科技部補助專題研究計畫成果報告
期末報告

近似無關分量迴歸

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處 理 方 式 ：
1.公開資訊：本計畫可公開查詢
2.「本研究」是否已有嚴重損及公共利益之發現：否
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中 文 摘 要 ： 考量外匯市場的通貨彼此有同期相關，本研究計劃使用分量迴歸方法，結合近似不相關迴歸模型，用以分析遠期匯率不偏性假說。本研究計劃有二大貢獻，第一，提出一個結合分量迴歸及近似不相關迴歸模型的新估計方式，且由本計劃的蒙地卡羅模擬可知，本計劃所提的方法的小樣本表現良好，因此未來將可應用到多種議題。第二，本計劃的國際金融實證發現遠期匯率是即期匯率的偏誤估計式，而且此偏誤會隨著即期匯率的變化程度而有不同，故支持 Huisman et al (1998)的分析。

中文關鍵詞： 遠期匯率，即期匯率，分量迴歸，近似不相關迴歸模型

英 文 摘 要 ：

英文關鍵詞：

1 Introduction

Is the forward exchange rate a good predictor of the future spot exchange rate? When the foreign exchange market is efficient, following the argument of Fama (1970), the forward exchange rate should be an unbiased predictor of the future spot exchange rate. The resulting theory is the "forward rate unbiasedness hypothesis" from Levich (1979). The hypothesis is an important issue in the field of international finance. Many researchers are devoted to test this hypothesis. For example, the studies of Cornell (1977), Levich (1979) and Frankel (1980) support the hypothesis. More recent contributions to the linterature include Cornell (1989), Bilson (1981), Fama (1984), Froot and Frankel (1989), Lewis (1989), Froot (1990), Engel (1996) and Campbell et al. (2007), among others. They find the forward exchange rate to be a biased predictor of the future spot exchange rate. In addition, since the foreign exchange markets are subject to common external shocks, a contemporaneous correlation between currencies is inevitable. Thus, the seemingly unrelated regression (SUR) model is used to test the validity of the forward rate unbiasedness hypothesis (Bailey et al, 1984; Chiang, 1988; Doroodian and Albarano, 1998; Frankel and Poonawala, 2010).

Moreover, it is noted that the bias of forward exchange rate depends on the amount of the future change in the spot exchange rate. Huisman et al (1998) find that the bias is small in large change of spot exchange rate and is large in small change of spot exchange rate. Lobo and Tufe (1998) argue that the exchange rates are dynamic correlated and are asymmetry. Rogoff (1977), Hansen and Hodric (1980) and Frankel (1980) point out that exchange rates are non-normal distribution. According to these characteristics, the quantile regression method, instead of the ordinary least square technique, should be considered when testing the forward rate unbiasedness hypothesis. Therefore, a feasible method of quantile regression for the SUR model is needed. To the best of our knowledge, Jun and Pinkse (2009) is the only theoretical research on quantile regression for SUR model. Jun and Pinkse (2009), following Zhao's (2001) weighted quantile regression, propose an efficient semiparametric estimator of a multivariate linear regression model. They show that the proposed estimator is asymptotical and they obtain good simulation results. However, since Jun and Pinkse (2009) use the nonparametric estimating method, it is difficult to apply their method for large number of equations. For example, Jun and Pinkse (2009) do not even provide simulation results in their paper for number of equation larger than 3. In the empirical research of forward rate unbiasedness hypothesis, the number of currencies used are large, which makes the method of Jun and Pinkse (2009) not feasible. Therefore, one motivation of this paper is to propose an alternative on quantile regression for SUR model and apply the proposed method to test the forward rate unbiasedness hypothesis.

In this paper, we propose a quantile regression method for SUR model. The Monte Carlo simulation is provided to show that the proposed method has better small sample performances. We then apply the proposed method to investigate the forward rate unbiasedness hypothesis. Our empirical results show that the forward exchange rate is biased and the bias depends on the amount of the future change in the spot exchange rate. When the amount of the future change in the spot exchange is large, the biased is small and vice versa. Our empirical results are consistent with those in Huisman et al (1998).

The remainder of this paper is organized as follows. Section 2 provides the literature review. The econometric methodology are presented in Section 3. In Section 4, I discuss the empirical study of the paper. Section 5 concludes the paper.

2 Literature review

Forward rate unbiasedness hypothesis, proposed by Levich (1979), is one of the fundamental theoretical building blocks for understanding the behavior of spot exchange rate in foreign exchange markets. Forward rate unbiasedness hypothesis implies that the forward exchange rate is an unbiased predictor of the future spot exchange rate. Cornell (1977), Levich (1979), and Frankel (1980) regress spot exchange rate on forward exchange rate and their results support the hypothesis. However, the empirical studies of Bilson (1981), Fama (1984), and Froot and Frankel (1989) reject the hypothesis. Various researches have been proposed for this rejection, such as Froot and Frankel (1989), Lewis (1989, 1995), Engel (1996) and Campbell et al. (2007). Froot and Frankel (1989), Lewis (1989), and Campbell et al. (2007) argue that the foreign exchange market is not efficient because invests do not have rational expectations. Most traders are risk aversion within the market, and there exists risk premium, e.g. Fama (1984), Engel (1996b).

