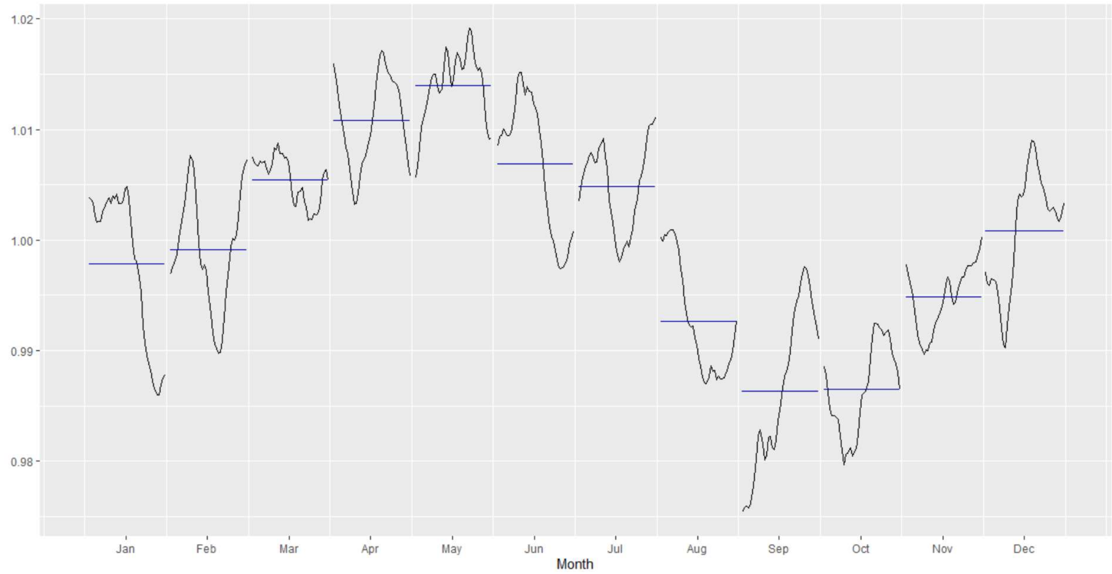
M_FX=ΔL(USD-JPY): USD/JPY exchange rate return, M_SRD=ΔLS&P500-ΔLNIKKEI225: stock returns differentials, M_NEF: normalized net equity flow from the US to Japan.

The ANOVA test shows that only for the stock returns differentials we can reject the null at a 5% significant level, concluding that in this case the average returns are not equal for all months. The Kruskal-Wallis non-parametric test shows that we cannot reject the null for the foreign exchange returns, the net equity flows and the stock returns differentials, proving that the mean ranks of all the three variables are almost the same across months. Finally, these tests show no significant difference between monthly means for all the analyzed variables.

Appendix C

X-13ARIMA-SEATS: S&P500 seasonal subseries plot and net equity flows estimation coefficients

Figure A4: Seasonal subseries plot of S&P500 Seasonal Component



The S&P500 seasonal subseries plot has been computed with the ggsubseriesplot function of the Rstudio's seasonal package. The seasonal subseries plot collects the data for each season in separate mini time plots, allowing us to see clearly the underlying seasonal patterns. The horizontal lines indicate the means for each month.

Table A3: X-13ARIMA estimated coefficients of Net equity flows from US to Japan over the five sub-periods

Net equity flows from US to Japan estimated coefficents

	December 1980 - December 1988	January 1989 - December 1998	January 1999 - March 2004	April 2004 - August 2010	December 2011 - December 2019
Jan	-8,1081	-98,0949 *	-0,0639	0,30940	0,55470 ***
Feb	-8,5120	31,3705	0,2746	-0,06670	0,38490 **
March	-8,4985	31,5856	1,3313 ***	-0,15340	0,33540 **
Apr	-9,0981	30,9919	-0,7848	-0,00540	0,56740 ***
May	-8,9799	13,6080	-0,3575	-0,60740 ***	-0,06680
Jun	-8,6717	30,9240	0,0597	-0,18160	0,03640
Jul	-8,3429	31,1294	-0,4859	0,03950	-0,21370
Aug	-8,7163	-93,3258 *	-0,2031	0,50650 **	-0,09950
Sep	-8,6894	-76,5536	-0,3866	0,14880	0,17950
Oct	-8,5270	30,8404	-0,0479	-0,09250	-0,88160 ***
Nov	-8,5005	30,6444	0,4145	-0,35360	-0,50770 **
Dec	9,4644	36,8802	0,2495	0,45660	-0,28880 **

'***' significant at 1% level, '**' significant at the 5% level, '*' significant at the 10% level

Positive values correspond to equity flows from the US to Japan, while negative values refer to equity flows from Japan to US.

