Lingnan Journal of Banking, Finance and Economics

Volume 2 *2010/2011 Academic Year Issue* Article 4

January 2010

The uncovered interest rate parity failure from 2002 to 2005 : an implicit consensus of carry trade

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The Uncovered Interest Rate Parity Failure from 2002 to 2005: An Implicit Consensus of Carry Trade

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Abstract

There are many literatures devoted to the study of the uncovered interest parity (UIP); however, majority of them focus on whether UIP exists and only a few concentrate on the pattern of the UIP failure. By using a panel VAR approach, this paper compares the intensive carry trade period, between 2002 and 2005, and the pre-intensive carry trade period, between 1998 and 2001. The results show that during the intensive carry trade period UIP failure was caused by the self-fulfilling behaviour of investors. High interest rate currencies made investors believed that the currencies would appreciate and bided their price even higher. This finding may inspire a new concept of explaining the short run exchange rate movement and the fundamental reason why UIP seldom exists in the international exchange market.

1. Introduction and Literatures Review

UIP is a well known hypothesis in international finance. It asserts that, for example, if the home currency interest rate is 3% and foreign currency interest rate is 10%, then in the future, the home currency must appreciate by 7% against that foreign currency in order to make the return of two currencies' deposit equal. If home currency is expected to appreciate by only 6%, all investors will sell home currency and buy foreign currency, because the return of home currency is lower, immediately home currency will depreciate 1%. Thus, the appreciation of home currency in the future will be 7% again. Mathematically:

$$\Delta \ln s_t = \alpha + \beta(r^*_{t-1} - r_{t-1})$$

$\Delta \ln s_t$: % change of home currency's price in terms of foreign currency from time t-1 to t (s_t is the price of home currency in terms of foreign currency)

r^*_{t-1}: Foreign currency interest rate at time t-1

r_{t-1} : Home currency interest rate at time t-1

Therefore, if UIP holds, α equals to zero and β is unity. However, dozens of academic papers found that UIP did not hold empirically. For example, McCallum (1992) proved UIP failed in a manner that β statistically can be as small as -3, and he suggested that the cause may be policies preventing exchange rate fluctuation. Flood and Rose (1994) discovered that β sometimes was positive, i.e. high interest rate currencies would depreciate in the future, but the magnitude of β was still less than one. Flood and Rose (2001) found that the departure from UIP was more serious in long run than short run. Brunnermeier, Nagel and Pedersen (2009) proved that UIP did not hold in the recent two decades and provided the opportunity for carry trade.

Behavioural economists Froot and Thaler (1990) pointed out that, the difficulties in explaining the failure of UIP may be because of the extremely restrictive assumption of "a rational efficient market paradigm". Some academic economists, with the intention of explaining any abnormal return by using risk premium which is an unobservable variable, argue that the failure of UIP may be caused by the inefficiency of the market (such as investors were not fully rational and act slowly). Game theorists Shin and Plantin (2008) developed a game theory model and argued that if investors can engage in and carry out trade freely and flexibly, and the speed of the exchange rate reverses, to its fundamental level is slow, investors may bid up the price of a currency with a higher interest rate, i.e. β is negative. Brunnermeier, Nagel and Pedersen (2009) also discovered that the carry trade target currency tend to appreciate gradually and depreciate suddenly, showing that carry traders themselves bided up the price of the high interest rate currency slowly. Therefore, the failure of UIP may be a phenomenon of the self-fulfilling behaviour of investors.

2. Methodology and Data

The study of UIP in this paper contains two parts. First, a traditional method was used to test whether UIP existed. The following fixed effect panel model is estimated,

$$\Delta \ln s_{i,t} = \alpha_i + \beta\left(r^*_i - r\right)_{t-1} + e_{i,t}$$

$\left(r^*_i - r\right)_{t-1} = \left(r^*_{i,t-1} - r_{t-1}\right)$ and $e_{i,t}$ is the error term

The definition of the algebras are the same as those in the introduction, except that i denotes the variable of currency i, r denotes the interest rate of the benchmark currency , i.e. U.S dollar, and $s_{i,t}$ is the price of U.S. dollar in terms of currency i at time t. After proving that UIP did not hold, the study moves to the second part, to analyze the pattern of the failure of UIP. A fixed effect panel VAR approach is applied in order to see whether the interest rate differential between currencies Granger caused the exchange rate movement and review their impulse response.

The 6 currencies data set includes U.S. dollar, Australian dollar, Canadian dollar, British Pound, Japanese Yen and Norwegian Krone. USD is the benchmark for comparison, so there are 5 cross sections. Exchange rate and 1-month interest rate of the currency are generated from Data Stream Advance. Observation frequency is monthly. See Reminder 1 in Appendix for details of the 1 month interest rate of each currency.

Since carry trade activities implies a certain kind of UIP failure, it is meaningful to study the UIP during the carry trade period and before the carry trade period. Galati, Health and McGuire (2007) showed carry trade reached the peak from 2002 to 2005. Therefore, this study contains two periods. The first is the pre carry trade period from 1998 to 2001, and the second is the carry trade period from 2002 to 2005.

3. Empirical Results

Before going to the UIP FEM (Fixed Effect Model), this paper suggests a simple but useful UIP test. If UIP held for a certain period, the return of carry trade would not be much different from the return of investing in the home currency. Suppose there were a carry trader and a Yen investor in Japan, and they had each 100 Yens at the beginning. The Yen investor only invests in Yen. The carry trader, however, will invest in a high interest rate currency compare to Yen in the beginning of each month, then convert back his fund to Yen at the end of the month, and make another decision in next month according to the interest rate. Also assume British pound is the target currency[1] of the carry trader. According to the data (See Example 1 (All Tables, Figures and Examples are in Appendix)), from 1998 to 2001, the wealth of the Yen investor increased from 100 Yens to 101.42 Yens, while the carry trader's wealth increased from 100 to 103.56. Though there was a difference, the difference was small. Between 2002 and 2005, the wealth of the Yen investor only increased from 100 Yens to 100.25 Yens, but the carry trader's wealth increased sharply from 100 Yens to 128.84 Yens. The huge difference implies that the UIP in the carry trade period had collapsed totally, even we did not use any sophisticated econometric test.

