

Business Hours and the Foreign Exchange Market

by

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(Under the Direction of William D. Lastrapes)

Abstract

This paper aims to explore a phenomenon that has been noticed in the foreign exchange market. Using intraday data from Bloomberg's BFIX index, we are able to show that currencies are weaker during their domestic trading hours compared to their values during foreign trading hours. We find that this trend extends across almost all G10 currencies which is consistent with the existing literature. However, we also find that when controlling for key economic variables, the impact of business hours may actually have the reverse effect as anticipated.

Key Words: Foreign exchange; Business hours; Intraday effects

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A Thesis Submitted to the Graduate Faculty
of The University of Georgia in Partial Fulfillment
of the
Requirements for the Degree

MASTER OF ARTS

ATHENS, GEORGIA

2017

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1 Introduction

This paper aims to explore a phenomenon that has been noticed in four previous papers: currencies tend to depreciate (lose value) during their domestic trading hours and appreciate (gain value) during foreign trading hours.¹ This paper, however, shows that against most of the G10 currencies the US dollar on average appreciated during US business hours, which we contribute to an overall rally in the US dollar since 2010. This is not contradictory to the trend found in the previous literature because the dollar's appreciation is strongest during foreign business hours and weakest during US business hours. This more nuanced observation holds for all studied currency pairs except for the Japanese yen.²

In recent years the foreign exchange market has also experienced major changes that have greatly impacted the spot market, which will be the focus of this paper.³ Three of the previous papers that have looked into this trend, with the exception being a theoretical study, use only pre-recession data. Thus our analysis will redo previous analyses with updated data, explore our more nuanced characterization of the trend, and control for balance of goods, interest rates, and bid/ask spread.

1.1 Market Trends

Since the financial crises, the overall foreign exchange market has seen a reduction in risky behavior. This flight to safety has only intensified in the last few years due to a change in the

¹Note that the former lends itself to the latter since all currencies are traded in pairs. So, for example, if a trader wanted to buy British Pounds they would have to “pay for them” in a different currency, such as euros or US dollars. To put it another way: to buy one currency, the transaction must be offset by selling another. Hence downward movements on one side of the pair would lead to upward movements on the other side, *ceteris paribus*.

²This coincides with the previous literature which also observes the counter movement of the Japanese yen compared to the studied trends.

³Spot trades are agreements that are executed at the moment they are agreed upon, whereas for futures or derivative contracts there is an exchange that occurs at some point in the future.

business environment and increased government regulation in the banking sector. There are now fewer leveraged firms, such as hedge funds, taking bets on currencies and instead more banks and corporations using foreign exchange to hedge against currency risks associated with other deals. Moore, Schrimpf, and Sushko (2016) postulate that this has helped contribute to a decreased turnover in spot trading, which is used for prop betting, and an increased turnover in derivatives, which are used to protect positions against fluctuations.

Additionally, the foreign exchange market has seen significant growth in dealer electronic trading which allows direct sales between parties without going through inter-dealers such as EBS and Reuters. This direct electronic trading has been a focus of bigger institutions because it provides the ability to decrease transaction costs while maintaining the client relationship that exists with trader-directed trading. Additionally, non-bank firms have entered the market to provide liquidity and have gained a collectively large foothold in the market. The changes to this market add an incentive to explore the work done in previous papers to see if the discrepancy between business hours still exists.

1.2 Market Structure

The foreign exchange market is one of the largest markets in the world, with over \$5 trillion in daily turnover. The market mostly consists of large firms, the top ten of which control over 75 percent of the total market, as well as some smaller firms that recently have found growth opportunities. The large firms keep the market open 24 hours a day, passing their books from offices in New York, to Australasian offices (including Tokyo, Singapore, Sydney, and Hong Kong) to European offices (including London, Paris, Frankfurt, and Zurich). The books are then passed back to New York at the end of European hours. Thus, from Monday morning in East Asia (or Sunday 5pm EST) until Friday 4pm EST, the foreign exchange market is open. Some of these hours have less liquidity than others, but with the increase of electronic trading there has been more constant liquidity throughout the day.

1.3 Key Drivers

There are many different factors that move the foreign exchange market but this paper will focus on three indicators that could also be driving the market to be disproportionately valued during different times of the day. The three variables we include are interest rates, goods traded, and the bid/ask spread.⁴ Interest rates are an important factor because of the the “carry trade” which is a well-known strategy among traders that consists of borrowing money at a low interest rate from one country and investing that money in a different country with a higher interest rate.⁵ We would expect that the currency of a country with a low interest rate would be weaker during its home business hours as money flows to countries that have higher interest rates.

Another variable we will include is a measure of the current account balance, or the amount of money coming in or out of a country. We would expect, for example, if a country increases its imports while keeping exports constant, that businesses in that country would require more foreign currency to buy the imported items.⁶ In this scenario, we would expect to see a weakening of the domestic currency during business hours.

The last important measure we will look at is the spread, or the difference between the bid and ask prices. This is a good proxy for both the liquidity and volatility in the market since the less liquid or more volatile a market is during a given time, the higher the spread will be. Ideally we would prefer to separate volatility and liquidity however this would require data typically obtained from firms or market-makers.

A separate issue that may drive the market is the day of the week or holidays, which Rinaldo (2009) addresses. The foreign exchange market is open all week long, every week of the year, and only ever closes on New Years day and Christmas. Thus, holidays in different

⁴In the currency market, trades are proposed using a bid/ask model where the trader is willing to buy at the lower price (the bid) or sell at the higher price (the ask). The mid is in the middle of these two numbers and, in theory, represents what the true value should be. The spread is just the ask price minus the bid price.

⁵For more information on the carry trade see Galati, Heath, and McGuire (2007).

⁶Cornett, Schwarz, and Szakmary (1995) show that there is a tendency for transactions to be invoiced in the exporters’ country’s currency.

countries may affect how this trend occurs. Ranaldo finds weak evidence that holidays have much of an effect on the trend. Meanwhile, other papers have found that there is a day of the week effect on the foreign exchange market. While we do not address this in our main model, Appendix J addresses this issue by isolating our regression on different days of the week.

2 Literature Review

The first to recognize and document the effect of business hours were Cornett, Schwarz, and Szakmary in 1995 who use International Monetary Market futures prices from 1977 to 1991. They show a significant appreciation of foreign currencies during US trading hours when looking at the Deutsche mark, British pound, Swiss franc, Japanese yen, and Canadian dollar. Interestingly, they find that foreign currencies appreciate during the first hour of trading, have a statistically insignificant decrease from then until 11:30, and then appreciate again at the end of the day. They also find that domestic currency depreciation during business hours is strongest at the beginning of the week and the trend is reversed at the end of the week. We find similar results using our data, the results of which can be found in Appendix J. This paper also shows that transactions are invoiced using the exporting country's currency and thus domestic firms, which are open during the home country's business hours, are net buyers of foreign currency.

