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Our currency, your attention: Contagion spillovers of investor attention on currency returns

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ABSTRACT:

This study investigates financial contagion among currency markets through the novel channel of investor attention measured by Google search volume index (SVI). These contagion spillovers, generated rapidly, are mainly positive and relatively short-lived. The effects are more remarkable for lagged currency attention from developed markets on emerging currency returns. Besides, the effects are barely affected by additionally controlling for liquidity, which means that investor attention plays an indispensable role in financial contagion. Additionally, past currency appreciation negatively impacts contagion spillovers of attention on present currency returns. Hence, increased attention diminishes the return predictability and therefore alleviates market inefficiency. Furthermore, we corroborate that investor attention provides a statistically significant out-of-sample forecast on currency returns, which is congruent with the previous in-sample results. Overall, our findings support the attention reallocation channel as an important contagion mechanism among currency markets and show that attention works as a predictive variable.

1. Introduction

Classical asset pricing models have difficulty in explaining certain stylized empirical facts on currency dynamics that are unrelated to macro fundamentals (Meese and Rogoff, 1983; Obstfeld and Rogoff, 2000; Andersen et al., 2003; Engel et al., 2007; Bacchetta and van Wincoop, 2013; Balke et al., 2013). These findings have stimulated a growing literature concerned with the profound theoretical framework and empirical evidence that investor attention, which is unrelated to fundamentals, has a significant impact on determining currency returns. They suggest that investor attention, measured by Google SVI, co-moves with contemporaneous currency fluctuations and has enhancive predictive power beyond orthodox methods such as the random walk and GARCH models after controlling for macroeconomic fundamentals (Smith, 2012; Goddard et al., 2015; Han et al., 2018a; b).

Notice, however, that the aforementioned studies mainly concentrate on the direct effect of investor attention via currency-by-currency tests; that is, for example, the effect of investor attention focusing on “Yen” or “Euro” on the yen or euro returns. These tests on direct and specific investor attention, however, have several shortcomings.

First, the implicit assumption of the currency-by-currency approach is that the currencies of different countries are mutually independent at least to some extent. The fact is, however, that exchange rate fluctuations tend to be strongly affected by other currencies, especially in the period of subprime and sovereign debt crises (Hong, 2001; Aroskar et al., 2004; Malik, 2005; Cai et al., 2008; Bubák et al., 2011; Antonakakis, 2012; Haidar, 2012; Dua and Tuteja, 2016; Hasler and Ornthanalai, 2016; Dimitriou et al., 2017). For example, the famous tequila effect is used to describe the regional currency collapse resulting from the 1994 economic crisis in Mexico. It occurred because of a sudden devaluation in the Mexican peso, which then provoked other currencies in South America, namely, Argentina, Brazil, Chile, and Uruguay, to decline sharply. Analogous evidence is repeated in the 1999 Brazilian financial crisis. The enormous damage it brings is generalized vividly as the Samba effect, which first massively devalued the Brazilian real and then led to the depreciation of other Latin American currencies.

Second, investors' fluctuating attention on one specific currency may indeed be an important channel through which contagion arises in other currency markets. Taking the Asian crisis that erupted in Thailand with the devaluation of the Thai baht on July 2, 1997, as an example, in a few months after events in East Asia became headline news in American and British newspapers in mid-October, the crisis spread to the Philippines, Malaysia, Indonesia, Hong Kong, Korea, Japan and Singapore. North and South American, European and African stock markets were also affected.

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Before then, however, the press in these countries and international investors paid little attention to the earlier stock market movements in Thailand and Indonesia. A possible explanation may be that financial contagions between currencies occur when international investors start paying attention. Analogous evidence also exists in the period of the Brexit vote in 2016. It was assumed that a vote for Brexit would devalue the pound, which made international investors anxious and fearful about the future value of the pound. Under these conditions, investors sought to exchange the pounds held in their asset portfolios into other safe-haven currencies such as the US dollar, Japanese yen, and Swiss franc. This sentiment is clearly reflected in internet searches: Google Trend showed that the one-week search volumes of the US dollar, Japanese yen, and Swiss franc in the world-wide increased 26%, 35%, and 38%, respectively.[1] That is, paying attention to the information about a specific currency will probably influence investors' attention and the corresponding transaction behavior of other related currencies.

This possibility is consistent with recent empirical studies on limited attention in stock market settings. For example, Mondria and Quintana-Domeque (2013) find evidence supporting the attention reallocation mechanism of financial contagion based on an analysis of the representative stock markets in the area of Asia and Latin America. Hasler and Ornthanalai (2016) indicate that contagion arises because investors pay fluctuating attention to news via testing it in different sectors of the US equity market. They all note that an increase in attention in one market (sector) positively affects the return volatility of the other market (sector) even if they are fundamentally unrelated.

There is also theoretical support for these empirical evidences. As suggested by Peng and Xiong (2006), limited investor attention leads to category-hearing behavior; that is, investors tend to process market-wide information rather than specific information. This is not surprising because decision-makers tend to choose the information comprising a general market instead of a specific one (Maćkowiak and Wiederholt, 2015). In this case, attention on a specific currency is not necessarily the best predictor for that currency, while attention comprising market-wide information may have better predictability.

Taking the above into account, it is necessary to explore the financial contagion among currency markets thorough the channel of investor attention. However, little evidence has been found to study it deeply. Therefore, we aim to investigate whether contagion in currency markets occurs when returns are transmitted through investor attention channels. These questions are crucial to understanding the role of investor attention unrelated to fundamentals playing out in contagion spillovers across different currencies.

The contributions of this paper are threefold. We first conduct a pioneering study focusing primarily on the contagion effect of investor attention in the currency markets. Unlike the bulk of the literature, which considers international capital flow (Balli et al., 2015), interest spread (Kim et al., 2015), sovereign CDS premium (Pu and Zhang, 2012), terms of trade (Haidar, 2012), financial intermediaries (Goldfajn and Valdes, 1997) and exchange rate regimes (Haile and Pozo, 2006), a distinguishing feature of our analysis is that the novel channel of investor attention plays an indispensable part in the process of the contagion spillover of exchange rates. Focusing on the innovation channel of investor attention is interesting as it ultimately belongs to the information channel, which is typically different from the traditional channel, which mostly concentrates on trade and financial linkages (Caramazza et al., 2004). Our study indicates that investor attention on specific currencies measured by Google SVI (Da et al., 2011) can have a positively contagious affect other currency returns, which is especially embodied in the currency attention from developed markets impacting the currency returns from emerging markets.

Our paper also contributes to the literature on the financial contagion impact of attention by providing predictions on the joint impact of time-varying attention and liquidity on currency returns. Although the positive contagion impacts of attention on returns are proved to exist, we still investigate the role attention plays in the contagion impact by additionally controlling for liquidity. The reason we do this is because a market with higher liquidity, such as the currency market, may have a lesser effect of information acquisition (Han et al., 2018a). Thus, detecting the contagion impact of attention based on controlling for liquidity is of importance in that the currency market is a good setting for experimentation due to its enough liquidity. If we successfully find the contagion impact is unrelated to liquidity, it is necessary to considering the innovation channel of attention in the currency market, which will further support the growing literature of investor attention affecting asset prices in the financial markets (Da et al., 2011; Ding and Hou, 2015; Ruan and Zhang, 2016). Our study attests that the liquidity, defined as the bid-ask spread of a specific currency, does not exhibit its significant effect on the currency returns when investigating this joint impact. This means that the contagion spillover of attention is essentially not influenced by liquidity. Our findings are partly akin to the results provided by Goddard et al. (2015), which indicate that the positive association between the intensity of information acquisition and the variance risk premium for the currency markets is not affected by the control additionally for liquidity.

Moreover, we further consider past returns as a part of the information the market receives (and reacts to). Inspired by Vozlyublennaia (2014), Andrei and Hasler (2015) and Han et al. (2018b), among others, investor attention on specific assets is state dependent and can be affected by the past performance of the corresponding asset. In particular, investors generally regard an asset's decreasing or negative performance as "bad news" and are likely to become increasingly worried about their investments during the bad times, which probably lead them to pay considerable attention to the asset's fundamentals. Therefore, discriminating among signs from past returns becomes more important and meaningful in that it can help to identify the nature of the information received by investors. To interpret this effect, we include the interaction terms between lagged attention of specific currency and a dummy variable for the past returns of other currencies in the model to incorporate the possibility of what the market may consider as "news." Our results demonstrate that the decreasing or negative change of past returns generates a negative effect on the contagion spillovers of attention on the present returns.

The remainder of the paper is organized as follows. Section 2 describes our data and provides some descriptive statistics. Sections 3 and 4 report the empirical results for the in-sample and out-of-sample analysis, respectively. Section 5 concludes.