As $\ln s_{i,t}$ and $\left(r^*_i - r\right)_{t-1}$ are proven to be I(1) in both periods as shown in Table 1 and Table 2. Both $\ln s_{i,t}$ and $\left(r^*_i - r\right)_{t-1}$ need to be 1st differenced. Therefore, the UIP Fixed Effect Model should be transformed into the following equation,

[1] Galati, Health and McGuire (2007) suggested that from 2002 to 2005, British pound is one of the popular target currencies, while Japanese Yen is a popular fund currency, i.e. people tended to short Yen and long Pound.

$$\Delta \ln s_{i,t} = \alpha_i + \beta\Delta\left(r^*_i - r\right)_{t-1} + e_{i,t} = \alpha_i + \beta\left[\left(r^*_i - r\right)_{t-1} - \left(r^*_i - r\right)_{t-2}\right] + e_{i,t}$$

$$\Delta \ln s_{i,t} = \alpha_i + \beta\left(r^*_i - r\right)_{t-1} - \beta\left(r^*_i - r\right)_{t-2} + e_{i,t}$$

After rearranging, we see that the β still has the original meaning[2]. Table 3 shows that the Durbin Watson d-statistics and the result of White test, the model in the former period suffered from serial correlation and heteroscedasticity, while in the latter period the model suffered from heteroscedasticity, so White (diagonal) coefficient covariance method is used to adjust the S.E. in order to give consistent results. Table 3 shows that we cannot reject UIP existed during the pre carry trade period from 1998 to 2001. The mean of α_i in the FEM is not significantly different from zero since the t-statistic is 1.26 and does not exceed the critical value of 5% significant level. β is not significantly different from 1, and the t-statistic with the null hypothesis β =1 is 1.16, lower than the critical value of 5% significant level.

However, the carry trade period between 2002 and 2005 was completely different as shown in Table 3. UIP collapsed. The mean of α_i is significantly lower than zero by having a high t-statistic -3.21. The reason may be that holding currencies other than USD is risky, so even if there was no interest difference, USD tends to depreciate in this period. The striking point, however, is that β is significantly lower than 1 at 10% significant level in this period, though the t-statistic with the null hypothesis β =1 is -1.89, cannot exceed the 5% significant level critical value. Moreover, β also significantly lower than 0 at 10% significant level in this period, the t-statistic with the null hypothesis β =0 is -1.82. Therefore, higher interest rate currencies tend to appreciate in the carry trade period.

Diagrammatically, Figure 1 shows the scatter graph of $\Delta \ln s_{i,t}$ and $\Delta(r^*_i - r)_{t-1}$ between 1998 and 2001. There is a positive relationship suggested by UIP, though whether UIP held perfectly is not clear. Figure 2 shows the scatter graph of $\Delta \ln s_{i,t}$ and $\Delta(r^*_i - r)_{t-1}$ between 2002 and 2005 and they had a negative relationship, implying that high interest rate currencies will appreciate in the future.

Now we discovered that UIP did not hold in the carry trade period. We go one step further to study the pattern of the UIP failure between 2002 and 2005 by using VAR, since both lns and ($r^*_i - r$) are I(1). And they are not co-integrated as Table 4 shows that the residual of the liner combination of these two series has a unit root in both periods. So we apply the following fixed effect VAR for $\Delta \ln s$ and $\Delta(r^*_i - r)$,[3]

$$\Delta \ln s_{i,t} = \theta_{0i} + \theta_1\Delta \ln s_{i,t-1} + ... + \theta_k\Delta \ln s_{i,t-k} + \phi_1\Delta(r^*_i - r)_{t-1} + ... + \phi_k\Delta(r^*_i - r)_{t-k} + u_{1i,t}$$

$$\Delta(r^*_i - r)_t = \lambda_{0i} + \lambda_1\Delta(r^*_i - r)_{t-1} + ... + \lambda_k\Delta(r^*_i - r)_{t-k} + \gamma_1\Delta \ln s_{i,t-1} + ... + \gamma_k\Delta \ln s_{i,t-k} + u_{2i,t}$$

The optimal lag *k* is selected by AIC (Akaike Information Criteria) and the maximum

[2] This means that the β still shows the relationship between $\left(r^*_i - r\right)_{t-1}$ and $\Delta \ln s_{i,t}$.

[3] Though the VARs is for $\Delta \ln s$ and $\Delta(r^*_i - r)$, it still can show the +ve or –ve relation between $\Delta \ln s$ and $(r^*_i - r)$, as 1 unit increase in $(r^*_i - r)_t$ leads to 1 unit increase in $\Delta(r^*_i - r)_t$.

lag is 8. $u_{1i,t}$ and $u_{2i,t}$ are error terms. Table 5 shows the VAR results of the period between 1998 and 2001, the optimal lag is 1 month. Therefore, interest rate differential, and exchange rate, did not have a long impact on each other; the market reached its equilibrium within a month. Table 6 shows the results of Granger Causality test that high *P*-values implied that we cannot reject interest rate differential and exchange rate did not have any causal relationship. Note that the inability of rejecting the notion that the two variables did not have any causal relationship does not mean that we can reject that they had causal relationship. Therefore, this result still does not contradict with the result of UIP FEM above.

The VAR results of the carry trade period from 2002 to 2005 are very meaningful and have deep implications. Table 7 shows the result of the VAR. The optimal lag number is 7 according to AIC, implying that the market during this period took a longer time to reach the equilibrium. Table 8 reports the result of the Granger Causality test. The *P*-value of the Granger Causality from $\Delta(r^*_i - r)$ to $\Delta \ln s$ is 0.0000, while the *P*-value of the Granger Causality from $\Delta \ln s$ to $\Delta(r^*_i - r)$ is 0.1450 and is not significant at 5% level. Therefore, between 2002 and 2005 $\Delta(r^*_i - r)$ Granger caused $\Delta \ln s$ but not the opposite. Note that LM autocorrelation test and White Heteroskedasticity test are also performed for the VARs. They do not suffer from these problems (see Table 5 and 7).

