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The Day-Of-The-Week Effect

The day-of-the-week effect is one of the calendar anomalies of the stock market. According to this phenomenon, average daily returns are not constant over the week. Furthermore, it suggests the tendency of assets to have lower average daily returns on Monday and relatively high daily returns at the end of the week.

In this paper we will examine the day-of-the-week effect in the Forex market. We will see if the effect occurs in currency returns, and, if so, whether it is similar to the stock market anomaly. For this study we have chosen the top five of our most traded currency pairs: EUR/USD, GBP/USD, USD/JPY, USD/CHF, and EUR/JPY. The data consist of daily closing exchange rates and cover the period from January 2005 to March 2013. However, due to the eventfulness of these eight years, the behavior of daily returns could have changed. Therefore we have divided the period into two parts – from 2005 to 2008, and from 2008 to 2013.

Methodology

To examine the relationship between currency pair returns r_t and days of the week, we use linear regression. This method allows us to model the dependence as a linear equation with unknown coefficients. The model employed in our study is:

$$r_t = \alpha + \beta_M D_M + \beta_W D_W + \beta_{Th} D_{Th} + \beta_F D_F + \varepsilon,$$

where D_M, D_W, D_{Th} and D_F are so-called dummy variables for Monday, Wednesday, Thursday, and Friday. A dummy variable is a qualitative variable. It takes the value of 1 if a certain feature is present in the series, and 0 – if not. For example, D_M would be 1 if return r_t occurred on Monday, and 0 if it occurred in any other day. Because of the effect known as "the dummy variable trap", one day should be excluded from the model. Otherwise the model will be meaningless.

To further explore the relationship and account for non-normality of the data, we use a GARCH (1, 1) model. GARCH stands for generalised autoregressive conditional heteroskedasticity and models the variation of the series – σ_t^2. The GARCH model in our study is:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \gamma_1 \sigma_{t-1}^2 + \beta_M D_M + \beta_W D_W + \beta_{Th} D_{Th} + \beta_F D_F$$

Here the variation of returns is assumed to depend on its previous value (σ_{t-1}^2), average return on the respective day of week ($\beta_M D_M$, $\beta_W D_W$, $\beta_{Th} D_{Th}$, and $\beta_F D_F$), and an error term ε_{t-1}^2. Our main interest, just like in the regression equation, is the β coefficients of the dummy variables.

Results

1. Average daily returns for separate days of the week are not significantly different.

Table 1 provides some descriptive statistics of daily returns for each day of the week. Relatively high kurtosis values indicate that the series have higher peaks and fatter tails than the normal distribution. Despite this, for some days we cannot reject the hypothesis of the normal distribution of the data. The hypothesis holds, for example, for GBP/USD and USD/CHF Thursday returns in the period from 2008 to 2013.

The average daily changes are around zero. For all pairs except USD/CHF, the lowest returns are observed on Mondays, but the highest on Wednesdays and Thursdays.

	EURUSD				GBPUSD				USDJPY				USDCHF				EURJPY			
	Mean	SD	Kurtosis	p-value	Mean	SD	Kurtosis	p-value	Mean	SD	Kurtosis	p-value	Mean	SD	Kurtosis	p-value	Mean	SD	Kurtosis	p-value
Monday	-0.0559	0.6093	2.6254	0.0000	-0.0670	0.6243	3.3364	0.0000	-0.0395	0.6152	5.2148	0.0001	0.0064	0.6207	2.7982	0.0000	-0.0930	0.8529	5.7087	0.0000
Tuesday	0.0054	0.6488	1.2889	0.0964	0.0162	0.6130	3.6305	0.0007	-0.0060	0.6961	9.2224	0.0000	-0.0074	0.8354	33.7447	0.0000	-0.0004	0.8581	11.2300	0.0000
Wednesday	0.0343	0.6513	2.8357	0.0016	-0.0066	0.6054	2.7803	0.0010	0.0201	0.6647	3.1727	0.0000	-0.0479	0.7045	5.7162	0.0000	0.0547	0.7898	3.4251	0.0000
Thursday	0.0310	0.6434	1.0396	0.0959	0.0181	0.5974	2.6564	0.0847	0.0054	0.7103	3.6655	0.0002	-0.0169	0.6826	5.2966	0.0048	0.0362	0.8854	5.9680	0.0000
Friday	-0.0211	0.6679	0.6233	0.2186	-0.0113	0.5907	0.7611	0.2290	0.0089	0.6770	1.6972	0.0090	0.0166	0.7151	0.3497	0.5475	-0.0149	0.8437	5.8301	0.0000
All	-0.0013	0.6447	1.6533	0.0000	-0.0101	0.6065	2.7248	0.0000	-0.0022	0.6732	4.7330	0.0000	-0.0099	0.7148	15.1264	0.0000	-0.0035	0.8473	6.6806	0.0000