2. Data

We utilize weekly exchange rates of twelve currencies circulated in some emerging and developed currency markets against the US dollar as well as the weekly US dollar index (USDX). Specifically, we consider the Brazilian real (BRL), Chinese yuan (CNY), Indian rupee (INR), Russian ruble (RUB), South African rand (ZAR), Australian dollar (AUD), Canadian dollar (CAD), Swiss franc (CHF), Euro (EUR), Great Britain Pound (GBP), Japanese yen (JPY), Swedish krone (SEK) and US dollar index (USDX). It should be noted that the exchange rate of CNY is still partly managed by the central bank of China. Thus, we replaced CNY with the Chinese yuan offshore (CNH) in that the exchange rate of CNH is not subject to the central bank's interventions or stipulations (Funke et al., 2015). These nominal spot exchange rates can be readily downloaded from DataStream, and USDX is obtained from the Intercontinental Exchange (ICE). All currency returns are computed as the log of change in the average of daily exchange rates ($LN(P_{i,t+1}) - LN(P_{i,t})$), where $P_{i,t}(P_{i,t+1})$ refers to the weekly mean value of the exchange rate of currency i at week t $(t+1)$. The sample periods of all currency returns except USDCNH range from January 2004 to November 2016, while that of

[1] The details of the search volume can be gained from the Google Trend (http://www.Google.com/trends).

USDCNH runs from October 2010 to November 2016 as this is when data on USD/CNH are available.

We then use the Google search volume index (SVI), obtained from Google Trends (http://www.Google.com/trends), to describe the investor attention on specific currencies. The Google SVI shows the percentage of search volumes for certain keywords relative to the total number of searches over a given period. For the investor attention on specific currencies, the Google search keywords are the official currency names and their closely related terms. Specifically, we regard the United States dollar as the search keywords of "USD" or "US dollar," etc., in Google Trends and thus find the weekly SVI of USD. The reason to search these keywords is that they can effectively avoid the potential problem about ambiguity. If we view the currency codes as search keywords, their SVI may contain multiple meanings that are probably unrelated to the investor attention on specific currencies. For example, searching the keyword "CAD" is more likely to obtain the information about the design software. By contrast, a search for the keyword of "Canadian dollar" explicitly reflects investors' demand for currency-specific information on Google. Ultimately, we download weekly SVI spanning from the same periods as the currency returns to obtain the investor attention of all currencies, and we also turn them into the forms of log-difference.

Descriptive statistics for investor attention and currency returns are shown in Table 1. Observing the statistical characteristics for the currency returns, they imply that all currencies except CHF experienced depreciation against the US dollar over the sample period, which is supported by the positive mean values of changes in the currency returns. Additionally, all of the investor attention and currency returns are common financial time series in that they generally present the characteristics of excess kurtosis and non-zero skewness. Finally, the Jarque-Bera statistics are sufficiently positive to reject the null hypothesis that all investor attention and currency returns are estimated with a good fit by the normal distribution.

3. The empirical results of the in-sample analysis

3.1. VAR analysis for contagion spillovers

We employ a VAR model to acquire information about the sign, timing and persistence of the cross relationships between investor attention and currency returns, especially the contagion spillovers of investor attention on currency returns. We then achieve the results of VAR estimations and the corresponding impulse response functions by using the following equations:

$$Re_t = \alpha_{01} + \alpha_{11}Atten_{t-1} + \cdots + \alpha_{n1}Atten_{t-n} + \beta_{11}Re_{t-1} + \cdots + \beta_{n1}Re_{t-n} + e_t, \quad (1)$$

$$Atten_t = \alpha_{02} + \alpha_{12}Atten_{t-1} + \cdots + \alpha_{n2}Atten_{t-n} + \beta_{12}Re_{t-1} + \cdots + \beta_{n2}Re_{t-n} + e_t, \quad (2)$$

where *Atten* and Re denote investor attention and currency return, respectively. Additionally, we can further investigate the reaction of each investor attention/currency return to the shocks in the remaining investor attention and currency returns over time by running the impulse response function under the VAR analysis framework. It should be noted that we only consider the contagion spillovers of cross-variables between investor attention and currency returns, while the one-to-one

Table 1
Descriptive statistics of investor attention and currency returns.

	# Obs	Mean	Std. dev.	Median	Max	Min	Skewness	Kurtosis	Jarque-Bera
Panel A: Investor attention									
BRL	672	0.000	0.083	0	0.279	−0.487	−0.226	6.009	259.144[a]
CNH	320	0.000	0.127	0	1.079	−0.735	2.836	37.539	16334.589[a]
INR	672	−0.000	0.113	0	0.777	−1.221	−0.940	30.399	21119.525[a]
RUB	672	0.000	0.169	0	1.347	−2.339	−2.893	67.138	116119.59[a]
ZAR	672	−0.000	0.076	0	0.436	−0.386	0.216	8.348	806.114[a]
AUD	672	−0.001	0.101	0	0.806	−0.891	0.422	22.749	10940.348[a]
CAD	672	−0.000	0.066	0	0.528	−0.280	1.729	15.317	4582.212[a]
CHF	672	−0.001	0.146	0	1.715	−1.466	2.729	65.646	110719.09[a]
EUR	672	−0.001	0.085	0	0.752	−0.708	−0.018	29.253	19298.302[a]
GBP	672	−0.001	0.146	0	1.238	−0.960	0.519	15.205	4200.997[a]
JPY	672	−0.000	0.095	0	0.767	−0.693	0.353	22.595	10764.46[a]
SEK	672	0.000	0.064	0	0.250	−0.386	−0.112	7.152	484.172[a]
USD	672	−0.001	0.071	0	0.494	−0.511	−0.004	19.522	7643.623[a]
Panel B: Currency return									
USDBRL	672	0.000	0.018	−0.001	0.142	−0.061	1.268	10.111	1596.050[a]
USDCNH	320	0.000	0.004	−0.000	0.028	−0.012	1.996	17.009	2829.143[a]
USDINR	672	0.001	0.009	0.000	0.042	−0.044	0.009	6.984	444.390[a]
USDRUB	672	0.001	0.017	−0.000	0.126	−0.152	0.465	20.712	8808.300[a]
USDZAR	672	0.001	0.020	−0.001	0.111	−0.076	0.766	5.738	275.555[a]
USDAUD	672	0.000	0.015	−0.001	0.135	−0.061	1.235	12.599	2750.644[a]
USDCAD	672	0.000	0.011	−0.000	0.058	−0.054	0.321	5.824	234.768[a]
USDCHF	672	−0.000	0.013	−0.000	0.056	−0.099	−0.812	10.394	1604.771[a]
USDEUR	672	0.000	0.011	0.000	0.045	−0.070	−0.068	5.496	174.953[a]
USDGBP	672	0.001	0.012	0.000	0.083	−0.035	1.028	8.338	916.199[a]
USDJPY	672	0.000	0.011	0.000	0.047	−0.047	−0.061	4.475	61.310[a]
USDSEK	672	0.000	0.014	0.000	0.054	−0.069	0.096	4.738	85.570[a]
USDX	672	0.000	0.009	0.000	0.036	−0.054	−0.124	5.012	115.063[a]

Note: This table reports summary statistical characteristics regarding investor attention and currency returns. Here, the Google search volume indexes of specific currencies are employed to denote investor attention. All currency returns are computed as the log of change in the average of daily exchange rates ($LN(P_{i,t+1}) - LN(P_{i,t})$), where $P_{i,t}(P_{i,t+1})$ refers to the weekly mean value of the exchange rate of currency *i* at week t (t+1). The exchange rates of all currencies are by convention quoted against the US dollar. Meanwhile, the exchange rate of USD is represented by the US dollar index (USDX). Panel A and B reports the results of descriptive statistics of investor attention and currency returns, respectively. The data on investor attention and exchange rates of all currencies except CNH are obtained from January 2004 to November 2016 at a weekly frequency, while that of CNH ranges from October 2010 to November 2016 at a weekly frequency. All data are turned into the form of log-difference. 0.000 (−0.000) indicates a numerical value smaller than 0.0005 (−0.0005).

[a] Denotes refusing the null hypothesis of obeying normal distribution at confidence level of 99%.

relationships between investor attention and their corresponding currency returns are not incorporated into our VAR analysis.

Table 2 reports the estimation results of Eq. (1) regarding the contagion spillovers of investor attention on currency returns.[2] To keep the table parsimonious and emphasize the existence of contagion spillovers, we do not report the nonsignificant results for the contagion spillovers of attention on currency returns. As shown in Table 2, the results for each contagion spillover are arranged in two rows. The first row presents the one-period lagged regression coefficient of the attention term with the currency return as the dependent variable in the VAR model, while the second row presents the two-period lagged regression coefficient of the attention term. The reason to consider two lag specifications is that the lag length in the VAR model is optimal according to the AIC information criterion.