4. Analysis of the Impulse Response in the Carry Trade Period

Figure 3 shows the VAR impulse response function in terms of standard deviation of the period between 2002 and 2005. The first striking result is the response of $\Delta \ln s$ to $\Delta(r^*_i - r)$ was negative at the beginning, but becomes positive after 3 months. This suggests that higher interest rate currencies tend to appreciate first and then depreciate. The second important finding is the response of $\Delta(r^*_i - r)$ to itself remained positive for more than ten months. This means an increase in interest rate will lead to increases in interest rate in the later periods.

A reasonable explanation for the fact that higher interest rate currencies tends to appreciate first and then depreciate is the self-fulfilling behaviour of the carry traders. Carry traders in this period discovered that higher interest rates would persist for a long period (shown by the impulse response of $\Delta(r^*_i - r)$ to itself). Moreover, carry traders knew that other investors would also engage in carry trade. Hence, they built up a consensus that the demand for high interest rate currencies would remain large for a period, and the currencies would appreciate. Thus they were more willing to short low interest rate currencies and long high interest rate currencies. This behaviour caused high interest rate currencies appreciated eventually, even though there was no fundamental reason for the currency price to go up. As a result, UIP cannot hold. Nevertheless, after the appreciation, investors made a profit and tried to unwind the carry trade by selling the high interest rate currency. This explains why the high interest rate currency would appreciate first but depreciates after two or three months.

Reader may ask why carry traders did not act in this way in the pre carry trade period from 1998 to 2002. The reason may be because at that time carry traders still did not built up a consensus. If an investor believed that other investors would not engage in carry trade, the high interest rate currency would not appreciate or even depreciate. So, there is no point for the investor to do carry trade at the beginning. However, the fact shows that the consensus eventually was built up. Therefore, it must be that some investors started carry trade, as vanguards, and made other investors believed that carry trade was the norm. Nevertheless, this paper still did not find out the reason why those vanguards were willing to start carry trade. A noteworthy point is that even though the investors built up a consensus, and realized the carry trade profit by themselves, it is different from a coordinated game or focal point suggested by Schelling (1960). This is because the carry traders still faced a zero sum game. They sooner or later had to unwind the carry trade, and whether they could earn a profit finally, still depends on the timing of clearing the carry trade position.

Actually, higher interest rate leads to appreciation does not totally contradict to the UIP. For example, at the beginning the interest rate of the home currency and foreign currency are the same, but later the home currency interest rate increases by 3%. Assume the expected exchange rate is fixed, so home currency's return is higher. Therefore, investors will buy home currency until it appreciates by 3% in order to make the return of the two currencies equal. The key question is how fast this 3% appreciation happens. If it happens very slowly, it would lead to the UIP seemingly failed.

5. Conclusion and Implications

This study reveals that the behaviours and consensuses of the international financial market will change from time to time. Different behaviours and consensuses will lead to different relationship between exchange rate and other factors such as interest rate. As a result, using one or two rigid theories to generalize the operation of the ever changing market may not be effective. In addition, probably it is more appropriate to narrow down the range of time when doing empirical researches. Moreover, variables representing risk may be added for reflecting the risk premium of currencies.

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Appendix I:

(Test result details such as White test and LM test are available subject to request)

Table 1: Im, Pesaran and Shin Panel Unit Root Test, Jan 1998 – Dec 2001
Optimal lag is selected according to Schwarz Criterion

	Order	**W-statistics**	***P*-value**	**t-bar**	
lns – I(1)	Level (intercept and trend)	-0.53444	0.2965	-2.36625	
				Critical Values	
				1% level	-3.02300
				5 % level	-2.76300
				10 % level	-2.63000
	1st difference (intercept)	-16.2607	0.0000	-7.88164	
				Critical Values	
				1% level	-2.42400
				5% level	-2.15400
				10% level	-2.02000
idm – I(1)	Level (intercept and trend)	4.45312	1.0000	N/A	
				Critical Values	
				1% level	N/A
				5% level	N/A
				10% level	N/A
	1st difference (intercept)	-13.0275	0.0000	N/A	
				Critical Values	
				1% level	N/A
				5% level	N/A
				10% level	N/A

Note: idm denotes $\left(r^*_i - r\right)_t$

Table 2: Im, Pesaran and Shin Panel Unit Root Test, Jan 2002 – Dec 2005
Optimal lag is selected according to Schwarz Criterion

	Order	**W-statistics**	***P*-value**	**t-bar**	
lns – I(1)	Level (intercept and trend)	1.70935	0.9563	-1.56373	
				Critical Values	
				1% level	-3.02300
				5 % level	-2.76300
				10 % level	-2.63000
	1st difference (intercept)	-13.2679	0.0000	-6.71176	
				Critical Values	
				1% level	-2.42400
				5% level	-2.15400
				10% level	-2.02000
idm – I(1)	Level (intercept and trend)	5.36188	1.0000	N/A	
				Critical Values	
				1% level	N/A
				5% level	N/A
				10% level	N/A
	1st difference (intercept)	-5.46560	0.0000	N/A	
				Critical Values	
				1% level	N/A
				5% level	N/A
				10% level	N/A

Note: idm denotes $\left(r^*_i - r\right)_t$

Table 3: Uncovered Interest Parity Fixed Effect Model – standard error in parenthesis

Dependent / **Independent**	**Jan 1998 – Dec 2001 Standard error is adjusted by White (diagonal) coefficient covariance method**		**Jan 2002 – Dec 2005 Standard error is adjusted by White (diagonal) coefficient covariance method**	
	$\Delta \ln s_{i,t}$		$\Delta \ln s_{i,t}$	
α	0.002455 (0.001946)	t-statistic 1.261326	-0.005880 (0.001832)	t-statistic -3.209975**
β (null hypothesis of the t-test is β =1)	10.00561 (8.596752)	t-statistic 1.163883	-24.92243 (13.71784)	t-statistic -1.889687*
t-statistic for null hypothesis β =0	1.163883		-1.816789*	
R-squared	0.016706		0.025061	
Adjusted R-squared	-0.004304		0.004229	
Durbin-Watson d-stat	2.416486		2.069568	
White-test	22.92456		12.04032	