Ranaldo (2009) takes a similar approach, using foreign exchange prices from 1993 to 2005 to evaluate the time-of-day effects. He also looks both during US business hours and when other countries are conducting business. Ranaldo finds that most currencies tend to depreciate during the home country's business hours and correspondingly appreciate during foreign business hours. In addition to the explanation used by Cornett, Schwarz, and Szakmary (1995), this paper also explains this phenomenon through international portfolios which are long foreign currency.⁷

Breedon and Ranaldo (2013) build on this trend using data from the Electronic Broking Services (EBS), an inter-dealer electronic platform. They take not only the spot rates for the major foreign exchange pairs, but also the order flow to test the hypothesis of the

⁷See Lane and Milesi-Ferrentti (2007) for more on portfolios.

previous two papers. They are able to get data on many currency pairs including the euro, Japanese yen, British pound, Swiss franc, and Australian dollar, all crossed with the US dollar. The authors find for these currency pairs (as well as the euro crossed with the Japanese yen) that the domestic currency does indeed lose value during domestic business hours and appreciate during foreign business hours, when measuring using a simple mid price. The only exception is the Japanese yen when paired with the US dollar had the opposite effect during US business hours and an almost negligible effect during the Japanese hours. Interestingly, when the authors look at the direction of the order flow of these trades, they find that it is only the US dollar and Japanese yen pair where both sides are significant sellers of the home currency during domestic business hours. The authors also look specifically at the pair between the euro and US dollar to show how it provides a profitable trading strategy.

Additionally, Breedon and Ranaldo use firm-level data from BNP Paribas to further investigate the business hour trend. They find that banks and investment funds have a strong tendency to buy foreign currency during domestic business hours. This is consistent with the theory in previous literature that international funds are net buyers of foreign currency because they receive inflows of their own currency. Since they also conduct trades during their country's business hours, these funds would contribute to the depreciation of the domestic currency during the local business day.

The most recent study from Jiang (2016) takes a very different approach as to why this pattern has emerged. He argues that firms inside each country are net buyers of domestic currency, and thus sellers of foreign currency. However since intermediary institutions charge a premium when the foreign markets are closed, this leads to an appreciation of foreign currency. Similar to Breedon and Ranaldo, Jiang shows that the pair between the euro and US dollar provides a profitable trading strategy, even when controlling for the bid/ask spread.

3 Data

3.1 Specification of the Dependent Variable

The Bloomberg BFIX database is an ideal candidate for our use. First, it pulls from a wide-range of sources including large and regional banks, broker-dealers, inter-dealer brokers, and trading platforms. Second, Bloomberg has an extensive geographical reach and is used by traders throughout the world. Lastly, the BFIX database has quotes for every 30 minutes on the hour and half-hour from the interbank market for all ten G10 currencies since May 2007 for mid prices, as well as bid and ask prices from August 2010. The G10 are ten of the most traded currencies in the world and include the the United States dollar (USD), the euro (EUR), the Japanese yen (JPY), the British pound sterling (GBP), the Swiss franc (CHF), the Australian dollar (AUD), the New Zealand dollar (NZD), the Canadian dollar (CAD), the Swedish krona (SEK), and the Norwegian krone (NOK). The quotes are time-weighted average prices using the prices before and after the desired time and weighted accordingly.⁸

For ease of comparison, all prices are quoted with USD as the counter currency. So, for example, even though the standard way to quote the cross price between the Japanese Yen and the US dollar would be USD/JPY⁹ (i.e. the number of yen needed to exchange for one dollar), we will quote the pair as JPY/USD to keep our comparisons constant throughout currency pairs.

⁸For all the G10 currencies this weighting starts five minutes before the desired time and six seconds afterwards, however it is longer for non-G10 because they have less liquidity. Though not an issue for this study, to add in non-G10 currencies researchers may want to use a different database.

⁹Here we call the USD the “base currency” and JPY the “counter currency.”

There are a few different ways to use this data. The simplest would be to use normal mid price quotes.¹⁰ However, this may not yield statistically significant results since gains and losses throughout the day may lose significance in the amount of data being collected. We use discrete percent change from four hours before as an alternative to using regular quoted prices, similar to the method used in Ranaldo (2009).¹¹

We calculate percent change from four hours ago as follows:

$$Mid4h_{i,t} = \frac{Mid_{i,t} - Mid_{i-8,t}}{Mid_{i-8,t}} * 10,000 \quad (1)$$

where:

$Mid_{i,t}$ = Mid price at time i on trading day t .

$i \in \{0, 1, 2, \dots, 47\}$ represents all half hour increments of the day.¹²

t are all trading days between August 2010 and December 2016.

Note that:

- $Mid_{i-8,t}$ occurs four hours prior to $Mid_{i,t}$ on trading day t since prices are measured in increments of 30 minutes.¹³
- Although we have data for mid prices since May 2007, we will only use data since August 2010 to remain consistent throughout the paper (unless otherwise specified).
- If $Mid_{i-8,t}$ does not exist for a given i and t , either because it is the weekend or a holiday, we do not use $Mid4h_{i,t}$.

¹⁰Additionally we can regress on the mid, bid, or ask prices. If the true price were moving, we would expect the bid and ask prices to move in tandem controlling for willingness-to-risk and liquidity. While we will not delve into these realms, slight deviations among these categories may yield results that could shed light on the motives behind the price movements between business and non-business hours. However for our model, regressions using the bid or ask prices yield similar results (see Appendix C).

¹¹Although other increments work similarly, four allows for a time jump that is not to be too large while also allowing a smoother change from hour to hour. Additionally, since stock markets are open approximately eight hours a day, four hours allows us to compare the beginning of the stock market to before it was open, and the last hours track how it has changed throughout the day.

¹²For example, $i = 17$ corresponds to 8:30am EST.

¹³If $i < 8$ we use data from the previous day to get the mid price from four hours prior.

- $Mid4h_{i,t}$ is measured in basis points, or one hundredth of one percent.¹⁴
- We calculate this specifically for each different currency pair.

Figure 1 shows the average percent change from four hours ago for each country by time of day. Note that the positive shaded region indicates when the US stock market is open and the bottom shaded region indicates when the other stock market is open.