In summary, the results shown in Table 2 suggest that investor attention measured by searching on a specific currency can significantly influence the future returns of other currencies. These contagion spillovers universally exist in most of the cross impacts of investor attention on currency returns. Specifically, the investor attention on USD has a pronounced impact on the returns of all currencies except CAD and CHF, and the contagion spillovers of investor attention on the returns of the emerging currencies (namely, BRL, CNH, INR, RUB and ZAR) appear to be relatively longer than those of the currencies from developed currency markets (namely, AUD, CAD, CHF, EUR, GBP, JPY, SEK and USD). Additionally, it presents dominantly positive contagion spillovers of attention on the returns of all currencies except JPY. By contrast, almost the completely opposite effect emerges for the contagion spillovers of attention on the USDJPY; in other words, increased external attention should promote all currencies except JPY depreciation compared to the US dollar, while the JPY presents appreciation compared to the US dollar.[3] Moreover, the results from Table 2 summarize an interesting phenomenon that investor attention on currencies from developed currency markets clearly generates more contagion spillover effects than that of the emerging currencies. Further, the investor attention on currencies from developed markets is more inclined to contagiously affect the emerging currency returns. By contrast, contagion spillovers rarely arise from attention of emerging currencies on the currency returns from developed markets. We extrapolate that this is mainly related to the market efficiency hypothesis. The information originating from developed currency markets is more likely to generate an effective influence on the emerging currency returns because of the relatively low level of market efficiency of the emerging currency markets (Ajayi and Karemera, 1996; Azad, 2009; Abounoori et al., 2012; Katusiime et al., 2015; Kumar and Aiah, 2016). In particular, the investors in the emerging currency markets must not only search for information from their own markets but also from other markets, especially from developed currency markets. Due to the relative maturity of developed currency markets (Belaire-Franch and Opong, 2005, 2010; Pilbeam and Olmo, 2011; Charles et al., 2012), however, it may be difficult for information originating from the emerging currency markets to affect the currency returns of developed markets (Oh et al., 2007; Şensoy, 2013). Additionally, the phenomenon that investor attention of developed markets is more inclined to contagiously affect the emerging currency returns is also related to the fact that developed economies have more influence on emerging economies (Fidrmuc and Korhonen, 2010; Balli et al., 2015), which is obviously embodied in the financial markets (Lee et al., 2004; Kenourgios et al., 2011; Bekiros, 2014), especially in the foreign exchange markets (Bubák et al., 2011; Celik, 2012; Kilic, 2017). The underlying reason for this fact is that the relatively higher efficiency of developed markets gives them better pricing power than the emerging markets, which induces further information spillover effects on the emerging markets. Thus, investor attention on currencies generated from developed currency markets could be useful to help forecast return changes in the representative emerging currency markets. Furthermore, unlike in previous studies, our study illustrates the fact that the spillover effects of developed markets (economies) on emerging markets (economies) can accrue through the channel of investor attention, which is typically different from the traditional channels including the terms of trade, international capital flow, interest spread, and so on. This clearly belongs to the information spillover channel as investor attention from the developed currency markets has more influence on the returns of emerging currency markets. This conclusion can be partly supported by Wongswan (2006) in that his study only focuses on the transmission effects of fundamental economic information from developed to emerging equity markets. Finally, all of the contagion spillovers appear immediately in that they are highly significant at the first or second lag specification. They do not persist for a long time, however, but vanish rapidly, which can be strongly supported by the corresponding impulse response functions since they converge to zero quite quickly.[4]

3.2. Joint contagion spillovers

Investor attention on specific currencies as revealed by SVI has a noted contagion spillover effect on the future returns of other currencies. Notice, however, that liquidity may also contemporaneously affect the currency performance (Goddard et al., 2015). In this subsection, we examine whether liquidity can significantly influence currency returns, even to the degree of altering the contagion spillovers of investor attention. Thus, we attempt to empirically investigate this joint effect by incorporating liquidity as a new term into the following model (3) so that we can achieve more accurate information about the contagion spillovers of investor attention on currency returns after controlling the additionally liquidity. The related model is expressed as follows:

$$Re_{it} = \phi_i + \sum_{l=1}^{2} \alpha_{il} Atten_{it-l} + \sum_{l=1}^{2} \beta_{il} Re_{it-l} + \sum_{l=1}^{2} \delta_{il} Liquid_{it-l} + e_{it}, \quad (3)$$

where coefficient δ on the *Liquid* term is used to estimate the quantitative effect of liquidity acting on the future currency return. The term indicates the liquidity variable, which is computed as "two multiply (ask – bid)/(ask + bid)," where the "ask" and "bid" denote the offer price and bid price for each currency, respectively.[5] The meanings of the other terms in Eq. (3) are congruent with the corresponding terms as described above. It means that coefficient $\alpha + \delta$ is devoted to measuring the magnitude of the joint impact of the contagion spillover of attention and liquidity on currency return. As before, we employ VAR estimation of two lag specifications with currency return as the dependent variable.

Table 3 shows the concrete results regarding the joint effects of the contagion spillovers for all currencies. To enhance the readability and highlight the main consequences, we choose to report the attention term and liquidity term of Eq. (3) and present them in a different part of the table.[6] We only report the significant components for the regression results of the joint effects, which mainly depend on the significant results of the attention term rather than those of the liquidity term. Moreover, the results for each joint contagion spillover are displayed in two rows as in Table 2, the first of which presents the one-period lagged regression coefficients for the quantitative effects of the attention term and liquidity

[2] For the sake of highlighting the results of the contagion spillovers of attention on currency returns, we do not report the estimation results of Eq. (2) for the cross impacts of currency returns on investor attention.

[3] It should be noted that increased external attention impels the US dollar to appreciate since the augmentation of external attention has led to an increase in the US dollar index.

[4] The figures are available upon request.

[5] The related results are unaffected if we use the liquidity indicator defined as the difference between the ask price and bid price of each currency.

[6] We do not report the joint impacts of contagion spillovers of attention and liquidity on the USDX due to the inability to compute its liquidity status.

Table 2
Contagion spillovers of investor attention on currency returns.

	BRL	CNH	INR	RUB	ZAR	AUD	CAD	CHF	EUR	GBP	JPY	SEK	USD
USDBRL			0.017***			0.014**					0.018**	0.026**	0.031***
			0.001			0.008					0.005	−0.002	0.015
USDCNH	0.009**		0.003*				0.002		−0.002	−0.002	0.004**		0.007***
	0.000		0.003**				0.007**		0.005***	0.005***	0.001		0.006**
USDINR		0.004*		0.003*	0.009*	0.006*			0.007*		0.007**	0.013**	0.015***
		0.002		−0.000	0.011**	−0.000			0.003		−0.001	0.005	0.007
USDRUB									0.024***		0.016**		0.045***
									−0.011		0.006		−0.016*
USDZAR			0.012*			0.014*	0.008	0.008	0.020**		0.015*	0.031**	0.023**
			0.002			0.022***	0.028**	0.011**	0.006		0.010	0.017	0.026**
USDAUD	0.011		0.014***	0.009**	0.011		0.006	0.007	0.007		0.026***	0.024**	0.034***
	0.014*		0.005	0.002	0.029***		0.017*	0.008**	0.012*		0.013**	0.000	0.024***
USDCAD		0.002			0.007							0.018**	
		0.007**			0.016***							0.001	
USDCHF					−0.006								
					0.016**								
USDEUR					−0.003					−0.003			0.005
					0.011*					0.008*			0.010*
USDGBP					−0.006	−0.009**	−0.014**	−0.001	−0.004				−0.008
					0.017***	0.003	0.007	0.007**	0.009*				0.011*
USDJPY	−0.011*	−0.006**		−0.001	−0.012**	−0.012***		−0.009***					−0.015**
	−0.007	0.001		0.005**	0.001	0.003		0.000					0.009
USDSEK					−0.002	0.001			0.005				0.008
					0.020***	0.010**			0.010*				0.017**
USDX					−0.004	−0.002							
					0.011**	0.006*							

Note: This table reports VAR estimation results for the contagion spillovers of investor attention on currency returns. As shown in the table, there are two rows contained in each cross between attention and return of specific currencies. The first row denotes the estimation results of one-period lagged for the contagion spillovers of attention on currency returns, while the second row denotes the estimation results of two-period lagged. To keep the table parsimonious and highlight the existence of contagion spillovers, we only report the significant estimation results of the attention terms of equation (1) .[8] 0.000 (−0.000) indicates a numerical value smaller than 0.0005 (−0.0005).
*, **, ***denote significance at 10%, 5% and 1% level, respectively.