Table 4: Augment Engle-Granger Two Step Co-integration Test (none) between lns_t and idm_{t-1} (Use IPS penal unit root test for the residual of the linear combination of lns_t and idm_{t-1}) Optimal lag is selected according to Schwarz Criterion

Period		**W-statistics**	***P*-value**	**t-bar**	
Jan 1998 – Dec 2001 (rejected)	(intercept and trend)	0.12559	0.5500	-2.12981	
				Critical Values	
				1% level	-3.02400
				5 % level	-2.76400
				10 % level	-2.63000
Jan 2002 – Dec 2005 (rejected)	1st difference (intercept)	2.419465	0.9922	-1.30797	
				Critical Values	
				1% level	-3.02400
				5% level	-2.76400
				10% level	-2.63000

Table 5: Fixed Effect VAR Jan 1998 – Dec 2001, t-statistics in parenthesis

~~Dependent~~ **Independent**	**Dlns**		**didm**	
dlns(-1)	-0.178049	(-2.78255)	-0.000695	(-1.01354)
didm(-1)	7.751998	(1.26420)	0.003581	(0.05435)
dm(AUS)	0.006504	(1.53588)	0.000057	(1.25838)
dm(CAD)	0.002270	(0.53914)	0.000046	(1.02659)
dm(GBP)	0.003975	(0.94590)	0.000008	(0.17536)
dm(YEN)	-0.001164	(-0.27653)	0.000053	(1.18439)
dm(NOK)	0.004329	(1.01218)	0.000128	(2.78999)
R-squared	0.048330		0.019905	
Adjusted R-squared	0.023824		-0.005334	
LM-test (See Table 11 for details)	0.176075		0.018095	
White-test *P*-value (joint test) (See Table 9)	0.4286			
AIC	-17.51075			

Table 6: Granger Causality Jan 1998 – Dec 2001 *F*-statistics and *P*-value in parenthesis

Dependent / Excluded	**Dlns**		**didm**	
Dlns			1.027272	(0.3180)
Didm	1.598199	(0.2062)		

Abbreviations:

dlns - $\Delta \ln s$ dlns(-x) - $\Delta \ln s_{t-x}$

didm - $\Delta(r^*_i - r)$ didm(-x) - $\Delta(r^*_i - r)_{t-x}$

dm(AUS) – dummy variable for Australian Dollar.
dm(CAD) – dummy variable for Canadian Dollar
dm(GBP) – dummy variable for British Pound
dm(YEN) – dummy variable for Japanese Yen
dm(NOK) – dummy variable for Norwegian Krone
These abbreviations are also available in the following Tables.

Table 7: Fixed Effect VAR Jan 2002 – Dec 2005, t-statistics in parenthesis

Dependent / Independent	**Dlns**		**didm**	
dlns(-1)	-0.103427	(-1.56524)	-0.000645	(-2.04294)
dlns(-2)	-0.027166	(-0.41975)	-0.000502	(-1.62259)
dlns(-3)	-0.000395	(-0.00617)	0.000081	(0.26521)
dlns(-4)	-0.034577	(-0.54183)	-0.000098	(-0.32198)
dlns(-5)	-0.084070	(-1.33608)	-0.000572	(-1.90226)
dlns(-6)	-0.078191	(-1.22813)	-0.000342	(-1.12383)
dlns(-7)	-0.261246	(-4.07049)	0.000053	(0.17538)
didm(-1)	-24.40622	(-1.70908)	0.217685	(3.19212)
didm(-2)	-8.758285	(-0.62387)	0.129876	(1.93730)
didm(-3)	32.57596	(2.77876)	0.008014	(0.14316)
didm(-4)	11.28085	(0.99412)	0.042346	(0.78143)
didm(-5)	-8.422279	(-0.74922)	0.175579	(3.27069)
didm(-6)	-40.88579	(-3.59424)	0.026485	(0.48755)
didm(-7)	-13.87031	(-1.21305)	0.021627	(0.39608)
dm(AUS)	-0.011035	(-2.73343)	-0.000036	(-1.85411)
dm(CAD)	-0.009941	(-2.58042)	-0.000018	(-0.98867)
dm(GBP)	-0.006894	(-1.79955)	-0.000029	(-1.59755)
dm(YEN)	-0.001848	(-0.49346)	-0.000034	(-1.94903)
dm(NOK)	-0.014754	(-3.34487)	-0.000071	(-3.41499)
R-squared	0.177046		0.358066	
Adjusted R-squared	0.110018		0.305781	
LM-test (see Table 12 for details)	0.332261		0.09071	
White-test *P*-value (joint test) (see Table 10)	0.2464			
AIC	19.59206			

Table 8: Granger Causality Jan 2002 – Dec 2005 *F*-statistics and *P*-value in parenthesis

Dependent / Excluded	Dlns		didm	
Dlns			10.85663	(0.1450)
Didm	32.29167	(0.0000)		