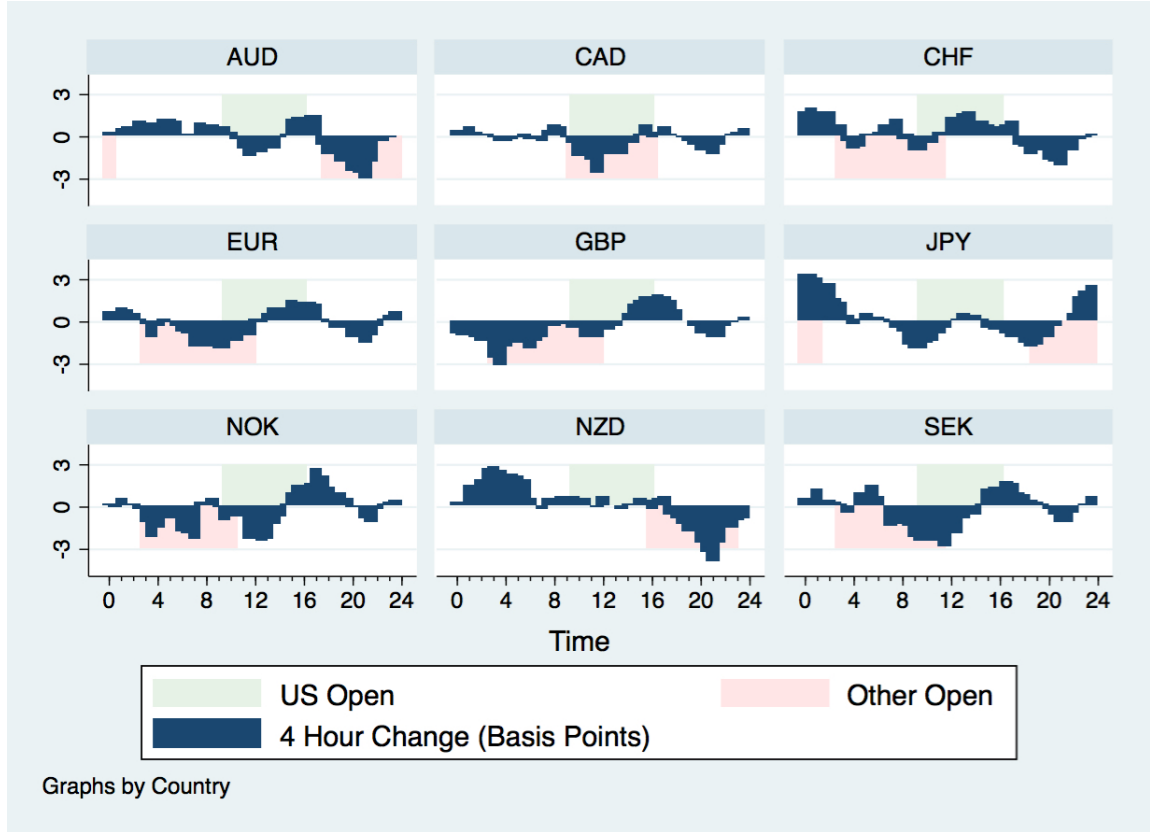


Figure 1: Average Hourly Percent Change in Mid Price from Four Hours Prior by Country

3.2 Determination of Business Hours

Before determining the dummy variable for hours, it is important to define a market being open. We use hours of operation for the major stock exchanges in each country to represent

¹⁴This is why we multiply the term by 10,000. It is a common practice in the FX market to quote in basis points, and makes our observations easier to read.

the typical hours of operation for most businesses in their respective country.¹⁵ However, these hours are likely not equivalent to a typical workday for most foreign exchange traders. For example, in New York FX traders typically start work between 6 and 7am and end around 5 to 6pm, well before the US-based stock exchanges open and slightly after they close.

Adjusting the hours of business can in some circumstances improve our results. However, we will not consider these alternative specifications in our main analysis for a few reasons. One is that using stock market hours gives a fairly strict sense of what is and is not a business hour. This not only adds order to our selection, but also avoids hours being arbitrarily manipulated to get the best results. Second, trying to find typical hours of operation for traders in multiple locations across different firms which even in the same country may have different workdays, makes finding strict hours difficult. The third, and most important reason, is that the stock market hours still cover the “sweet spot” of a country’s business hours where everyone including financial firms, money managers, and corporations, are all operating. Thus stock market hours are a good estimate of a country’s peak business hours.

Using stock market hours, we can segment the market into four exhaustive and mutually exclusive categories. Table 1 takes the average of each currency pair over these four market classifications which are:

1. When the US stock market is open and the other stock market is closed.
2. When the other stock market is open and the US stock market is closed.
3. When both stock markets are open.
4. When both stock markets are closed.

¹⁵Note that for the euro, we use the stock market hours consistent among France, Germany, Spain, and Italy as representative of the overall euro area.

	US Only Open	Other Only Open	Both Open	Both Closed
EUR	0.8697	-0.9117	-1.6913	-0.0284
GBP	0.4877	-0.7706	-1.4978	-0.2813
AUD	-0.3343	-1.2328	-	0.4652
NZD	-0.0366	-1.3172	-0.1695	0.9438
JPY	-0.6185	0.7533	-	-0.4678
CHF	0.8206	0.2334	-0.3887	-0.1965
NOK	-0.3413	-1.1133	-1.3689	0.103
SEK	-0.497	0.1941	-2.5814	-0.153
CAD	-	-	-0.6987	-0.415

Stated currencies are the base currency with the USD as the counter currency

All values are given in average basis points

Data since August 2010

Table 1: Means of Mid4h Conditional on the States of US and Other Stock Markets

A majority of the currencies show a strong trend of depreciation during their business hours. The only exceptions were the JPY, which has been previously documented to be an anomaly, the SEK and CHF. However, contrary to what has been documented in the previous literature, on average the US dollar appreciated during US business hours against five of the nine currencies. As noted before, this coincides with an increase in the value of the dollar, which from August 2010 to December 2016 appreciated almost 20 percent against the other G10 currencies.

Despite this divergence from previous literature, our estimates show that besides the JPY and SEK, all of the currencies fared better when only the US stock market was open then when only their own stock market was open. Hence while we do not find a consistent theme of strict depreciation of currencies during their country's home business hours, we do find that currencies are generally weaker during their home business hours when compared to the business hours of the paired currency.

For our main regression we would like to use a dummy variable which compares two sets of time, when the US market is open and when the other market is open. Thus we will use the following hours variable for each country in our sample:

$$Hrs_i = \begin{cases} 1, & \text{if the US stock market is open and the other stock market is closed} \\ 0, & \text{if the other stock market is open and the US stock market is closed} \end{cases} \quad (2)$$

where:

$i \in \{0, 1, 2, \dots, 47\}$ represents all half hour increments of the day.

This variable will take the other country's business hours as a baseline and compare it with US business hours. This is ideal because it tracks the difference between the periods, opposed to only focusing on an individual time period which can be heavily swayed by the overall market direction.¹⁶ As such, this specification would find that the trend observed in previous literature indeed held in our sample, even though the US dollar on average appreciated against G10 currencies during US business hours from 2010 to 2016.