Table 3
Joint impacts for contagion spillovers of attention and liquidity on currency returns.

	BRL	CNH	INR	RUB	ZAR	AUD	CAD	CHF	EUR	GBP	JPY	SEK	USD
Part A: Attention term													
USDBRL			0.017***			0.015**		0.000			0.018**	0.025**	0.031***
			0.001			0.007		−0.008*			0.005	−0.000	0.014
USDCNH	0.008*		0.003*			0.000	0.005		−0.002	−0.002	0.005**		0.008***
	−0.002		0.003**			0.005*	0.009***		0.005***	0.006***	0.002		0.006**
USDINR		0.004*		0.003*	0.009*	0.006*			0.007*		0.007**	0.013**	0.015***
		0.002		−0.000	0.011**	−0.000			0.003		−0.001	0.005	0.006
USDRUB					0.011				0.023***		0.016**		0.044***
					0.016*				−0.010		0.006		−0.015
USDZAR			0.012*			0.013*	0.007	0.008	0.020**		0.015*	0.031**	0.022**
			0.002			0.022***	0.028**	0.011**	0.007		0.010	0.018	0.026**
USDAUD	0.011		0.014***	0.009***	0.011		0.008	0.006	0.008		0.026***	0.022**	0.035***
	0.014*		0.006	0.001	0.028***		0.016*	0.008*	0.012*		0.013**	−0.002	0.023***
USDCAD		0.002			0.007							0.018**	
		0.007**			0.016***							0.001	
USDCHF					−0.006	−0.007					−0.010**		
					0.018***	0.009*					−0.005		
USDEUR					−0.003					−0.003			0.005
					0.011*					0.008*			0.010*
USDGBP				0.004*	−0.006	−0.009**	−0.015**	−0.001	−0.004				−0.008
				0.001	0.016***	0.003	0.007	0.007**	0.009*				0.011*
USDJPY	−0.011*	−0.006**		−0.001	−0.012**	−0.012***		−0.009***					−0.015**
	−0.006	0.001		0.005**	0.001	0.002		0.000					0.009
USDSEK					−0.001	0.001			0.005				0.009
					0.020***	0.010*			0.010*				0.017**
Part B: Liquidity term													
USDBRL			−0.004			−0.004		−0.004			−0.004	−0.004	−0.005
			0.003			0.003		0.003			0.003	0.003	0.002
USDCNH	−0.000		−0.000			−0.000	−0.000		−0.000	−0.000	−0.000		−0.000
	−0.000		−0.000			−0.000	−0.000		−0.000	−0.000	−0.000		−0.000
USDINR		−0.000		−0.000	−0.000	−0.001			−0.000		−0.000	−0.001	−0.001
		−0.000		−0.000	−0.000	−0.000			−0.000		−0.000	−0.000	−0.001
USDRUB					−0.004				−0.003		−0.004		−0.002
					0.004				0.003		0.004		0.004
USDZAR			−0.004			−0.003	−0.003	−0.004	−0.003		−0.004	−0.005	−0.004
			−0.002			−0.001	−0.002	−0.004	−0.002		−0.004	−0.003	−0.003
USDAUD	0.013*		0.014**	0.013**	0.011		0.013**	0.013*	0.013**		0.014**	0.012*	0.014**
	−0.002		−0.001	−0.002	−0.002		−0.001	−0.002	−0.001		−0.000	−0.001	−0.000
USDCAD		0.003			0.004							0.004	
		−0.001			0.000							−0.000	
USDCHF					0.006	0.007					0.006		
					−0.001	−0.001					−0.001		
USDEUR					−0.001					−0.001			−0.001
					−0.001					−0.001			−0.001
USDGBP				0.005	0.003	0.005	0.005	0.004	0.005				0.005
				0.004	0.002	0.003	0.004	0.003	0.003				0.003
USDJPY	−0.003	−0.004		−0.004	−0.004	−0.004		−0.003					−0.003
	−0.004	−0.004		−0.004	−0.003	−0.004		−0.004					−0.004
USDSEK					0.003	0.004			0.004				0.004
					0.005	0.004			0.004				0.005

Note: This table reports VAR estimation results for the joint impacts of contagion spillovers of investor attention and liquidity on currency returns. To facilitate reading the table and highlighting the main results, we split the estimation results of the joint impacts into two parts. Part A and B present the results of the attention term and liquidity term, respectively. Specifically, the results of the attention term originate from the evaluations of "*Atten*" term of model (3), while those of the liquidity term obtain from the evaluations of "*Liquid*" term of model (3). The liquidity is calculated as "two multiply (ask – bid)/(ask + bid)," where the "ask" and "bid" denote the offer price and bid price for each corresponding currency, respectively. It should be noted that the estimation results are unaffected if we define the difference between the ask price and bid price of each currency as computing of liquidity. Additionally, there are two rows contained in each cross of the table between attention and return of specific currency. The first row denotes the estimation results of one-period lagged for the joint impacts of contagion spillovers of attention and liquidity on currency returns, while the second row denotes the estimation results of two-period lagged. As in Table 2, we only report the significant estimation results for the joint effects of contagion spillovers, which mainly depend on the significant results of the attention term rather than the liquidity term.[9] Furthermore, we also do not report the joint impacts of contagion spillovers on the USDX since it cannot compute the corresponding liquidity indicator. 0.000 (−0.000) indicates a numerical value smaller than 0.0005 (−0.0005).
*, **, ***denote significance at 10%, 5% and 1% level, respectively.

term, while the second row presents the two-period lagged regression coefficients. Specifically, coefficients α_1 and α_2 are successively exhibited in the two rows of each cross in part A of the table (namely, the regression results of the attention term). For coefficients δ_1 and δ_2, they are shown in the two rows of each cross in part B of the table (namely, the regression results of the liquidity term), respectively.

In general, the joint impacts of contagion spillovers of attention and liquidity on currency returns are mainly positive and statistically significant, suggesting that investor attention still exerts a pronounced contagion spillover effect on currency returns even if we additionally control for the liquidity. As portrayed in Table 3, the results regarding the joint impacts of contagion spillovers are completely consistent with the results of the baseline contagion spillover effects epitomized in subsection 3.1. Meanwhile, the amounts of the contagion spillovers of attention on currency returns in terms of the joint impacts are slightly larger in comparison with those of the baseline contagion spillovers. It should be noted that the slightly increased contagion spillover effects are dominantly embodied in the contagion spillovers of investor attention from developed currency markets on other currency returns, especially on the emerging currency returns. Moreover, the liquidities of most currencies barely manifest a significant explanatory capability for the movements of the future currency returns except USDAUD. This means that the contagion spillovers of investor attention on these currency returns are not altered by their corresponding liquidity indicators. With regard to the performance of USDAUD, it is positively influenced by the changes of its relevant liquidity status, which indicates that the contagion spillovers of investor attention on the USDAUD are remarkably strengthened when controlling for the corresponding liquidity. The intuition for this phenomenon can be understood as follow. When the bid-ask spread increases (i.e., liquidity shrinks) in the currency markets, higher investor attention induces higher return volatility and then higher risk premiums for currency returns to largely bear the enhanced liquidity risk. Thus, we can take it for granted that a high bid-ask spread (low liquidity) boosts the joint impacts of the contagion spillovers of attention on returns.

3.3. Asymmetric effects

We have already demonstrated that the contagion spillovers of investor attention on currency returns are pronounced. And it is more highlighted for the contagion spillovers of investor attention on currencies from developed markets on the emerging currency returns. Intuitively, the previous analysis for the contagion spillovers may not be intact and accurate in that investor attention on a specific currency, in turn, could be intuitively influenced by the past performances of other currencies. It is also strongly supported by some classical studies (Vozlyublennaia, 2014; Andrei and Hasler, 2015; Han et al., 2018b). Moreover, these studies further note the importance and necessity of incorporating the sign of past returns into the process of measuring contagion spillovers of investor attention on present returns for the reason that negative change in the past performance of specific asset viewed as “bad news” could draw considerable attention to the asset. Thus, we should take into account the nature of the information received by investors in the currency markets, revealed by past currency appreciation or depreciation, to further analyze the asymmetric effects of the contagion spillovers.