	EURUSD				GBPUSD				USDJPY				USDCHF				EURJPY			
	Mean	SD	Kurtosis	p-value	Mean	SD	Kurtosis	p-value	Mean	SD	Kurtosis	p-value	Mean	SD	Kurtosis	p-value	Mean	SD	Kurtosis	p-value
Monday	-0.0473	0.4588	0.6973	0.0237	-0.0430	0.4666	1.2349	0.1602	0.0015	0.4716	0.2686	0.2164	0.0398	0.4931	0.7833	0.0075	-0.0439	0.5180	1.7261	0.0068
Tuesday	0.0453	0.4971	1.0156	0.4648	0.0763	0.4792	-0.1209	0.2074	-0.0016	0.5972	1.2675	0.1096	-0.0515	0.5607	0.9578	0.5737	0.0429	0.5445	1.8173	0.0088
Wednesday	0.0460	0.4418	0.1285	0.4298	0.0052	0.4571	0.2984	0.7784	0.0743	0.5531	1.9976	0.0108	-0.0032	0.4988	0.2621	0.0762	0.1214	0.5305	2.6449	0.0269
Thursday	0.0164	0.4787	0.3306	0.4514	-0.0109	0.4760	0.0907	0.3324	-0.0391	0.5602	2.7883	0.0003	-0.0126	0.5240	0.1613	0.0048	-0.0228	0.5640	3.5214	0.0001
Friday	-0.0090	0.5143	-0.0808	0.1959	-0.0011	0.5004	0.0341	0.1649	0.0186	0.5722	0.0993	0.2321	0.0194	0.5832	-0.1716	0.6409	0.0074	0.5358	0.5075	0.0165
All	0.0103	0.4789	0.4944	0.0156	0.0053	0.4765	0.3723	0.2417	0.0107	0.5523	1.5211	0.0000	-0.0016	0.5326	0.4699	0.0002	0.0210	0.5405	2.3172	0.0000

	EURUSD				GBPUSD				USDJPY				USDCHF				EURJPY			
	Mean	SD	Kurtosis	p-value	Mean	SD	Kurtosis	p-value	Mean	SD	Kurtosis	p-value	Mean	SD	Kurtosis	p-value	Mean	SD	Kurtosis	p-value
Monday	-0.0608	0.6805	2.2348	0.0004	-0.0806	0.6983	2.8248	0.0000	-0.0627	0.6829	5.0038	0.0000	-0.0124	0.6826	2.5860	0.0001	-0.1208	0.9934	4.1680	0.0000
Tuesday	-0.0171	0.7215	0.8676	0.5427	-0.0179	0.6765	3.4261	0.0015	-0.0082	0.7485	10.3904	0.0001	0.0176	0.9577	29.8164	0.0000	-0.0245	0.9939	9.2568	0.0000
Wednesday	0.0277	0.7448	2.1330	0.1086	-0.0133	0.6757	2.4339	0.0030	-0.0105	0.7194	3.0013	0.0001	-0.0732	0.7974	4.9191	0.0171	0.0170	0.9028	2.3898	0.0000
Thursday	0.0393	0.7207	0.6467	0.2235	0.0345	0.6564	2.6368	0.0643	0.0306	0.7824	3.1411	0.0058	-0.0194	0.7586	5.1201	0.2681	0.0695	1.0228	4.4889	0.0026
Friday	-0.0280	0.7415	0.3421	0.1958	-0.0170	0.6369	0.6990	0.7549	0.0034	0.7306	1.7754	0.0091	0.0150	0.7809	0.1914	0.8199	-0.0275	0.9764	4.5064	0.0036
All	-0.0078	0.7221	1.2509	0.0005	-0.0188	0.6691	2.5393	0.0000	-0.0095	0.7331	4.8083	0.0000	-0.0145	0.8001	14.7271	0.0000	-0.0173	0.9793	5.2197	0.0000

Table 1: Summary statistics of daily returns for 2005-2013, 2005-2008 and 2008-2013

To analyse the significance of the distinction between daily returns, we use Tukey-Kramer comparison circles and the Games-Howell test (see Appendix for additional information). Figure 1 shows the comparison of average returns for different days. In the 2008-2013 and 2005-2013 time periods Monday returns are evidently lower, while Thursday and Wednesday average price growth has the highest values. The only exception is USD/CHF – it has its lowest returns on Wednesdays.