Under our chosen specification (which we will call "US Only Open v Other Only Open"), we disregard when both markets are closed and when both markets are open. While we could have used a measure that tracked when the US is the only stock market open against when the other stock market is open (regardless of US hours) this would have included times when both markets are open, an overlap that does not exist for all countries in our sample. Thus for consistency we will use "US Only Open v Other Only Open" but run our main regression on other specifications of hours which can be found in Appendix D.

¹⁶Breedon and Ranaldo (2013) find that for their sample "although returns over each session individually show considerable variation by year, the difference in returns between the two sessions remains remarkably stable."

3.3 Macroeconomic Data

Additionally, we include controls for interest rates, current account balance, and spread which account for changes in the foreign exchange market and may influence the magnitude of the business hour trend.

For interest rates, we use the OECD’s long-term interest rate as the main indicator because it represents the important ten year interest rate that is widely used by traders and financial analysts.¹⁷

To measure current account balance we employ goods imported and exported between the US and its counter parties using data from the Census’ US Trade in Goods Data.¹⁸ Ideally we would use the complete current account balance including services, however the information found was either quarterly data or yearly for some of the G10 countries, significantly reducing the number of observations.

We also include the spread in our analysis. This helps account for both the liquidity and risk in the market, but is not useful for separating the two. For the spread, we will simply take the difference between the ask and bid prices that we have in our sample since this is the basic way that spread is calculated. We conduct regressions using the four-hour percent change in the spread as well as the spread divided by the average of the bid and ask prices. See Appendix K for these tables.

Information on turnover of the foreign exchange market is provided by the Federal Reserve Bank of New York twice a year through the *FX Volume Survey* which receives information from all major domestic dealers and records turnover by counter party, currency pair, type of foreign exchange instrument, and execution type. While this data on turnover

¹⁷See Appendix G for regressions using short-term interest rates as well as the difference between US interest rates and those of the other country in the currency pair.

¹⁸We also apply the complete regression on goods imported and exported independently in Appendix L, though it does not prove to be significant when breaking up net goods and in fact all but two of the hour variables become insignificant.

and electrification by currency pair would be useful, because it is only conducted twice a year we opt to leave it out of our regression.¹⁹

¹⁹The Fed's *FX Volume Survey* only covers transactions in which US institutions are involved which is also somewhat problematic. There is a triennial survey compiled by the Bank of International Settlements that covers all of our geographies, however because of the extreme infrequency of this data it is not useful for our regression. Additionally, other central banks such as the Bank of England and Bank of Japan put out similar surveys which can be used to supplement the US-centric data.

4 Empirical Specification

The model tries to incorporate three major components that could explain currency depreciation during home business hours. We run six variations of the following regression on each of the currency pairs. The first regression uses only the hours variable and shows what the trend would be without any of our other explanatory variables. The second, third, and fourth regressions use interest rates, net goods, or spreads with their respective interaction term. The fifth regression uses all variables except for those including the spread, and the final regression uses all seven independent variables. The regression is specified as follows:

$$Y_{i,m} = \beta_0 + \beta_1 hrs_i + \beta_2 intr_m + \beta_3 intr_m X hrs_i + \beta_4 netgoods_m + \beta_5 gnet_m X hrs_i + \beta_6 spread_{i,m} + \beta_7 spread_{i,m} X hrs_i + \epsilon_{i,m} \quad (3)$$

$i \in \{0, 1, 2, \dots, 47\}$ represents all half hour increments of the day.

$m \in 08/2010 - 12/2016$ are the months in our sample.

where:

$Y_{i,m}$	= average of $Mid4h_{i,t}$ for each time i, given day t is in month m.
Hrs_i	= the dummy variable for US Only Open v Other Only Open.
$Intr_m$	= average monthly long-term interest rate of the country that is being paired with the USD.
$Intr_m X hrs_i$	= monthly long-term interest rate multiplied by hours dummy.
$Netgoods_m$	= monthly total good exports minus total good imports by trading partner (or region for the euro area).
$Gnet_m X hrs_i$	= monthly total net good multiplied by the hours dummy.

$Spread_{i,m}$ = average monthly spread (ask price minus the bid price) at
time of day i for month m.

$Spread_{i,m}Xhrs_i$ = spread multiplied by the hour dummy.

Note that all data which is available daily is being aggregated up to a monthly frequency using averages. We are interested in the variables interacted with hours, as well as the hours variable itself, to see how the included data effects the difference between US business hours and the other country's business hours with respect to the four hour percent change in mid price.

Because data for the spread variable starts in August 2010, we will only use data from that date. For regressions using all available data see Appendix A.

Table 2 expresses the full regression on each country and the subsequent nine tables (Tables 2a-2h) show all six regression on each of the eight currencies with the USD as the counter currency.²⁰

²⁰We exclude the CAD for these regressions since the US and Canadian stock markets maintain the same hours.

	EUR	GBP	AUD	NZD	JPY	CHF	NOK	SEK
	prices	prices	prices	prices	prices	prices	prices	prices
hrs	18.35*** (5.19)	3.178* (2.42)	-9.246*** (-3.36)	-5.090* (-2.04)	-0.394 (-0.12)	1.486 (1.34)	-1.342 (-0.69)	-7.787** (-3.09)
intr	0.852** (3.11)	0.794** (2.85)	-0.116 (-0.34)	-0.322 (-0.79)	-2.879** (-3.29)	0.946 (1.64)	-0.694 (-1.34)	-0.264 (-0.69)
intrXhrs	-2.032*** (-4.74)	-0.0204 (-0.05)	1.190* (2.47)	1.745** (2.98)	2.703* (2.23)	-0.573 (-0.63)	1.321 (1.75)	1.273* (2.19)
netgoods	0.000278 (1.96)	-0.000409 (-0.99)	-0.00182 (-1.59)	0.00927** (2.66)	0.000300 (0.74)	0.000392 (0.75)	-0.00731*** (-3.87)	0.0110*** (4.10)
gnetXhrs	0.000343 (1.54)	0.000323 (0.50)	0.00373* (2.35)	-0.0208*** (-4.23)	0.000303 (0.54)	0.000831 (1.04)	0.0117*** (4.30)	-0.00776 (-1.91)
spread	3.425*** (4.03)	0.632 (1.58)	-0.446 (-0.72)	0.189 (0.98)	57.53 (1.61)	-0.0322 (-0.15)	-2.163*** (-3.95)	-4.426*** (-4.68)
spreadXhrs	-7.444*** (-5.67)	-1.310* (-2.13)	0.729 (0.81)	-0.182 (-0.44)	-98.70* (-2.01)	-0.141 (-0.39)	1.906* (2.57)	4.681*** (3.68)
Constant	-4.305 (-1.92)	-3.471*** (-4.10)	2.188 (1.09)	-0.646 (-0.36)	3.732 (1.62)	-0.153 (-0.22)	0.465 (0.35)	7.118*** (4.28)
Observations	1694	1694	2079	2002	2079	1771	1925	1771

t statistics in parentheses

intr = Long-Term Interest Rate, hrs = US Only Open vs. Other Only Open, prices=mid4h