To precisely measure the asymmetric contagion spillovers, we attempt to incorporate an interaction term between lagged investor attention and currency return into our model in the following analysis. Specifically, we consider the interaction term between lagged attention and a return dummy, which is assigned the value of 1 if the lagged currency return is negative and 0 otherwise. This can help us to discriminate between the contagion spillovers of investor attention on current returns based on past currency appreciation versus those based on past currency depreciation. The model is specified as follows:

$$Re_{it} = \phi_i + \sum_{l=1}^{2} \pi_{il} Atten_{it-l} + \sum_{l=1}^{2} \gamma_{il} Re_{it-l} + \sum_{l=1}^{2} \lambda_{il} Atten_{it-l} * D(Re_{it-l} < 0) + e_{it}, \quad (4)$$

where coefficient λ on the interaction term of Eq. (4) estimates the quantitative effect of the contagion spillover of investor attention on the future currency return based on the negative changes of the past currency return. In other words, it is used to measure the magnitude of the asymmetric contagion spillovers of investor attention on currency returns. For the dummy variable D in the interaction term, its value is defined as 1 if the return of currency i at period t is negative and 0 otherwise. For the sake of the consistency of the context, we only consider a two lag specifications in the model for estimating asymmetric contagion spillovers.

Table 4 reports the regression results of Eq. (4) for all asymmetric effects of the contagion spillovers of investor attention on currency returns. In line with the arrangement of Table 3, we only report the significant results for the asymmetric contagion spillovers of investor attention on currency returns, which mainly depend on the significant results of the attention term instead of the interaction term. We choose to present the attention term and interaction term of Eq. (4) in parts A and B of the table, respectively. Moreover, the result of each asymmetric contagion spillover is arranged in two rows as shown in Table 4, the first of which presents the one-period lagged regression coefficients (namely, π_1 in the attention term and λ_1 in the interaction term) in model (4), while the second row presents the two-period lagged regression coefficients (namely, π_2 in the attention term and λ_2 in the interaction term).

The detailed results of Table 4 indicate that the interaction terms are pronounced for most of the cross relationships of investor attention on currency returns, revealing that past currency appreciation has a significant influence on the magnitude of the contagion spillover of investor attention on the present currency return.[7] In other words, the asymmetric contagion spillovers based on past currency appreciation or depreciation clearly exist in most of the cross relationships of investor attention on current returns. Specifically, the first or second lag of the interaction terms for the combinations of investor attention on a specific currency and the past return dummy of other currencies shows a predominantly negative impact on the future returns of other currencies, which indicates that the asymmetric contagion spillovers emerge rapidly to some extent. In other words, the information about the return of specific currency that was generated in the immediate past, namely, the previous week or two, easily attracts considerable attention of investors in other currency markets that further influences the future returns of the specific currency. Additionally, the investor attention on currencies from developed currency markets generates more asymmetric contagion spillovers on the future returns of emerging currencies than the reverse contagion mechanisms, which is similar to the results of previous analysis shown in subsections 3.1 to 3.2. Observing the signs of coefficients λ_1 and λ_2 for all of the interaction terms, we find that they generally remain significantly negative. This may imply that almost all the currency markets are dominated by the momentum investors based on the perspective of asymmetric contagion spillovers. We interpret the evidence as follows. For currencies other than the US dollar, currency appreciation in the past is viewed by investors of other currency markets as a useful indicator that

[7] Regarding the US dollar, the depreciation of its past returns has a significant influence on the magnitude of the attention of external currencies impacting its present returns.

[8] The complete estimation results are not provided for brevity but are available upon request.

[9] The complete estimation results for the joint effects of contagion spillovers are not provided for brevity but are available upon request.

[10] The complete estimation results for the asymmetric effects of contagion spillovers are not provided for brevity but are available upon request.

Table 4
Asymmetric contagion spillovers of investor attention on currency returns.

	BRL	CNH	INR	RUB	ZAR	AUD	CAD	CHF	EUR	GBP	JPY	SEK	USD
Part A: Attention term													
USDBRL		0.017*	0.034***			0.044***	0.043***	−0.002	0.038***		0.024**	0.041**	0.054***
		−0.000	−0.006			−0.013	−0.013	−0.015**	0.023		−0.011	−0.016	0.008
USDCNH	0.015***		−0.000			−0.005	0.003	0.004***	−0.004	−0.004**	0.010***		
	−0.000		0.008***			0.010**	0.008*	−0.005***	0.008***	0.008***	0.002		
USDINR	0.010*	0.013***		0.004*	0.019***	0.013***	0.019**	0.007**	0.015***		0.009*	0.025***	0.037***
	−0.002	0.004		0.002	0.009	−0.004	−0.001	−0.006*	0.007		−0.009*	0.007	0.006
USDRUB	0.022*		0.022***		0.016	0.021**	0.044***		0.044***		0.024**	0.027*	0.092***
	0.012		−0.003		0.024**	0.013	0.006		−0.012		0.007	−0.007	−0.021*
USDZAR		0.020**	0.018*			0.014				−0.013*		0.063***	0.024*
		0.014*	0.002			0.021*				−0.002		0.023	0.012
USDAUD	0.033***	0.029***	0.057***	0.013**	0.026**		0.076***	0.017***	0.054***		0.053***	0.045***	0.090***
	0.011	0.004	0.008	0.005	0.035***		0.008	0.003	0.016		−0.002	0.002	0.015
USDCAD		0.001		0.009**	0.014*	0.011**						0.039***	0.021***
		0.013***		0.003	0.017**	0.006						0.012	0.009
USDCHF					−0.003							0.022**	
					0.028***							−0.001	
USDEUR				0.009**	0.001					0.003		0.026***	0.023**
				−0.001	0.018**					0.008*		0.012	0.002
USDGBP				0.010**	−0.006		−0.010	0.000					0.003
				0.003	0.027***		0.020**	0.008**					0.019**
USDJPY													
USDSEK				0.014***	0.003	0.005			0.026**				0.028***
				0.006	0.030***	0.014*			0.009				0.018
USDX				0.008**	0.001	0.005		0.003				0.020***	
				0.001	0.020***	0.009**		0.005*				0.010	
Part B: Interaction term													
USDBRL		−0.020*	−0.032***			−0.051***	−0.070***	0.006	−0.053***		−0.010	−0.024	−0.059***
		0.003	0.013			0.033**	0.027	0.013	−0.016		0.029**	0.027	0.019
USDCNH	−0.011		0.004			0.006	−0.001	−0.006***	0.004	0.010**	−0.009*		
	0.001		−0.007**			−0.012**	−0.001	0.005**	−0.005	−0.008**	0.001		
USDINR	−0.009	−0.012**		−0.002	−0.024***	−0.016**	−0.030***	−0.008*	−0.016**		−0.006	−0.022**	−0.052***
	0.005	−0.001		−0.008*	0.002	0.007	0.004	0.007	−0.007		0.018**	−0.004	0.002
USDRUB	−0.026		−0.029**		−0.014	−0.029**	−0.069***		−0.045***		−0.016	−0.040**	−0.132***
	−0.008		−0.000		−0.029	−0.014	−0.007		0.004		0.000	−0.007	0.011
USDZAR		−0.025**	−0.012			−0.000				0.022**		−0.055**	−0.002
		−0.010	−0.001			0.001				0.004		−0.008	0.030
USDAUD	−0.041***	−0.030***	−0.060***	−0.006	−0.029*		−0.105***	−0.016*	−0.064***		−0.052***	−0.042**	−0.106***
	0.006	0.001	0.000	−0.004	−0.011		0.013	0.011	−0.005		0.028**	−0.004	0.021
USDCAD		0.002		−0.008	−0.019*	−0.016*						−0.041***	−0.040***
		−0.009		−0.003	−0.004	−0.002						−0.020	−0.006
USDCHF					−0.005							−0.047***	
					−0.021							0.001	
USDEUR				−0.013**	−0.009					−0.002		−0.045***	−0.029**
				0.005	−0.015					−0.009		−0.019	0.016
USDGBP				−0.009*	−0.005	−0.031***	−0.009	−0.005	−0.015				−0.023*
				−0.001	−0.030**	−0.012	−0.025*	−0.004	0.002				−0.014
USDJPY													
USDSEK				−0.018***	−0.010	−0.007			−0.031**				−0.037**
				−0.008	−0.020	−0.007			0.001				0.001
USDX				−0.010**	−0.015	−0.019***		−0.010*				−0.031***	
				0.002	−0.021**	−0.009		−0.005				−0.016	

Note: This table reports the estimation results for the asymmetric effects of contagion spillovers of investor attention on currency returns based on past currency appreciation or depreciation. To facilitate reading the table and highlighting the main results, we split the estimation results of the asymmetric contagion spillovers into two parts. Part A and B present the attention term and interaction term, respectively. Specifically, the results of the attention term originate from the evaluations of the "*Atten*" term of model (4), while those of the interaction term obtain from the evaluations of the interaction term of model (4), which consists of lagged investor attention and a dummy variable of lagged currency return. The dummy variable is equal to 1 if the lagged return is negative and 0 otherwise. Additionally, there are two rows contained in each cross of the table between attention and return of specific currency. The first row denotes the estimation results of one-period lagged for the asymmetric effects of contagion spillovers of attention on currency returns, while the second row denotes the estimation results of two-period lagged. As in Table 3, we only report the significant estimation results for the asymmetric effects of contagion spillovers, which mainly depend on the significant results of the attention term rather than the interaction term.[10] 0.000 (−0.000) indicates a numerical value smaller than 0.0005 (−0.0005).
*, **, ***denote significance at 10%, 5% and 1% level, respectively.