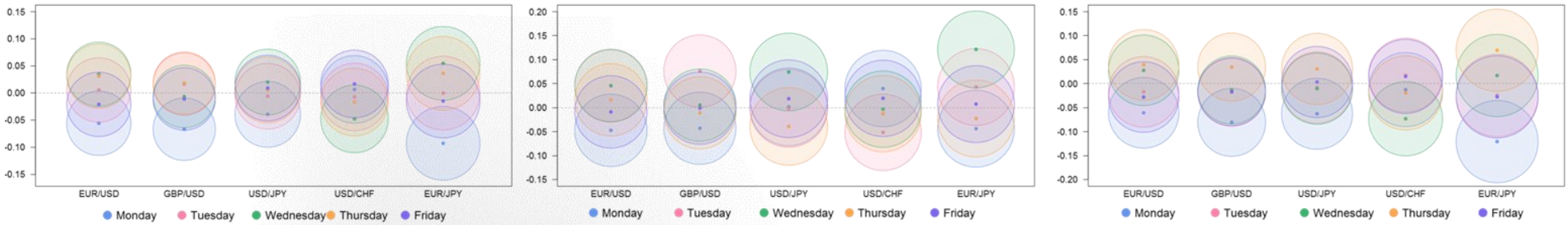


Figure 1: Tukey-Kramer comparison circles for 2005-2013, 2005-2008 and 2008-2013

Despite this seemingly clear distinction, a statistically significant difference in average returns is observed only in one currency pair. EUR/JPY Monday and Thursday returns were not equal in the 2008-2013 and 2005-2013 time periods, but Monday and Wednesday returns - in 2005-2008 and 2005-2013. The Games-Howell test also supports the difference of average returns in these cases only. For the other pairs we cannot reject the hypothesis of average returns being constant over the week.

2. Regression results indicate that returns do not depend on the day of the week.

The Tukey-Kramer and Games-Howell tests suggest that the day-of-the-week effect does influence EUR/JPY returns. However, their results can be misleading if the data series are autocorrelated – that is, if there is a dependency between values of the series at different times. To account for such a possibility we use regression of returns and dummy variables for Monday, Wednesday, Thursday, and Friday. We exclude Tuesday from the list to avoid the dummy variable trap.

Tables 2 and 3 show that almost all coefficients of dummies are insignificantly different from zero. The exception is GBP/USD returns, as their Monday coefficients are significant on 5% level in 2005-2008 and 2005-2013. On the whole, such results imply that average returns might in fact be constant over the week.

Simple regression is good in cases of linear dependency in the series. For nonlinear data, on the other hand, it can produce incorrect results. As the data we use prove to have a more complicated structure, we utilise a GARCH model to investigate possible dependency.

		Regression	GARCH (Norm.)	GARCH (St.)	GARCH (GED)
EUR/USD	Monday	-0.0926	-0.1045	-0.0975	-0.0912
	Wednesday	0.0007	-0.0412	-0.0333	-0.0300
	Thursday	-0.0289	-0.0633	-0.0612	-0.0602
	Friday	-0.0543	-0.0576	-0.0509	-0.0446
GBP/USD	Monday	-0.1192 *	-0.1297	-0.1169	-0.1095
	Wednesday	-0.0710	-0.0899	-0.0851	-0.0792
	Thursday	-0.0871	-0.1282	-0.1312	-0.1244
	Friday	-0.0773	-0.0973	-0.0840	-0.0775
USD/JPY	Monday	0.0032	0.0640	0.0417	0.0661
	Wednesday	0.0759	0.0852	0.0980	0.1154
	Thursday	-0.0375	-0.0000	0.0234	0.0476
	Friday	0.0202	0.0766	0.0821	0.1089
USD/CHF	Monday	0.0913	0.1111	0.1026	0.0963
	Wednesday	0.0483	0.0952	0.0877	0.0898
	Thursday	0.0389	0.0656	0.0659	0.0735
	Friday	0.0709	0.0797	0.0792	0.0779
EUR/JPY	Monday	-0.0868	-0.0610	-0.0464	-0.0481
	Wednesday	0.0784	0.0432	0.0488	0.0410
	Thursday	-0.0657	-0.0502	-0.0227	-0.0224
	Friday	-0.0355	-0.0104	0.0050	0.0065