Appendix D

Profitability of arbitrage: net profit after transaction costs

To show that the findings of month effects in the foreign exchange market are not a statistical anomaly but they can indeed be exploited for trading, the transaction costs are taken into accout. The most common form of transaction costs is the bid-ask spread: bid and ask quotes for the USD/JPY currency pair have been retrieved from DataStream and the Bid-Ask spread has been computed as follow: $Bid - Ask\ spread\ (\%) = \frac{Ask\ price - Bid\ price}{Ask\ price}$. *Table A4* reports the net profits after transaction costs.

Table A4: Net profit after transaction costs – USD/JPY exchange rate (January 2012 – December 2019)

Profit after transaction costs: February and July

Exchange Date	USD/JPY return	Bid-Ask spread	Return after spread	Net profit per standard lot
feb-12	0,0624	0,01%	0,0622	6222,95
jul-12	-0,0214	0,05%	-0,0209	2091,41
feb-13	0,0118	0,06%	0,0112	1118,37
jul-13	-0,0087	0,03%	-0,0084	836,20
feb-14	-0,0020	0,01%	-0,0019	185,72
jul-14	0,0145	0,01%	0,0144	1441,69
feb-15	0,0194	0,05%	0,0189	1891,24
jul-15	0,0151	0,03%	0,0147	1474,69
feb-16	-0,0673	0,05%	-0,0668	6679,53
jul-16	-0,0044	0,03%	-0,0041	408,48
feb-17	-0,0059	0,05%	-0,0053	532,33
jul-17	-0,0180	0,01%	-0,0179	1788,08
feb-18	-0,0246	0,01%	-0,0245	2451,52
jul-18	0,0106	0,03%	0,0103	1030,00
feb-19	0,0233	0,03%	0,0231	2306,77
jul-19	0,0069	0,03%	0,0066	658,62

Profit after transaction costs: October

Exchange Date	USD/JPY return	Bid-Ask spread	Return after spread	Net profit per standard lot
oct-12	0,0259	0,03%	0,0257	2567,33
oct-13	-0,0019	0,01%	-0,0018	183,14
oct-14	0,0222	0,04%	0,0217	2171,44
oct-15	0,0074	0,02%	0,0072	717,98
oct-16	0,0381	0,02%	0,0379	3794,77
oct-17	0,0088	0,03%	0,0085	852,51
oct-18	-0,0055	0,02%	-0,0053	528,64
oct-19	-0,0002	0,03%	0,0001	9,27

Bid-ask quotes have been retrieved from DataStream. They are only available from January 2012.

Given the seasonal equity carry trades opportunities detected in the period from December 2011 and December 2019, only Februarys, Julys and Octobers are included in our calculation.

The left panel shows the net profit from buying USD in Februarys and Julys, while the right panel shows the net profit from buying the Japanese yen in Octobers.

Positive (negative) returns correspond to a depreciation (appreciation) of the US dollar vis-à-vis the Japanese yen and consequently, profits in red can be made from buying USD.

A standard lot represents 100 000 units of any currency.

In the period December 2011 - December 2019, the seasonal adjustment analysis has pointed out the presence of a significant seasonal overlap between the stock returns differentials and foreign exchange returns in Februarys, Julys and Octobers. Looking at the coefficients of the USD/JPY returns, we can see an average profit of 1.13 and 1.14 percentage points respectivelly in Februarys and Julys due to a USD appreciation and an average profit of 0.6 percentage points in Octobers due to a USD depreciation vis-à-vis the Japanese yen. *Figure A4* shows that the bid-ask spread from January 2012 to December 2019 was usually so small that it never exceeded the profit from the arbitrage transactions, making these seasonal opportunities in the foreign exchange market profitable also from the point of view of the net spread.

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