the exchange rates of these currencies will probably continue to appreciate in the future. Then, the consequent buying intention and action induces the appreciation of these currencies, and the degree of appreciation hinges on how much investor attention on other currencies was devoted to the past performances of these currencies. For the US dollar, the same transmission mechanism exists as for other currencies. The only difference is that the depreciation of its past returns is viewed as important information to generate the expectation of depreciation for future returns. Regarding the coefficient $\pi + \lambda$, it is used to measure the combination effects for the contagion spillovers of investor attention of specific currencies on the future returns of other currencies by given their past returns. Obviously, the combination effects of the asymmetric contagion spillovers are generally less than the baseline contagion spillovers reported in subsections 3.1 and 3.2 as the coefficient λ is dominantly negative. This means that there is a weaker connection between past attention of specific currencies and current returns of other currencies when their past returns are appreciation. Our results are congruent with those suggested by Vozlyublennaia (2014) and Han et al. (2018b). Both note that investor attention minifies the return predictability and therefore improves market efficiency. In other words, a currency market operates more efficiently and thus currency returns become less predictable when increased information of the external attention is poured into the market based on the former conditions of currency appreciation.

Furthermore, the contagion spillovers of investor attention on future currency returns are prominently added when discriminating between currency appreciation and depreciation in the past, which is supported by the regression results of the attention term of Eq. (4) listed in part A of Table 4. In particular, these incremental contagion spillovers are more embodied in the attention of currencies from developed currency markets on all of the currency returns. Then, the contagion spillovers of attention from the developed markets are still superior to those from the emerging markets. Meanwhile, it is also clearly added for the degree and size of the contagion spillovers of investor attention from developed currency markets on the emerging currency returns. Additionally, the negative contagion spillovers of investor attention on the USDJPY disappear when considering the asymmetric effects. In summary, it is significantly positive for almost all of the asymmetric contagion spillovers, which evidently surpassed the baseline contagion spillovers summarized in the previous analysis.

4. Out-of-sample forecast

In the previous in-sample analysis, we confirm that investor attention on specific currencies has significantly contagious spillovers on the future returns of other currencies, which is more clearly reflected in the contagion spillovers of investor attention from developed currency markets on the emerging currency returns. In other words, there probably exists a pronounced predictive power of investor attention toward specific currencies on the returns of other currencies. We cannot ensure, however, that the good performance of the contagion spillovers presented in the in-sample analysis still generates predictive power in the out-of-sample analysis according to the study of Welch and Goyal (2008). Thus, we next conduct an out-of-sample test to investigate the predictability of the contagion spillovers of investor attention on currency returns. In this subsection, we attempt to include several statistical indicators originating from the classical literature to quantitatively analyze the predictive power of the contagion spillovers in the out-of-sample forecast.

4.1. The related statistical indicators

The related statistical indicators used to analyze the out-of-sample forecast performance are listed as follows:

$$R^2 = 1 - \frac{\sum_{t=1}^{T}\left(Re_t - \hat{Re}_t\right)^2}{\sum_{t=1}^{T}\left(Re_t - \bar{Re}_t\right)^2}, \tag{5}$$

$$ENC - NEW = T \times \frac{\sum_{t=1}^{T}\left[\left(Re_t - \bar{Re}_t\right)^2 - \left(Re_t - \bar{Re}_t\right)\left(Re_t - \hat{Re}_t\right)\right]}{\sum_{t=1}^{T}\left(Re_t - \hat{Re}_t\right)^2}, \tag{6}$$

$$MSE - F = T \times \frac{\sum_{t=1}^{T}\left(Re_t - \bar{Re}_t\right)^2 - \sum_{t=1}^{T}\left(Re_t - \hat{Re}_t\right)^2}{\sum_{t=1}^{T}\left(Re_t - \hat{Re}_t\right)^2}, \tag{7}$$

where Re_t is the return of specific currency at week t. Let the forecasted currency return of the unrestricted model at week t, namely, $\hat{Re}_t$, rely on the recursive OLS estimation of the prediction model based on the data from the initial week up to week $t-1$. In the remaining analysis, we focus solely on evaluating the out-of-sample performances regarding the contagion spillovers of attention on returns and their asymmetric effects. Thus, the corresponding prediction models are models (1) and (4), as previously mentioned. As to which model to select, it depends on what effect will be calculated. Regarding the $\bar{Re}_t$, defined as the forecasted currency return of the benchmark model, it is obtained from the historical average currency return at week t.

To better perform the out-of-sample analysis, we must first set the period of the out-of-sample forecast. Here, we choose the data ranging from January 2004 to December 2009 at a weekly frequency for the USDINR, USDCHF, USDEUR, USDSEK and USDX, a total of 310 observations, as the initial estimation interval of the prediction model. In other words, we can acquire the forecast returns of these currencies from January 2010 to November 2016, namely, the out-of-sample period, by using the above re-estimate procedure. The forecasts of other currency returns have different out-of-sample periods, specifically, from July 2011 to November 2016 at a weekly frequency for the USDBRL. For the USDCNH, it is from January 2016 to November 2016. For the USDRUB, it is from February 2015 to November 2016. For the USDZAR, it is from July 2010 to November 2016. For the USDAUD, it is from January 2009 to November 2016. For the USDCAD, it is from April 2009 to November 2016. For the USDGBP, it is from February 2009 to November 2016 and for the USDJPY, it is from January 2008 to November 2016. It should be noted that the out-of-sample periods are completely consistent when performing the out-of-sample forecasts to check the predictability of both the baseline and asymmetric contagion spillovers of all investor attention on the return of specific currency. Additionally, T in Eqs. (5)–(7) is the size of the out-of-sample forecast, which is typically different from the sample size in the previous in-sample analysis.

We next interpret the detailed meanings for the statistical indicators of the out-of-sample forecast. First, the out-of-sample R^2 statistic, depicted by Eq. (5), originates from Campbell and Thompson (2008) and Welch and Goyal (2008). It is used to compare the mean squared forecast error (MSFE) of the unrestricted model with that of the benchmark model. A positive R^2 indicates that the reduction in the forecast error of the unrestricted model is more than that of the benchmark model, while a negative R^2 denotes the opposite. Second, the *ENC-NEW* statistic and the *MSE-F* statistic, depicted by Eqs. (6) and (7), are rooted in Clark and McCracken (2001) and McCracken (2007), respectively. If the *ENC-NEW* statistic and the *MSE-F* statistic are statistically significant, the null hypotheses of the two statistics can be rejected because they are all defined as the predictive power of the benchmark model surpassing the unrestricted model. Finally, we continue to introduce a new statistical

indicator, namely, the *MSFE-adjusted* statistic, proposed by Clark and West (2007). It is the t-statistic generated from the regression for the equation of $f_t = (Re_t - \bar{Re}_t)^2 - [(Re_t - \hat{Re}_t)^2 - (\bar{Re}_t - \hat{Re}_t)^2]$ on a constant. The null hypothesis of the statistic is that the unrestricted model has the same MSFE as the benchmark model, while the alternative hypothesis is that the unrestricted model has a smaller MSFE than the benchmark model. The alternative hypothesis should be accepted if the one-sided p-value of the *MSFE-adjusted* statistic is significantly lower than 10%.