		Regression	GARCH (Norm.)	GARCH (St.)	GARCH (GED)
EUR/USD	Monday	-0.0437	-0.0334	-0.0315	-0.0262
	Wednesday	0.0449	0.0242	0.0275	0.0245
	Thursday	0.0564	0.0326	0.0373	0.0462
	Friday	-0.0108	0.0175	0.0170	0.0188
GBP/USD	Monday	-0.0627	-0.0286	-0.0301	-0.0332
	Wednesday	0.0046	0.0089	0.0115	0.0116
	Thursday	0.0524	0.0640	0.0627	0.0559
	Friday	0.0009	0.0263	0.0246	0.0201
USD/JPY	Monday	-0.0545	-0.0422	-0.0534	-0.0276
	Wednesday	-0.0022	0.0369	0.0443	0.0477
	Thursday	0.0388	0.0069	0.0149	0.0324
	Friday	0.0116	-0.0295	-0.0151	0.0130
USD/CHF	Monday	-0.0300	-0.0248	-0.0067	-0.0119
	Wednesday	-0.0908	-0.0609	-0.0386	-0.0537
	Thursday	-0.0370	-0.0455	-0.0284	-0.0279
	Friday	-0.0027	-0.0342	-0.0042	0.0036
EUR/JPY	Monday	-0.0963	-0.0791	-0.0729	-0.1076
	Wednesday	0.0415	0.0689	0.0785	0.0534
	Thursday	0.0940	0.0659	0.0342	0.0053
	Friday	-0.0031	-0.0174	-0.0160	-0.0351

* Coefficient is statistically significant at the 5% level

Table 2: Regression and GARCH models results for the 2005-2008 and 2008-2013 time periods

3. The day-of-the-week effect in the currency market is not stable.

Assuming that the day-of-the-week effect might be sensitive to the structure of the data, we examine GARCH models with different error distributions – normal, Student's *t*-distribution, and the generalised error distribution (GED).

Tables 2 and 3 show that GARCH model coefficients are insignificant for all currency pairs. However, Monday returns are generally still the lowest, but Wednesday and Thursday - the highest. USD/CHF is, again, an exception. Their lowest returns are observed on Thursday, but the highest - on Monday (in 2005-2008 and 2005-2013) or Friday (in 2008-2013).

It appears that specified error distribution has an effect on the dummy variable coefficients. For example, in the model with normally distributed errors USD/JPY Thursday returns in 2005-2013 are the lowest, while in other models they had the highest values. Similarly, GBP/USD has its lowest returns on Thursdays under Student's *t*-distribution of the errors.

The changing signs of the coefficients in models with different error distributions indicate instability of the overall model. This is observed for USD/JPY and EUR/JPY in 2005-2008 and 2005-2013, and for USD/JPY and USD/CHF in the period from 2008 to 2013.

		Regression	GARCH (Norm.)	GARCH (St.)	GARCH (GED)
EUR/USD	Monday	-0.0614	-0.0719	-0.0643	-0.0605
	Wednesday	0.0289	-0.0108	-0.0024	-0.0042
	Thursday	0.0256	-0.0169	-0.0132	-0.0095
	Friday	-0.0265	-0.0222	-0.0175	-0.0148
GBP/USD	Monday	-0.0832 *	-0.0792	-0.0756	-0.0726
	Wednesday	-0.0228	-0.0461	-0.0419	-0.0385
	Thursday	0.0019	-0.0217	-0.0236	-0.0241
	Friday	-0.0275	-0.0345	-0.0301	-0.0281
USD/JPY	Monday	-0.0335	0.0045	-0.0112	0.0104
	Wednesday	0.0262	0.0630	0.0760	0.0852
	Thursday	0.0114	0.0008	0.0175	0.0432
	Friday	0.0149	0.0186	0.0318	0.0477
USD/CHF	Monday	0.0138	0.0463	0.0488	0.0410
	Wednesday	-0.0405	0.0228	0.0290	0.0221
	Thursday	-0.0095	0.0060	0.0155	0.0167
	Friday	0.0240	0.0250	0.0343	0.0312
EUR/JPY	Monday	-0.0927	-0.0603	-0.0546	-0.0702
	Wednesday	0.0550	0.0573	0.0629	0.0491
	Thursday	0.0366	-0.0042	0.0021	-0.0032
	Friday	-0.0146	-0.0091	-0.0060	-0.0058