Example 1: Case A – YEN GBP carry trade profit from 1998 to 2001

Time	Yen to GBP exchange rate	YEN inter-bank one month interest rate divided by 12	GBP inter-bank one month interest rate divided by 12	YEN one month interest return minus GBP one month interest return	The cumulative wealth using carry trade strategy	The cumulative wealth of investing in YEN only
1/1/1998	215.5332	0.000834	0.006198	-0.00536	100	100
1/2/1998	207.4414	0.000697	0.006172	-0.00547	96.84222	100.0834
1/3/1998	206.6678	0.00103	0.006185	-0.00516	97.07652	100.1532
1/4/1998	223.4331	0.00059	0.006185	-0.00559	105.6007	100.2563
1/5/1998	222.3426	0.00051	0.006068	-0.00556	105.7352	100.3154
1/6/1998	229.1762	0.000465	0.006146	-0.00568	109.6462	100.3665
1/7/1998	228.9889	0.000608	0.006263	-0.00566	110.2299	100.4132
1/8/1998	236.9123	0.000558	0.00625	-0.00569	114.7583	100.4742
1/9/1998	228.5523	0.000685	0.00625	-0.00556	111.4007	100.5303
1/10/1998	231.5368	0.000458	0.00612	-0.00566	113.5608	100.5992
1/11/1998	191.2646	0.000439	0.006042	-0.0056	94.38274	100.6452
1/12/1998	201.9848	0.000614	0.005729	-0.00512	100.275	100.6895
1/1/1999	188.2675	0.000481	0.005156	-0.00467	94.00057	100.7513
1/2/1999	188.8542	0.000414	0.004896	-0.00448	94.77972	100.7998
1/3/1999	192.7767	0.000376	0.00457	-0.00419	97.22194	100.8415
1/4/1999	193.251	0.000153	0.00431	-0.00416	97.90659	100.8795
1/5/1999	193.4975	0.000118	0.004349	-0.00423	98.45396	100.8949
1/6/1999	194.4391	8.53E-05	0.004362	-0.00428	99.3633	100.9068
1/7/1999	190.118	8.93E-05	0.004167	-0.00408	97.57893	100.9154
1/8/1999	185.0049	8.21E-05	0.004323	-0.00424	95.35021	100.9244
1/9/1999	175.3249	8.51E-05	0.004141	-0.00406	90.75185	100.9327
1/10/1999	173.9987	7.86E-05	0.004479	-0.0044	90.43831	100.9413
1/11/1999	171.0319	7.56E-05	0.004479	-0.0044	89.29445	100.9492
1/12/1999	164.4573	0.000726	0.004818	-0.00409	86.24648	100.9568
1/1/2000	166.3392	0.000132	0.004323	-0.00419	87.65371	101.0301
1/2/2000	174.1201	7.92E-05	0.005	-0.00492	92.15055	101.0434
1/3/2000	170.046	0.000105	0.005	-0.0049	90.44436	101.0514
1/4/2000	167.6151	9.58E-05	0.004935	-0.00484	89.59716	101.062
1/5/2000	168.913	7.92E-05	0.005052	-0.00497	90.73654	101.0717

Time	Yen to GBP exchange rate	YEN inter-bank one month interest rate divided by 12	GBP inter-bank one month interest rate divided by 12	YEN one month interest return minus GBP one month interest return	The cumulative wealth using carry trade strategy	The cumulative wealth of investing in YEN only
1/6/2000	162.0798	7.44E-05	0.004948	-0.00487	87.50572	101.0797
1/7/2000	159.8698	0.000136	0.004948	-0.00481	86.73964	101.0872
1/8/2000	162.9812	0.000108	0.004974	-0.00487	88.8653	101.101
1/9/2000	155.1179	0.000342	0.004974	-0.00463	84.99853	101.1119
1/10/2000	159.5979	0.000306	0.005	-0.00469	87.88839	101.1465
1/11/2000	157.0786	0.000286	0.004896	-0.00461	86.93353	101.1774
1/12/2000	160.3836	0.000579	0.004896	-0.00432	89.19725	101.2064
1/1/2001	171.1026	0.000453	0.004818	-0.00436	95.62451	101.2649
1/2/2001	170.5752	0.000355	0.004844	-0.00449	95.78901	101.3108
1/3/2001	170.7697	0.00027	0.004714	-0.00444	96.36274	101.3467
1/4/2001	179.6738	9.49E-05	0.004635	-0.00454	101.8651	101.374
1/5/2001	175.1722	6.09E-05	0.004427	-0.00437	99.77327	101.3837
1/6/2001	169.0574	5.19E-05	0.004271	-0.00422	96.71676	101.3898
1/7/2001	175.8821	5.71E-05	0.004271	-0.00421	101.0509	101.3951
1/8/2001	178.6032	5.45E-05	0.004323	-0.00427	103.0525	101.4009
1/9/2001	172.7312	5.9E-05	0.00401	-0.00395	100.0953	101.4064
1/10/2001	176.7672	5.06E-05	0.003854	-0.0038	102.8449	101.4124
1/11/2001	178.4377	5.06E-05	0.003438	-0.00339	104.2169	101.4175
1/12/2001	176.698	7.63E-05	0.003292	-0.00322	103.5556	101.4227

The case calculates the cumulative YEN return of a carry trader and a YEN investor, both of them have 100 YEN at the beginning. The YEN investor invested in YEN only, so each month he received the YEN interest return only. For example, the wealth of the YEN investor's wealth in 1/2/1998 was 100YEN*(1+0.000834) = 100.0834YEN. The cumulative wealth of the YEN investor is shown on the last column of the table above.

The carry trader invested in a higher interest rate currency in each month. Also assume he could only choose YEN and GBP. Therefore, at the beginning of each month, he chose the higher interest rate currency from YEN or GBP. If GBP offered a high rate, he would invest in GBP. At the end of the month he would convert the GBP back into YEN. And see whether GBP or YEN offered a higher rate in the next month, then invest in a higher interest rate currency again.

From 1998 to 2001 when the interest rate of GBP was always higher than YEN the carry trader at the first month converted YEN to GBP, and invested in GBP deposit. A t the end of the month, he converted the GBP back to YEN. At the beginning of the second month, he converted YEN to GBP and invested in GBP again for a month. He was repeating this action until 1/12/2001. The cumulative wealth is report at the

second last column of the table. For example, the wealth of the carry trader in 1/2/1998 was (100YEN/215.5332)*(1+0.006198)*207.4414=96.84222.