4.2. Analysis for the out-of-sample forecast

Table 5 reports the results of the out-of-sample forecasts for estimating the predictive powers of the contagion spillovers of investor attention on currency returns. By observing the four statistical indicators, namely, the out-of-sample R^2 statistic, the *ENC-NEM* statistic, the *MSE-F* statistic, and the *MSFE-adjusted* statistic, we can achieve the performance of the out-of-sample forecasts for all cross relationships based on the baseline contagion spillovers, which is described in subsection 3.1. As shown in Table 5, Panels A to M summarize the predictive powers of the out-of-sample forecasts for different currency returns, which are influenced by past investor attention from other currency markets. Taking the USDBRL as an example to interpret the results of the out-of-sample forecasts, the R^2 statistics are all positive by using the related investor attention (namely, INR, AUD, JPY, SEK and USD) to forecast the future return of USDBRL. This indicates that the reduction in the forecast errors of the unrestricted prediction model clearly exceeds that of the benchmark prediction model. Thus, the prediction model for the contagion spillovers of investor attention on the USDBRL is superior to the historical average forecasts based on the analysis of the out-of-sample forecast performances. Regarding the *ENC-NEW* statistics and the *MSE-F* statistics, they are all highly significant at the 1% level when forecasting the USDBRL by employing the related investor attention. It means that the forecast performances of the unrestricted prediction model exceed those of the benchmark model. In other words, there is great return predictability for the USDBRL based on the contagion spillovers of the above investor attention. The significance values of the *MSFE-adjusted* statistics, denoted by the one-sided p-values, are all less than 1% for the contagion spillovers of different investor attention on the USDBRL, which ultimately accepts the alternative hypothesis that the unrestricted prediction model has fewer forecast errors than the benchmark model. Generally, investor attention on specific currencies has significant predictive power on the future returns of other currencies in the out-of-sample forecasts, which is more obviously embodied in investor attention from developed currency markets on the emerging currency returns. In particular, the investor attention on USD has good predictability for the future returns of most currencies, and it behaves much better when considering the predictability for the future returns of the emerging currencies. A possible interpretation for this phenomenon is the following. The market efficiency is relatively weaker for the emerging currency markets by comparison with the developed currency markets (Oh et al., 2007; Şensoy, 2013). This means that the emerging currency returns are more likely to be influenced by external information. The investors searching the emerging currencies are more inclined to trace the currency performances from the developed currency markets in that they have important informational value. Hence, it is probable that the emerging currency returns are relatively susceptible to investor attention from the developed currency markets, while the reverse functional mechanism is relatively difficult to instantiate because information about the emerging currency returns is of lower value.

Table 6 reports the results of the out-of-sample forecasts for investigating the predictive powers of the asymmetric contagion spillovers of investor attention on currency returns based on employing prediction model (4). The return predictability of the out-of-sample forecasts appear to show a slight decline, which is mainly reflected in the out-of-sample

Table 5
Out-of-sample forecasts for contagion spillovers.

	R^2 (%)	ENC-NEW	MSE-F	MSFE-adjusted
Panel A: USDBRL				
INR	4.070	16.360***	11.965***	3.532***
AUD	4.472	10.365***	13.203***	3.101***
JPY	3.789	9.716***	11.107***	2.978***
SEK	3.946	9.531***	11.584***	3.123***
USD	4.800	16.416***	14.219***	3.190***
Panel B: USDCNH				
BRL	6.991	2.448***	3.157***	1.913**
INR	11.963	3.770***	5.707***	2.197**
CAD	12.751	3.859***	6.138***	2.073**
EUR	14.094	4.451***	6.891***	2.412***
GBP	20.484	7.596***	10.820***	1.666**
JPY	6.559	2.193**	2.948***	1.796**
USD	9.482	3.623***	4.399***	1.872**
Panel C: USDINR				
CNH	11.579	40.928***	47.143***	4.319***
RUB	10.533	39.823***	42.383***	4.156***
ZAR	12.079	45.163***	49.460***	4.497***
AUD	11.483	40.526***	46.700***	4.244***
EUR	11.212	42.252***	45.462***	4.287***
JPY	10.653	39.876***	42.924***	4.186***
SEK	11.946	42.114***	48.840***	4.391***
USD	12.865	47.249***	53.151***	4.444***
Panel D: USDRUB				
EUR	7.799	8.084***	8.204***	2.559***
JPY	8.597	7.944***	9.124***	2.681***
USD	7.977	9.438***	8.408***	2.935***
Panel E: USDZAR				
INR	1.828	11.026***	6.218***	2.593***
AUD	2.888	11.606***	9.933***	2.442***
EUR	−1.074	10.590***	−3.548	2.030**
CAD	3.805	12.955***	13.211***	3.151***
CHF	0.038	9.170***	0.128	1.939**
JPY	1.980	9.399***	6.746***	2.401***
SEK	1.945	8.699***	6.626***	2.353***
USD	3.132	14.307***	10.800***	2.679***
Panel F: USDAUD				
BRL	4.602	22.471***	19.874***	3.849***
INR	3.223	24.909***	13.722***	3.620***
RUB	3.121	26.004***	13.274***	4.212***
ZAR	6.525	31.756***	28.759***	5.010***
CAD	3.115	19.011***	13.248***	2.955***
CHF	0.363	21.596***	1.500*	3.001***
EUR	1.350	21.566***	5.638***	3.159***
SEK	4.484	21.772***	19.342***	3.837***
JPY	2.461	26.932***	10.397***	3.702***
USD	2.894	31.850***	12.277***	3.928***
Panel G: USDCAD				
CNH	6.259	25.654***	26.641***	3.784***
ZAR	6.099	27.056***	25.915***	4.059***
SEK	5.120	21.844***	21.532***	3.711***
Panel H: USDCHF				
ZAR	7.160	33.862***	27.762***	2.404***
Panel I: USDEUR				
ZAR	5.479	23.268***	20.869***	4.231***
GBP	6.059	24.376***	23.220***	4.444***
USD	5.292	23.514***	20.117***	4.040***
Panel J: USDGBP				
ZAR	3.751	17.507***	15.863***	3.206***
AUD	1.857	13.739***	7.701***	1.897**
CAD	1.845	15.087***	7.651***	2.134**
CHF	2.125	14.131***	8.835***	2.224**
EUR	1.382	12.979***	5.704***	1.913**
USD	1.418	12.818***	5.854***	1.885**
Panel K: USDJPY				
BRL	3.624	24.698***	17.448***	3.931***
CNH	3.762	26.866***	18.138***	4.055***
RUB	3.896	27.009***	18.809***	4.414***
ZAR	3.522	25.415***	16.938***	3.798***
AUD	3.541	28.206***	17.033***	3.628***
CHF	4.456	35.922***	21.639***	4.616***
USD	3.778	31.991***	18.222***	3.879***
Panel L: USDSEK				
ZAR	4.729	22.481***	17.871***	4.055***

(*continued on next page*)

Table 5 (*continued*)

	R^2 (%)	ENC-NEW	MSE-F	MSFE-adjusted
AUD	5.132	20.531***	19.474***	4.134***
EUR	3.765	21.640***	14.084***	3.767***
USD	5.739	22.935***	21.920***	4.307***
Panel M: USDX				
ZAR	7.913	31.700***	30.933***	5.073***
AUD	7.901	30.773***	30.885***	5.032***

Note: This table reports the out-of-sample forecast evaluations of currency returns based on the in-sample results of the baseline contagion spillovers. As shown in the table, panels A to M present the return predictability of different currencies by using investor attention from external currency markets. The out-of-sample forecast evaluations also consider a two lag specification as the in-sample analysis. Specifically, the title of each row is investor attention on a specific currency, and the column headings denote statistical indicators of forecast evaluations for the out-of-sample analysis. The R^2 statistic is obtained from Campbell and Thompson (2008) and Welch and Goyal (2008). The *ENC-NEW* statistical indicator is the forecast encompassing test statistic proposed by Clark and McCracken (2001). The *MSE-F* statistical indicator is the equal forecast statistic for accuracy test suggested by McCracken (2007). The *MSFE-adjusted* statistical indicator is the forecast error test statistic of Clark and West (2007). Moreover, it should be noted that forecasting different currency returns requires different out-of-sample periods. In particular, the out-of-sample period is 2010:01–2016:11 for forecasting USDINR, USDCHF, USDEUR, USDSEK and USDX. For USDBRL, it is 2011:07–2016:11. For USDCNH, it is 2016:01–2016:11. For USDRUB, it is 2015:02–2016:11. For USDZAR, it is 2010:07–2016:11. For USDAUD, it is 2009:01–2016:11. For USDCAD, it is 2009:04–2016:11. For USDGBP, it is 2009:02–2016:11. For USDJPY, it is 2008:01–2016:11.
*, **, ***denote significance at 10%, 5% and 1% level, respectively.

forecasts of the contagion spillovers of the CHF attention on other currency returns. The results for the out-of-sample forecasts of the asymmetric contagion spillovers, however, still support the results we have described in the above analysis for the out-of-sample forecasts of the baseline contagion spillovers. In other words, the predictive powers of the contagion spillovers of investor attention on currency returns are statistically significant, although we further investigate the out-of-sample forecast performances of the asymmetric contagion spillovers. Overall, both the baseline and asymmetric contagion spillovers almost perfectly verify the conclusion that investor attention on specific currencies has good predictive ability on other currency returns based on the whole out-of-sample forecasts. Furthermore, the results of the out-of-sample analysis are almost completely congruent with the previous in-sample analysis.