* Coefficient is statistically significant at the 5% level

Table 3: Regression and GARCH models results for 2005-2013

Conclusion

We have performed several types of analysis to examine safe-haven properties in nine currencies. It turned out that such properties are not permanent, and can be observed in different currencies at different times. Furthermore, safe-haven patterns seemed to be better pronounced as a response to S&P behaviour rather than one of market volatility or government bonds.

Examining currency pair returns in relation to different days of the week produced ambiguous results. It appears that, on average, the Forex market has the lowest returns on Mondays in the whole period from 2005 to 2013 and at the end of the 2008-2013 period. That confirms the presence of the day-of-the-week effect for EUR/USD, GBP/USD, USD/JPY, and EUR/JPY in the periods mentioned above. For USD/CHF, on the other hand, the lowest average returns occur in the middle of the week, but Monday returns are often the highest. Therefore, we can conclude that the day-of-the-week effect is manifested in different days for different currency pairs.

Dissimilar results for different time periods imply that the effect is not stable in time. For instance, on Thursdays in 2005-2008, USD/JPY has its lowest average returns, but in 2008-2013 – the highest.

All examined GARCH models gave insignificant coefficients, suggesting that the dependence is not strong enough to rely upon.

Appendix

Tukey-Kramer comparison circles are a method for comparing the average values of two data series. The difference is significant if $|x_1 - x_2| > \sqrt{r_1^2 + r_2^2}$, and insignificant if $|x_1 - x_2| < \sqrt{r_1^2 + r_2^2}$. In our study x_i represents the average return of the corresponding currency pair, but r_i is derived from the standard deviation of returns. It can be applied if the variance of each series is constant.

Games-Howell test – the method for comparing the means of two data series if their variances are not constant.

Distributions used in GARCH model:

Normal distribution is symmetric about its mean and is often called bell-shaped. *Student's t-distribution* is also symmetric, but has heavier tails than normal distribution. That is, data that follows *t*-distribution is more likely to take extreme values than a normally distributed series. *Generalised error distribution* (or *generalised normal distribution*) is the most flexible and can take various shapes depending on its parameters.

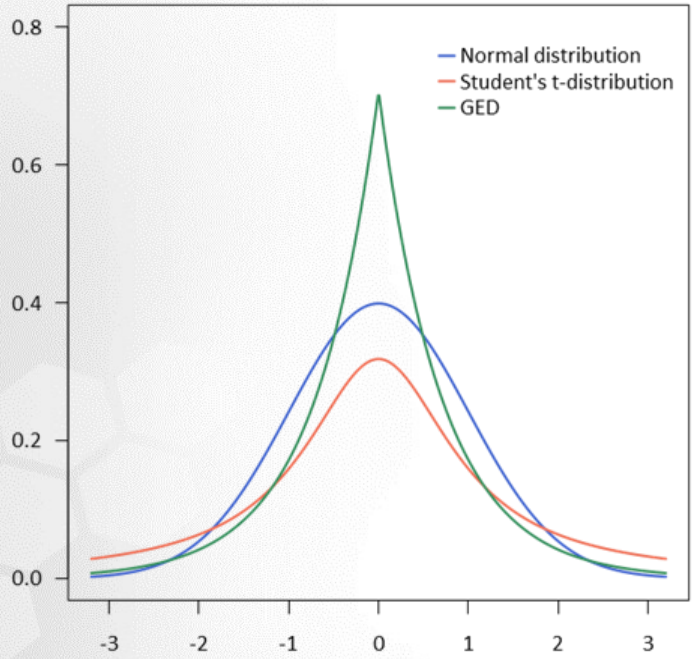
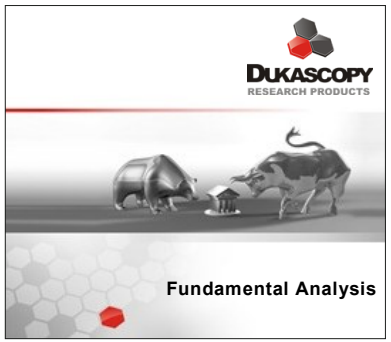


Figure 2: Probability density functions



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