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: Regression (6) for each country

	(1)	(2)	(3)	(4)	(5)	(6)
	prices	prices	prices	prices	prices	prices
hrs	1.857*** (5.31)	3.755*** (4.60)	0.215 (0.14)	6.280*** (4.74)	6.090* (2.16)	18.35*** (5.19)
intr		0.760*** (4.10)			0.369 (1.48)	0.852** (3.11)
intrXhrs		-0.745* (-2.57)			-0.970* (-2.50)	-2.032*** (-4.74)
netgoods			0.000477*** (4.50)		0.000335* (2.35)	0.000278 (1.96)
gnetXhrs			-0.000180 (-1.08)		0.000193 (0.87)	0.000343 (1.54)
spread				1.229 (1.64)		3.425*** (4.03)
spreadXhrs				-4.015*** (-3.46)		-7.444*** (-5.67)
Constant	-0.944*** (-4.22)	-2.881*** (-5.52)	3.411*** (3.43)	-2.282** (-2.70)	1.176 (0.65)	-4.305 (-1.92)
Observations	1694	1694	1694	1694	1694	1694

t statistics in parentheses

intr = Long-Term Interest Rate, hrs = US Only Open vs. Other Only Open, prices=mid4h

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2a: EUR

	(1)	(2)	(3)	(4)	(5)	(6)
	prices	prices	prices	prices	prices	prices
hrs	1.287*** (4.15)	1.463 (1.41)	1.289*** (4.13)	2.989*** (3.33)	1.472 (1.41)	3.178* (2.42)
intr		0.802** (2.89)			0.816** (2.93)	0.794** (2.85)
intrXhrs		-0.0773 (-0.18)			-0.0801 (-0.18)	-0.0204 (-0.05)
netgoods			-0.000185 (-0.46)		-0.000273 (-0.68)	-0.000409 (-0.99)
gnetXhrs			0.0000458 (0.07)		0.0000545 (0.09)	0.000323 (0.50)
spread				0.621 (1.58)		0.632 (1.58)
spreadXhrs				-1.219* (-2.02)		-1.310* (-2.13)
Constant	-0.775*** (-3.91)	-2.598*** (-3.93)	-0.784*** (-3.93)	-1.631** (-2.83)	-2.643*** (-3.97)	-3.471*** (-4.10)
Observations	1694	1694	1694	1694	1694	1694

t statistics in parentheses

intr = Long-Term Interest Rate, hrs = US Only Open vs. Other Only Open, prices=mid4h

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2b: GBP

	(1)	(2)	(3)	(4)	(5)	(6)
	prices	prices	prices	prices	prices	prices
hrs	0.997* (2.19)	-4.185* (-2.44)	-4.870* (-2.27)	-0.207 (-0.17)	-8.285*** (-3.31)	-9.246*** (-3.36)
intr		-0.246 (-0.73)			-0.150 (-0.44)	-0.116 (-0.34)
intrXhrs		1.457** (3.13)			1.258** (2.66)	1.190* (2.47)
netgoods			-0.00180 (-1.61)		-0.00170 (-1.51)	-0.00182 (-1.59)
gnetXhrs			0.00432** (2.79)		0.00354* (2.25)	0.00373* (2.35)
spread				-0.347 (-0.57)		-0.446 (-0.72)
spreadXhrs				0.948 (1.08)		0.729 (0.81)
Constant	-1.294*** (-3.96)	-0.420 (-0.34)	1.145 (0.74)	-0.834 (-0.95)	1.552 (0.86)	2.188 (1.09)
Observations	2079	2079	2079	2079	2079	2079

t statistics in parentheses

intr = Long-Term Interest Rate, hrs = US Only Open vs. Other Only Open, prices=mid4h

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2c: AUD

	(1)	(2)	(3)	(4)	(5)	(6)
	prices	prices	prices	prices	prices	prices
hrs	1.412** (2.92)	-3.097 (-1.35)	1.280** (2.65)	1.460 (1.31)	-5.698* (-2.41)	-5.090* (-2.04)
intr		-0.0549 (-0.14)			-0.327 (-0.80)	-0.322 (-0.79)
intrXhrs		1.137* (2.02)			1.752** (3.02)	1.745** (2.98)
netgoods			0.00846* (2.51)		0.00916** (2.63)	0.00927** (2.66)
gnetXhrs			-0.0169*** (-3.55)		-0.0207*** (-4.21)	-0.0208*** (-4.23)
spread				0.172 (0.89)		0.189 (0.98)
spreadXhrs				0.0519 (0.13)		-0.182 (-0.44)
Constant	-1.399*** (-4.10)	-1.181 (-0.73)	-1.333*** (-3.90)	-1.943** (-2.77)	-0.0299 (-0.02)	-0.646 (-0.36)
Observations	2002	2002	2002	2002	2002	2002

t statistics in parentheses

intr = Long-Term Interest Rate, hrs = US Only Open vs. Other Only Open, prices=mid4h

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2d: NZD

	(1)	(2)	(3)	(4)	(5)	(6)
	prices	prices	prices	prices	prices	prices
hrs	-1.340** (-3.19)	-3.663*** (-4.73)	3.574 (1.17)	-0.0858 (-0.16)	0.692 (0.22)	-0.394 (-0.12)
intr		-3.510*** (-4.49)			-3.516*** (-4.50)	-2.879** (-3.29)
intrXhrs		3.869*** (3.57)			3.779*** (3.48)	2.703* (2.23)
netgoods			-0.0000508 (-0.14)		0.0000474 (0.13)	0.000300 (0.74)
gnetXhrs			0.000847 (1.62)		0.000741 (1.42)	0.000303 (0.54)
spread				96.84** (3.26)		57.53 (1.61)
spreadXhrs				-152.9*** (-3.73)		-98.70* (-2.01)
Constant	0.731* (2.41)	2.839*** (5.09)	0.436 (0.20)	-0.0609 (-0.16)	3.117 (1.37)	3.732 (1.62)
Observations	2079	2079	2079	2079	2079	2079

t statistics in parentheses

intr = Long-Term Interest Rate, hrs = US Only Open vs. Other Only Open, prices=mid4h