5. Conclusion

In this study, we examine whether investor attention on specific currencies as revealed by Google SVI has contagious spillover impacts on other currency returns. We first prove that investor attention on specific currencies mainly leads to the depreciation of other currency returns based on the in-sample analysis. We then perform the out-of-sample forecasts to test the predictive powers of investor attention toward specific currencies on the future returns of other currencies and find that the conclusions of the out-of-sample forecasts are almost consistent with the in-sample analysis. The main results of our study are (I) Most of the contagion spillovers are sufficiently pronounced, which is obviously embodied in the contagion spillovers of investor attention from developed currency markets on emerging currency returns. These effects present relatively short-lived within two lag specifications. (II) This is almost coincident with the preceding findings in terms of the contagion spillovers of investor attention on currency returns while controlling additional liquidity. The related results indicate that the liquidity cannot remarkably influence the contagion spillovers of attention. (III) There exists an asymmetric effect for the contagion spillovers based on the movements of past currency returns. In other words, past currency appreciation negatively affects the magnitudes of contagion spillovers of

Table 6
Out-of-sample forecasts for asymmetric contagion spillovers.

	R^2 (%)	ENC-NEW	MSE-F	MSFE-adjusted
Panel A: USDBRL				
CNH	0.482	10.361***	1.365*	2.800***
INR	1.929	23.943***	5.547***	2.809***
AUD	3.198	15.256***	9.316***	2.527***
CAD	−0.629	12.221***	−1.763	1.690**
CHF	−0.600	11.408***	−1.683	2.040**
EUR	4.232	16.318***	12.461***	3.396***
JPY	1.671	9.649***	4.793***	2.598***
SEK	3.812	9.971***	11.177***	3.097***
USD	−3.700	23.012***	−10.062	2.561***
Panel B: USDCNH				
BRL	6.452	2.452***	2.897***	1.929**
INR	13.291	4.341***	6.438***	1.857**
AUD	7.091	2.509***	3.205***	2.048**
CAD	4.019	1.549*	1.759**	1.513*
CHF	−5.414	−0.029	−2.157	−0.015
EUR	14.538	4.976***	7.145***	2.497***
GBP	9.194	8.706***	4.252***	1.645*
JPY	5.996	2.395***	2.679***	1.543*
Panel C: USDINR				
BRL	11.476	40.595***	46.667***	4.299***
CNH	10.277	41.555***	41.237***	4.161***
RUB	11.121	41.700***	45.046***	4.295***
ZAR	12.500	48.290***	51.427***	4.574***
AUD	12.035	43.837***	49.253***	4.326***
CAD	11.033	41.953***	44.644***	4.326***
CHF	4.720	33.918***	17.834***	3.419***
EUR	9.806	41.895***	39.138***	4.125***
JPY	10.811	44.122***	43.638***	4.496***
SEK	11.667	41.259***	47.550***	4.414***
USD	14.135	70.970***	59.261***	4.518***
Panel D: USDRUB				
BRL	6.423	6.597***	6.659***	2.259**
INR	7.935	7.799***	8.360***	2.761***
ZAR	5.848	6.954***	6.025***	2.392***
AUD	6.612	6.650***	6.868***	2.407***
CAD	8.021	8.084***	8.459***	2.713***
EUR	3.340	7.707***	3.352***	2.115**
JPY	8.500	7.893***	9.011***	2.710***
SEK	7.742	7.393***	8.139***	2.490***
USD	8.286	13.887***	8.763***	3.436***
Panel E: USDZAR				
CNH	2.926	14.203***	10.067***	2.938***
INR	1.105	12.105***	3.733***	2.328***
AUD	2.287	10.877***	7.816***	2.300**
GBP	2.714	11.225***	9.318***	2.765***
SEK	0.853	8.226***	2.874***	1.919**
USD	2.824	15.284***	9.705***	2.670***
Panel F: USDAUD				
BRL	5.649	25.852***	24.668***	4.235***
CNH	3.577	23.926***	15.285***	3.329***
INR	6.032	45.899***	26.449***	4.605***
RUB	1.976	25.285***	8.305***	4.019***
ZAR	5.423	32.469***	23.626***	4.428***
CAD	1.169	37.683***	4.872***	3.902***
CHF	−8.813	18.890***	−33.370	1.915**
EUR	1.006	32.699***	4.186***	3.861***
SEK	4.663	22.863***	20.151***	3.856***
JPY	−1.506	44.252***	−6.114	3.523***
USD	−8.063	61.590***	−30.740	4.447***
Panel G: USDCAD				
CNH	5.121	25.259***	21.535***	3.749***
RUB	2.588	21.540***	10.599***	2.920***
ZAR	5.504	28.242***	23.242***	3.817***
AUD	5.452	23.359***	23.008***	3.603***
SEK	7.259	28.363***	31.228***	4.553***
USD	5.877	30.184***	24.912***	3.997***
Panel H: USDCHF				
ZAR	6.693	34.231***	25.822***	2.462***
SEK	6.238	32.260***	23.952***	2.320**
Panel I: USDEUR				
RUB	5.997	27.692***	22.966***	4.478***
ZAR	4.953	24.185***	18.761***	4.237***
GBP	5.894	24.568***	22.548***	4.323***

(*continued on next page*)

Table 6 (*continued*)

	R^2 (%)	ENC-NEW	MSE-F	MSFE-adjusted
SEK	6.721	26.724***	25.939***	4.620***
USD	3.668	25.885***	13.707***	3.703***
Panel J: USDGBP				
RUB	2.132	14.855***	8.868***	2.058**
ZAR	3.092	18.232***	12.987***	3.029***
CAD	1.941	15.733***	8.055***	2.312**
CHF	1.176	12.766***	4.843***	1.914**
USD	0.930	15.496***	3.819***	2.169**
Panel K: USDSEK				
RUB	3.457	24.159***	12.889***	3.790***
ZAR	4.689	24.985***	17.710***	4.136***
AUD	4.800	20.408***	18.151***	3.985***
EUR	3.770	27.051***	14.103***	3.851***
USD	5.810	26.731***	22.206***	4.027***
Panel L: USDX				
RUB	7.279	32.301***	28.262***	4.864***
ZAR	7.054	35.605***	27.323***	5.199***
AUD	8.650	34.579***	34.091***	5.246***
CHF	3.765	29.431***	14.084***	3.779***
SEK	7.306	30.312***	28.373***	4.915***

Note: This table reports the out-of-sample forecast evaluations of currency returns based on the in-sample results of the asymmetric contagion spillovers. As shown in the table, panels A to L present the return predictability of different currencies by using investor attention from external markets and discriminating between past currency appreciation and depreciation from domestic markets. The out-of-sample forecast evaluations also consider a two lag specification as the in-sample analysis. Specifically, the title of each row is investor attention on a specific currency, and the column headings denote statistical indicators of forecast evaluations for the out-of-sample analysis. The R^2 statistic is obtained from Campbell and Thompson (2008) and Welch and Goyal (2008). The *ENC-NEW* statistical indicator is the forecast encompassing test statistic proposed by Clark and McCracken (2001). The *MSE-F* statistical indicator is the equal forecast statistic for accuracy test suggested by McCracken (2007). The *MSFE-adjusted* statistical indicator is the forecast error test statistic of Clark and West (2007). Moreover, it should be noted that forecasting different returns requires different out-of-sample periods, which are consistent with the definitions of Table 5. In particular, the out-of-sample period is 2010:01–2016:11 for forecasting USDINR, USDCHF, USDEUR, USDSEK and USDX. For USDBRL, it is 2011:07–2016:11. For USDCNH, it is 2016:01–2016:11. For USDRUB, it is 2015:02–2016:11. For USDZAR, it is 2010:07–2016:11. For USDAUD, it is 2009:01–2016:11. For USDCAD, it is 2009:04–2016:11. For USDGBP, it is 2009:02–2016:11. For USDJPY, it is 2008:01–2016:11.

*, **, ***denote significance at 10%, 5% and 1% level, respectively.

attention on the present returns. This means the increased foreign attention minifies the return predictability of domestic currency when considering the impact of past currency appreciation on the contagion spillovers of attention, and therefore improves the efficiency of currency market. Additionally, the scopes of the contagion spillovers are obviously enlarged regarding this asymmetric effect by comparison with those of the baseline contagion spillovers, and they are mainly embodied in the contagion spillovers of attention from developed markets on emerging currency returns. Generally, our findings provide evidence for the literature on attention where investor attention on specific currencies contains information that impacts the movements of other currency returns, which further manifests in the fact that investor attention is an important channel through which financial contagion arises in international currency markets.

In closing, one implication for policy stemming from these results is that investors in emerging currency markets should enlarge the extent and scope of information gathering, especially regarding information about investor attention from developed currency markets. This could help related participants in emerging markets obtain more revenue and effectively prevent the risk of exchange rate fluctuations to some extent. Additionally, the emerging countries should reinforce prudential regulations and micro adjustments to mitigate increasing risks of contagion spillovers in the international foreign exchange markets. Possible future studies could explore the gains from hedging by managing a portfolio composed of multiple currency pairs, in which the forecast performance of a specific currency depending on investor attention constitutes the corresponding portfolio weight.

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