Case B – YEN GBP carry trade profit from 2002 to 2005

Time	Yen to GBP exchange rate	YEN inter-bank one month interest rate divided by 12	GBP inter-bank one month interest rate divided by 12	YEN one month interest return minus GBP one month interest return	The cumulative wealth using carry trade strategy	The cumulative wealth of investing in YEN only
1/1/2002	190.6769	5.77E-05	0.003412	-0.00335	100	100
1/2/2002	188.3657	5.14E-05	0.003307	-0.00326	99.12492	100.0058
1/3/2002	189.2578	0.000124	0.003333	-0.00321	99.9238	100.0109
1/4/2002	192.2069	8.13E-05	0.003307	-0.00323	101.8191	100.0233
1/5/2002	186.6813	5.97E-05	0.003229	-0.00317	99.21907	100.0314
1/6/2002	181.0158	5.14E-05	0.003333	-0.00328	96.51859	100.0374
1/7/2002	183.6553	4.79E-05	0.003281	-0.00323	98.25241	100.0425
1/8/2002	186.1202	4.44E-05	0.003229	-0.00318	99.89781	100.0473
1/9/2002	182.928	6.04E-05	0.003307	-0.00325	98.50145	100.0518
1/10/2002	191.7917	4.72E-05	0.003229	-0.00318	103.6159	100.0578
1/11/2002	191.338	4.72E-05	0.003229	-0.00318	103.7046	100.0625
1/12/2002	194.0869	6.53E-05	0.003307	-0.00324	105.5342	100.0672
1/1/2003	191.1717	5.07E-05	0.003333	-0.00328	104.2928	100.0738
1/2/2003	197.65	4.93E-05	0.003333	-0.00328	108.1864	100.0789
1/3/2003	185.7549	0.000075	0.00306	-0.00298	102.0144	100.0838
1/4/2003	186.2948	5.14E-05	0.003021	-0.00297	102.624	100.0913
1/5/2003	191.0277	0.00005	0.002917	-0.00287	105.5491	100.0964
1/6/2003	194.1398	0.00005	0.003047	-0.003	107.5815	100.1014
1/7/2003	198.3962	0.00005	0.003021	-0.00297	110.2751	100.1064
1/8/2003	193.6825	0.00005	0.002813	-0.00276	107.9803	100.1115
1/9/2003	183.315	6.88E-05	0.002995	-0.00293	102.4877	100.1165
1/10/2003	184.5769	0.00005	0.003021	-0.00297	103.5023	100.1233
1/11/2003	185.9742	0.00005	0.003073	-0.00302	104.6008	100.1283
1/12/2003	188.0887	5.83E-05	0.003151	-0.00309	106.1152	100.1334
1/1/2004	191.4122	0.00005	0.003177	-0.00313	108.3306	100.1392
1/2/2004	192.4276	0.00005	0.003281	-0.00323	109.2512	100.1442
1/3/2004	203.7678	5.97E-05	0.003412	-0.00335	116.0693	100.1492
1/4/2004	192.6026	0.00005	0.003385	-0.00334	110.0837	100.1552
1/5/2004	195.2959	0.00005	0.003516	-0.00347	112.0009	100.1602
1/6/2004	203.2101	0.00005	0.003672	-0.00362	116.9494	100.1652
1/7/2004	197.3876	0.00005	0.003802	-0.00375	114.0156	100.1702

Time	Yen to GBP exchange rate	YEN inter-bank one month interest rate divided by 12	GBP inter-bank one month interest rate divided by 12	YEN one month interest return minus GBP one month interest return	The cumulative wealth using carry trade strategy	The cumulative wealth of investing in YEN only
1/8/2004	202.2536	0.00005	0.00388	-0.00383	117.2705	100.1752
1/9/2004	196.2249	5.83E-05	0.003984	-0.00393	114.2164	100.1802
1/10/2004	198.7592	0.00005	0.003984	-0.00393	116.1526	100.1861
1/11/2004	195.2054	0.00005	0.003984	-0.00393	114.5302	100.1911
1/12/2004	198.5786	5.69E-05	0.003984	-0.00393	116.9736	100.1961
1/1/2005	195.9508	5.07E-05	0.00401	-0.00396	115.8856	100.2018
1/2/2005	195.2448	0.00005	0.003984	-0.00393	115.9311	100.2069
1/3/2005	200.4513	6.6E-05	0.00401	-0.00394	119.4969	100.2119
1/4/2005	202.4177	5.14E-05	0.00401	-0.00396	121.153	100.2185
1/5/2005	199.2515	0.00005	0.004023	-0.00397	119.7362	100.2237
1/6/2005	196.7301	0.00005	0.003984	-0.00393	118.6967	100.2287
1/7/2005	197.5959	0.00005	0.003932	-0.00388	119.6941	100.2337
1/8/2005	198.5598	4.93E-05	0.003802	-0.00375	120.751	100.2387
1/9/2005	201.3843	5.9E-05	0.003776	-0.00372	122.9343	100.2436
1/10/2005	200.3071	0.00005	0.003776	-0.00373	122.7384	100.2495
1/11/2005	206.1937	0.00005	0.003789	-0.00374	126.8225	100.2546
1/12/2005	208.6855	5.69E-05	0.003776	-0.00372	128.8415	100.2596

The logic is the same as Case A.

Reminder 1 – details of the one month interest rate

The 1-month interest rate of U.S. dollar is the 1-month interest rate in the certificate deposit secondary market of the U.S. The 1 month interest rate of Australian dollar is 1-month inter-bank interest rate in Australia. The 1-month interest rate of Canadian dollar is the 1-month interest rate of Treasury Bills of Canada. The 1-month interest rate of British pound is the 1-month inter-bank interest rate of the United Kingdom. The 1-month interest rate of Japanese Yen is the 1-month inter-bank interest rate in Japan. The 1-month interest rate of Norwegian Krone is the 1-month inter-bank interest rate in Norway. Though some of them are slightly different, all of them represent the risk-free and highly liquid interest rate. Since they are annualized interest rates, in the regression of this paper all of them are divided by 12 in order to reflect the monthly interest returns of each currency.