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2e: JPY

	(1)	(2)	(3)	(4)	(5)	(6)
	prices	prices	prices	prices	prices	prices
hrs	0.630 (1.48)	0.601 (1.05)	0.872 (1.72)	0.764 (1.44)	1.181 (1.44)	1.486 (1.34)
intr		1.191** (2.86)			0.989* (1.99)	0.946 (1.64)
intrXhrs		0.0477 (0.08)			-0.362 (-0.48)	-0.573 (-0.63)
netgoods			0.000951* (2.18)		0.000386 (0.74)	0.000392 (0.75)
gnetXhrs			0.000579 (0.87)		0.000786 (1.00)	0.000831 (1.04)
spread				-0.298 (-1.62)		-0.0322 (-0.15)
spreadXhrs				-0.117 (-0.40)		-0.141 (-0.39)
Constant	0.227 (0.81)	-0.502 (-1.33)	0.626 (1.87)	0.553 (1.60)	-0.217 (-0.40)	-0.153 (-0.22)
Observations	1771	1771	1771	1771	1771	1771

t statistics in parentheses

intr = Long-Term Interest Rate, hrs = US Only Open vs. Other Only Open, prices=mid4h

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2f: CHF

	(1)	(2)	(3)	(4)	(5)	(6)
	prices	prices	prices	prices	prices	prices
hrs	0.789 (1.82)	2.352 (1.67)	2.563*** (4.34)	-0.128 (-0.23)	1.746 (1.24)	-1.342 (-0.69)
intr		1.051* (2.58)			0.372 (0.84)	-0.694 (-1.34)
intrXhrs		-0.687 (-1.17)			0.408 (0.64)	1.321 (1.75)
netgoods			-0.00791*** (-4.55)		-0.00728*** (-3.84)	-0.00731*** (-3.87)
gnetXhrs			0.0110*** (4.39)		0.0117*** (4.28)	0.0117*** (4.30)
spread				-2.149*** (-4.69)		-2.163*** (-3.95)
spreadXhrs				1.751** (2.84)		1.906* (2.57)
Constant	-1.115*** (-3.72)	-3.508*** (-3.59)	-2.387*** (-5.84)	0.0542 (0.14)	-3.132** (-3.21)	0.465 (0.35)
Observations	1925	1925	1925	1925	1925	1925

t statistics in parentheses

intr = Long-Term Interest Rate, hrs = US Only Open vs. Other Only Open, prices=mid4h

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2g: NOK

	(1)	(2)	(3)	(4)	(5)	(6)
	prices	prices	prices	prices	prices	prices
hrs	-0.642 (-1.55)	-1.002 (-1.12)	-2.359 (-1.26)	-1.374** (-2.58)	-2.624 (-1.32)	-7.787** (-3.09)
intr		0.688* (2.14)			0.746* (2.32)	-0.264 (-0.69)
intrXhrs		0.221 (0.46)			0.192 (0.40)	1.273* (2.19)
netgoods			0.00665** (2.60)		0.00704** (2.76)	0.0110*** (4.10)
gnetXhrs			-0.00363 (-0.94)		-0.00353 (-0.91)	-0.00776 (-1.91)
spread				-3.119*** (-4.15)		-4.426*** (-4.68)
spreadXhrs				2.589* (2.55)		4.681*** (3.68)
Constant	0.183 (0.67)	-0.933 (-1.59)	3.330** (2.69)	1.108** (3.15)	2.304 (1.76)	7.118*** (4.28)
Observations	1771	1771	1771	1771	1771	1771

t statistics in parentheses

intr = Long-Term Interest Rate, hrs = US Only Open vs. Other Only Open, prices=mid4h

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2h: SEK

5 Results

We see a very surprising result: controlling for the interest rate, net goods, and the spread, as well as their multiplication with the interaction term, the hours dummy (1 for the US being the only market open and 0 for the other market being the only market open) has either a negative or insignificant effect on all but two of our currency pairs. This is opposite of the results we observed in Table 1 which shows that on average currencies are relatively weaker during their home business hours compared to other foreign business hours.

With this result, we can motivate an explanation for the absence of a market correction for predictable business hour fluctuations. To explain, suppose that higher foreign interest rates cause US firms to seek international currency. Then US firms would enter the market during US business hours seeking to sell USD in exchange for the foreign currency. Once a market-maker sells the foreign currency to the firm, she has the option to either cover her position immediately or wait until the corresponding foreign market opens to buy back the foreign currency to cover her position.²¹

For a trader whose main goal is to reduce risk, holding onto the position may seem like a useless risk in the hopes of a relatively small gain. Thus instead of shifting the buying pressure on the foreign currency from US business hours to foreign business hours, the trader will attempt to cover immediately which would add to, instead of correct, the overall trend that we observe. However, if there were also some smaller firms making a slight profit off the trend (though not enough to correct the market) or some other variable that we are leaving out that could have the opposite effect on business hours, than this

²¹Especially after the financial crises, market-makers have focused on providing liquidity rather than prop trading due to both a change in large institutions' risk-appetite and regulation. Thus traders routinely try to cover their positions to reduce risk by either covering the trade outright or hedging the risk through derivative contracts.

explanation would be consistent with the trend still existing in the raw data yet our added variables over-explaining the trend causing the coefficients to become negative.²²

We also see that, except for EUR (as well as statistically insignificant coefficients for GBP and CHF), interest rates multiplied by hours had a more positive impact than just interest rates. This aligns with our projection because if the interest rate of the other country was higher, than during the business day US firms would opt to sell dollars in order to buy the foreign currency and invest in that market. While the eurozone is the only statistically significant exception, the coefficients on intrXhrs for EUR are actually positive for all but two years, 2014 and 2016, which were turning points in the European and Greek debt crises respectively. In these scenarios a resolution would increase confidence in the European economy, leading to more investment from the US (and a further strengthening of the euro during US business hours) while also leading to a decrease in the interest rate.

There is more of a mixed bag when it comes to spreads. For five of the eight pairs, the impact of the spread during the foreign business hours has the opposite sign of that during the US business hours. Most of these instances occur when the coefficient on spread with the interaction term is negative. Nevertheless, because we cannot separate the different conditions expressed by spreads, especially volatility and liquidity, it is hard to make an assumption as to why this occurs.

Lastly, we find very limited and mixed significance with net goods. This result may indicate that firms paying for their imports may not be a major driver for the business hour discrepancies as the first three papers theorize. However, by only using goods in our regression we are missing a major aspect of this trade: services. Therefore, before we can say anything definitive on this subject, it would be useful to have the complete current account data.

²²This however does not explain why the smaller firms, or electronic trading strategies, would not take full advantage of this trend to increase profits and thus correcting the market completely.