Figure 1: Scatter Diagram of $\Delta \ln s_{i,t}$ and $\Delta(r^*_i - r)_{t-1}$, Jan 1998 – Dec 2001

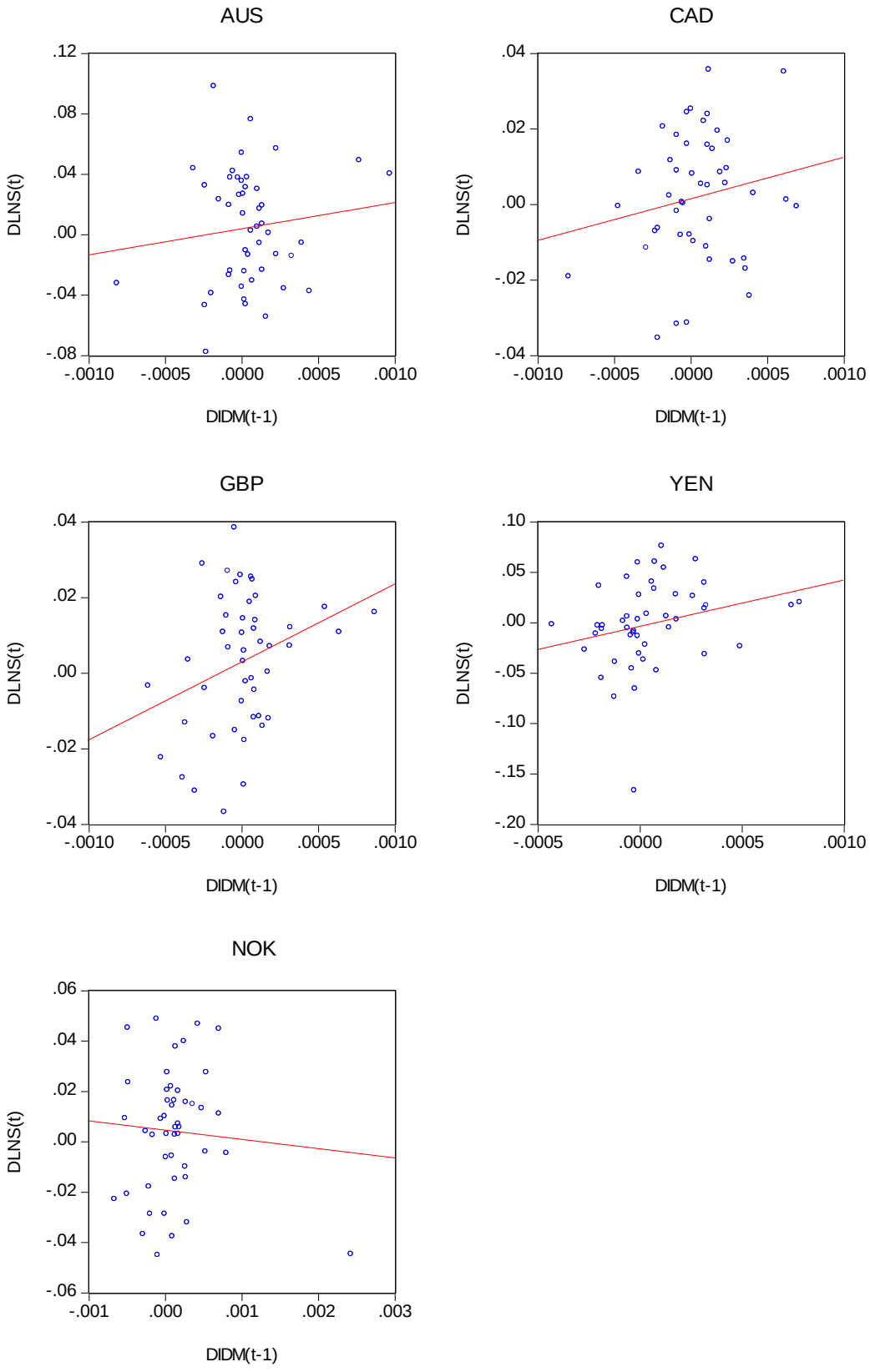


Figure 2: Scatter Diagram of $\Delta \ln s_{i,t}$ and $\Delta(r^*_i - r)_{t-1}$, Jan 2002 – Dec 2005

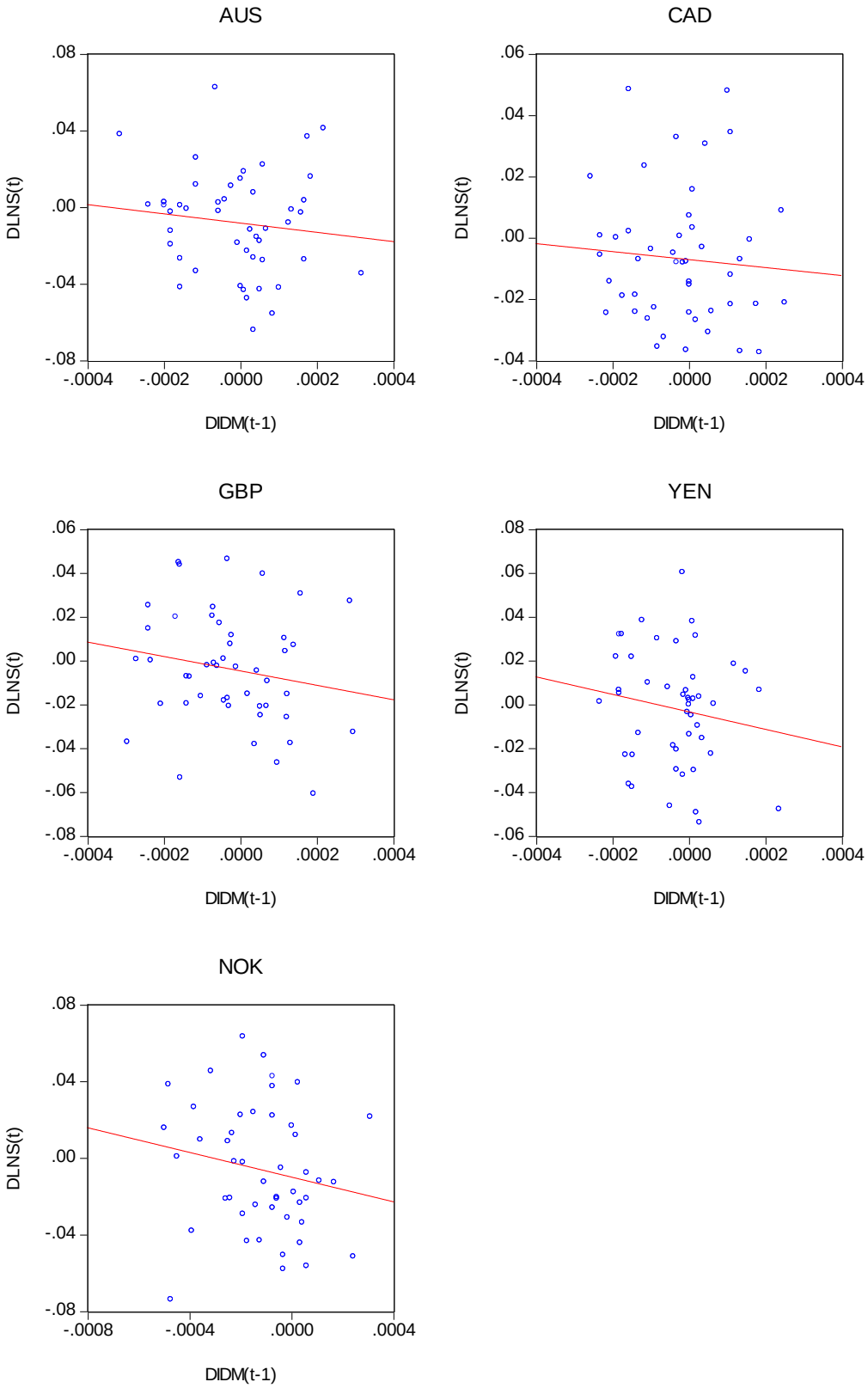
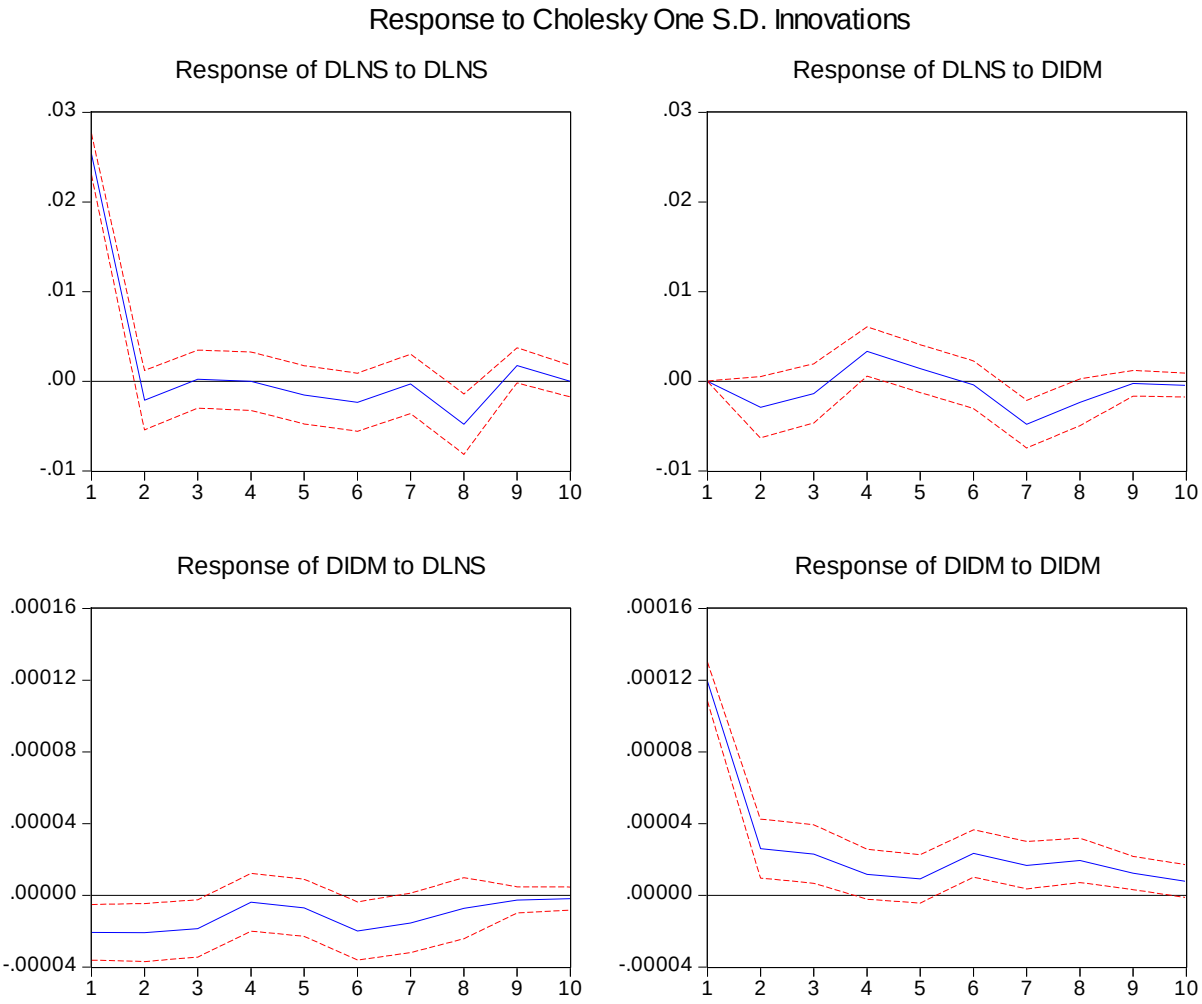


Figure 3: Impulse response in terms of 1 standard deviation, 2002-2005



Abbreviations:

DLNS - $\Delta \ln s$ DLNS(-x) - $\Delta \ln s_{t-x}$

DIDM - $\Delta(r^*_i - r)$ DIDM(-x) - $\Delta(r^*_i - r)_{t-x}$