6 Conclusion

The results in this paper hopefully will start a new discussion about this understudied phenomenon in the foreign exchange market. For over a decade, research has shown that implementing a trading strategy based on business hours would be profitable if one was able to buy and sell at the mid prices. While this would be impossible to achieve for normal traders, market-makers could surely take advantage of this strategy by lowering their ask prices or raising their bid prices at ideal times. Since 2013, the literature has even shown a basic trading strategy for the EUR/USD pair that is profitable when accounting for bid and ask prices, and hence accessible to the average currency trader.

I am able to replicate these results and find that the EUR remains a profitable trading strategy even when buying at the ask prices and selling at the bid prices. However, if one buys and sells at the mid prices, the remaining currencies profit an average of 8.5 percent annually by going long on the foreign currency during the US work day (8am-5pm) and shorting the foreign currency overnight (5pm-8am).²³ These back-of-the-envelope calculations use the same hours for all currencies and we would expect higher returns using different hours for each pair. Even more surprisingly, I have found that the potential profit has increased since 2010, though not as profitable as the strategy had been from 2007 to 2009 (though we should be skeptical of these years because of the financial crises).

Thus the issue becomes why there has remained a profitable trading strategy and why market-makers have not stepped in to increase returns. While my results give a plausible explanation to this answer, there is more work that needs to be done to understand the drivers of this trend in the market. In that spirit, there are a few simple ways to expand on the work done here.

²³Note that I implement the opposite strategy for the JPY/USD, motivated by our results in Table 1.

First if we were to have earlier data, we could both check the results of older papers and run our regressions on those years. Additionally, adding more years of data may help us understand why the significance of the coefficients on hours disappeared from 2010 to 2014.

Second, we could tighten up the interpretation of hours. Instead of using dummies of 1 or 0, we could weight the hours from the middle of the workday outwards. Another strategy could be to have a more rigorous and strict way of evaluating hours and when traders are working. With this type of data, we could take the difference between the stock market hours and the trading hours to perhaps better understand what part of this phenomenon is driven by firms and what is driven by intermediaries.

Third, adding in measures for volume (as done by Breedon and Ranaldo), liquidity, and risk could add more dimensions to our regression. Even though the spread is a quasi-representation for liquidity and risk, isolating these components may be fruitful to determining the cause of the movements.

Fourth, we could have overall current account, including services, rather than just goods. This may help add significance to the net trade and hours variable which was not very significant in our final regression.

After finding negative results when accounting for interest rates, net goods, and spreads, we should also look for variables that may express the opposite trend and bring the hour coefficients closer to zero. One of these variables could be the relative strength of the stock markets in each of the countries, which would have an effect on the desirability of that currency.

Finally, adding in variables for the electrification of the spot markets would be useful to account for the changes in trends over time. While we have already outlined that this data exists, it is too infrequent for our study. However with this information from a major market-maker, one could supplement the biannual data with the firm-level data.

Appendices

See <http://jadelman.weebly.com> for tables.

Appendix A: All Regressions on All Available Data

Note that compared to our original analysis, regressions (4) and (6) are the same since these include the spread variable which we only have data on since August 2010. However for regressions (1), (2), (3), and (5) we have all needed data since May 2007 and thus these results are slightly different than those of the regressions using data exclusively since August 2010.

Appendix B: Correlation Tables

The following are correlation tables corresponding to the variables in our regressions. Note that these, as well as the remainder of the appendices, exclusively use data since August 2010.

Appendix C: Main Regression on Different Measures of Price Changes

For the normal bid, mid, and ask prices we see that the regression is almost identical across all countries. But when looking at the four and one hour percent changes, we see some patterns emerge. One trend is that the coefficients on the spread are greater when regressing on the ask price changes and less when regressing on the bid price changes. We would expect this since when the spread widens, assuming a constant mid, the bid prices would decrease and ask prices would increase.

The major trend that we see with the one and four hour percent change dependent variables is that the coefficient on hours is largest when regressing on the ask prices and smallest when regression on the bid prices. This aligns with an outside analysis we have undertaken on the data to calculate the theoretical return from a trading strategy utilizing the business hour trend. When evaluating hours by the US market being open or closed, we find that most of the mid variations occur alongside a corresponding and greater shift in the ask prices. Thus is one were theoretically able to buy or sell at the ask prices according to our theory of business hour depreciation, they could earn a profit that is on average twice as large as executing on the mid prices. Conversely, while buying and selling at mid or ask prices would return a profit, we find that doing so on the bid prices would in fact return no or negative profit.²⁴ It is important to note that this exercise was purely theoretical as it is impossible, even for large institutional banks, to sell at the ask price at their discretion.

Appendix D: Main Regression using Different Measurements of Hours

There are different dummy measures we can create using just stock market hours of the different countries. We concluded above, that the best measurement would be comparing when the US stock market is only open and when the other stock market is only open. However, there are other criteria in that we could have used. These include:

- US Open v US Closed - this is the original boolean that is 1 when the US stock market is open and 0 when the US stock market is closed.
- US Only Open v US Closed - this variable is 1 when only the US stock market is open and 0 when the US stock market is closed. This excludes when both stock markets are open.

²⁴Contact the author for these calculations.

- US Only Open v Other Open - this variable is 1 when only the US stock market is open and 0 when the other stock market is open, even if the US stock market is also open during that time. This excludes when both markets are closed.
- US Only Open v Other Only Open - this variable is 1 when only the US stock market is open and 0 when only the other stock market is open. This excludes times when both stock markets are closed and when both stock markets are open.
- US Only Open v Both Open - this variable is 1 when only the US stock market is open and 0 when both stock markets are open. This excludes when both are closed and when only the other market is open.²⁵

The differences between these five different measures is shown in Figure D which takes the yearly average difference between the two periods for each currency pair. As we can see, these different comparisons of stock market hours lend themselves to slightly different values and trends across both time and currency pair.

Each of the measures also does not apply to each of the different currency pairs. This is because countries such as Australia and Japan never have stock market hours overlap with the United States, resulting in two consequences. The first is that there is never a time in which both markets are open and hence one of our classifications of hours does not exist. Secondly, since there is no overlap, the “Country Open” and “Country Only Open” measures are the same. Thus for Australia and Japan there are only two measures that appear in our figure, comparisons when either stock market is open and comparisons between the US stock market being open or closed. Another abnormality is Canada, which has the exact same hours as the US, and thus has only one measure between the US stock market being open or closed.

We find that “US Only Open v Other Open” and “US Only Open v Other Only Open” similarly yield very strong results, compared to the two measures that center around the

²⁵Note that a market is “only” open if the domestic stock market is open but the stock market of the other country in the currency pair is closed.

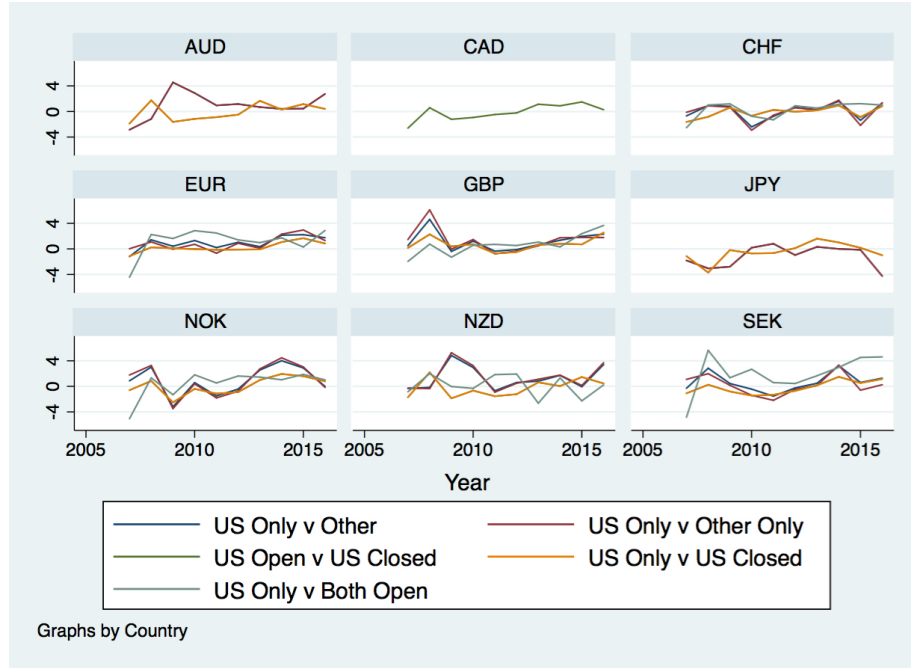


Figure D: Yearly Differences in Average Hourly Percent Change in Mid Price from Four Hours Prior by Country and Measure of Hours

US market being open or closed without regard for the other market which have similar but weaker results. These two different types of categorizing hours (aka using only US hours or comparing when either market is open) yield especially divergent results especially for AUD, NZD, and JPY. In fact all of these pairs, which had negative coefficients on hours using “US v Other” dummies in our regression, become less negative when using only US centric measures of business hours. This is similar to the trends we found in Table 1 and can be attributed to the appreciation of the AUD and NZD during the beginning of European business hours when both these markets and the US stock market are closed (see Graph 1). This phenomenon could be the Australasian currencies appreciating against the European currencies during the European business hours more so than the US dollar is appreciating against the European currencies during this time. This could occur because US business hours are so far from this specific time that they do not experience as strong of a bounce. Thus since currencies are transitory, the Australasian currencies would gain against the dollar during this period. Hence we can explain some of these differences through the

lens of our model and this may in fact be a future source of study on the business hour phenomenon.

Appendix E: Main Regression by Year

We see that in 2010 and 2011 our coefficients are very different than those found in the overall regression.²⁶ In Appendix F when just looking at the trend without accounting for interest rates, trade, or spreads (we will call this “the trend”) that the coefficients show a significantly different relationship than the trends we first established in Table 1 and which were consistent with other papers.

Using Table F we see that the trends are significantly lower across all countries during 2011 and corresponds to smaller coefficients on hours for 2011 when compared to the overall regression (see Table E3). However in 2012 these trends begin to revert to what we originally found, with 2013 and 2014 being very similar to the overall trend (see Table F). The corresponding tables (Tables E5 and E6) indeed show that during these years that the overall regression coefficients begin to revert back to those we found when regressing over all years. Hence the deviations seen between the tables of Appendix E are likely being driven by yearly distortions in our trend as documented in Table F.

Appendix F: Single-Variable Regression by Year

Table F shows how just the single-variable regression changes over time. While useful in explaining trends seen in the regressions of Appendix E, the results here bring up a need to further study this phenomenon. We see that the trend of currencies depreciating during their business hours is either not significantly significant or negative for most currencies in 2007, 2008, and 2011. The trend has held relatively strong since 2012, however a study

²⁶Note that our data starts in August 2010, so 2010 only contains five months of data. However this trend is in line with what we see in 2011.

that includes data from at least 2000 would be useful to observe how the trend has changed since some of the original literature was published on the topic.

Appendix G: Main Regression using Different Measurements of Interest Rates

We find that subtracting a country's long-term interest rate (our primary choice for interest rates) from that of the US does little to change the coefficients on hours. One exception is the Swiss franc which goes from positive and statistically significant to negative, making the trend of negative coefficients even greater. However, the coefficients on interest rates multiplied by hours decrease, with over half of the coefficients becoming negative. This goes counter to trend we saw in the original regression.

When changing from longer 10-year rates to shorter money market rates, we do not see a major shift in the coefficients on hours except for New Zealand where the coefficient goes from significantly negative to significantly positive. Yet for all the other countries both hours and interest rates multiplied by hours are about similar. Additionally, we do not see drastic changes in the coefficients of short-term interest rates when subtracting by US short-term interest rates.

Appendix H: Main Regression Using Different Days of the Week

While there are some distinctions across the different days, the coefficients are similar to those for the overall regression. One major trend that emerges is that Mondays show a greater coefficient on hours for all pairs except SEK. As seen in Table J, this corresponds to an increased strengthening of foreign currency during domestic business hours on Mondays. If we add Sunday to the calculation for Monday, all coefficients stay the same except for

AUD, NZD, and JPY. For these Australasian currencies the coefficient on hours decrease towards 0, closer to the coefficients we obtained for the overall values.²⁷

Appendix J: Single-Variable Regression Using Different Days of the Week

Here we see that Monday and Tuesday conform very well to our trend of domestic currency weakness during business hours. Alternatively, Thursday and Fridays appear to have opposite, though the magnitudes of the coefficients is smaller than for Monday and Tuesday. This is consistent with Cornett, Schwarz, and Szakmary (1995) which found that the trading strategy based on business hour returns had a negative profit on Fridays.

Appendix K: Main Regression Using Different Specifications of Spread

When using the spread divided by the average of the bid and ask prices, the coefficients throughout the table remain almost the same (note that for spread and spreadXhrs these coefficients have just been resized). However, when using the four hour percent change in the spread, we find that the coefficients on hours and spread for the NOK, SEK, and CHF experience some changes.

Appendix L: Main Regression Using Different Specifications of Traded Goods

We see that regressing just using imports or exports almost completely takes significance away from the coefficients on hours. This should be somewhat expected since using only

²⁷We add in Sunday since Sunday evening is the same trading day as most of Monday. We can also classify days as 5pm-5pm EST, contact author for these results.

one side of the trade does not tell much about the net demand that is being put on the currency.

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