Since the foreign exchange markets are subject to common external shocks, the SUR model is used to test the validity of the forward rate unbiasedness hypothesis. Bailey et al. (1984) use weekly data of spot and 3–day forward exchange rates of the UK pound, Germany mark, Italian lira, and French franc to test the hypothesis and their results reject the hypothesis. Chiang (1988) uses monthly data of spot and 30-day forward exchange rates of the Canadian dollar, French franc, Germany mark and UK pound to test the hypothesis and the results support the hypothesis. Doroodian and Albarano (1998) use monthly data of spot and forward exchange rates of the Canadian dollar, French franc, Germany mark and Swiss Franc, and show the exchange markets are inefficient.

Most studies of forward rate unbiasedness hypothesis focus on advanced market currencies and find that the coefficient of forward exchange rate is biased and negative. Frankel and Poonawala (2010) first test for bias in the forward markets in emerging market currencies, and to see how the bias compares to that for major currencies. Frankel and Poonawala (2010) use monthly data of spot and 1-month forward exchange rates of 21 advanced country currencies and 14 emerging country currencies. Their results reject the hypothesis and the bias of advanced market currencies are larger than that of emerging market currencies.

In the existing literature, the ordinary least square method is used for the SUR model on the forward rate unbiasedness hypothesis. However, in foreign exchange markets, it may occur peso problem. In an open environment, the expected impact of catastrophic events will be further spread and strengthened. People will expect depreciation in the future because overvalue the currency, making the expected depreciation to be self-realization. Thus, the change of exchange rates is not normal distributed. Rogoff (1977), Hansen and Hodric (1980) and Frankel (1980) point out that exchange rates are non-normal distribution. In addition, Lobo and Tufe (1998) argue that the exchange rates are dynamic correlated and are asymmetry. Huisman et al. (1998) find that the bias is small in large change of spot exchange rate and is large in small change of spot exchange rate. According to these characteristics, the quantile regression method, instead of the ordinary least square technique, should be considered when testing the forward rate unbiasedness hypothesis.

3 Seemingly Unrelated Quantile Regression

3.1 Model and estimation

The ordinary SUR model is to stack the data and to estimate parameters by generalized least square estimation. Following this procedure, we stack data to construct a SUR model and then estimate the model by quantile regression. The resulting estimation method is called "stacking quantile regression". For example, consider two regression equations as follows.

$$y_t = x_t^{'}\beta_0 + \varepsilon_t, \quad Q(\varepsilon_t|x_t) = 0, \quad t = 1, \ldots, T,$$

where $Q(\cdot|\cdot)$ is the conditional quantile function,

$$y_t = \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix}_{2\times 1}, \quad x_t = \begin{bmatrix} x_{1t} & 0 \\ 0 & x_{2t} \end{bmatrix}_{K\times 2}, \quad \beta_0 = \begin{bmatrix} \beta_{01} \\ \beta_{02} \end{bmatrix}_{K\times 1}.$$

Or equivalently,

$$y_{it} = x_{it}^{'}\beta_{0i} + \varepsilon_{it}, \quad i = 1, 2; \; t = 1, \cdots, T,$$

where $y_t \in R^2$, $x_t \in R^{K\times 2}$, β_o is a vector of parameters, and K is total number of unknown regression coefficients. This paper suggests using the quantile regression technique to estimate the stacked data to obtain the parameters of interest.

In this paper, we provide some preliminary simulation results to show that the proposed method is feasible. In our Monte Carlo simulation, we compare three estimators: the stacking quantile regression of this paper, the weighted quantile regression of Zhao (2001), and the estimator of Jun and Pinkse (2009). The estimating procedure of Jun and Pinkse (2009) is in the following:

Step1 Run regression for each equation uses quantile regression:

$$\hat{\beta}_1 = \arg\min_{\beta_1} \sum_{\{t: y_{1t} \geq x_{1t}^{'}\beta_1\}} \tau|y_{1t} - x_{1t}^{'}\beta_1| + \sum_{\{t: y_{1t} < x_{1t}^{'}\beta_1\}} (1-\tau)|y_{1t} - x_{1t}^{'}\beta_1|,$$

$$\hat{\beta}_2 = \arg\min_{\beta_2} \sum_{\{t: y_{2t} \geq x_{2t}^{'}\beta_2\}} \tau|y_{2t} - x_{2t}^{'}\beta_2| + \sum_{\{t: y_{2t} < x_{2t}^{'}\beta_2\}} (1-\tau)|y_{2t} - x_{2t}^{'}\beta_2|.$$

Save the residuals $\hat{\varepsilon}_{1t}$ and $\hat{\varepsilon}_{2t}$.

Step2 Suppose that w_{td} are the k-nearest neighbor (KNN) weights, satisfying

$$\sum_{d=1}^{T} w_{td} = 1, \quad w_{tt} = 0, \quad w_{td} \geq 0, \quad t, d = 1, 2, \cdots, T.$$

The kernel density estimator of ε_t at zero is defined as

$$\hat{F}_t = \begin{bmatrix} I_{\{|\hat{\varepsilon}_{1t}| \leq \theta_T \iota\}}/(2\theta_T) & 0 \\ 0 & I_{\{|\hat{\varepsilon}_{2t}| \leq \theta_T \iota\}}/(2\theta_T) \end{bmatrix},$$

where ι is a vector of ones, and θ_T is a bandwidth parameter. Then, we can obtain

$$\hat{S}_t = \sum_{d=1}^{T} w_{td} \hat{F}_d x_t^{'}.$$

Step3 Compute

$$\hat{G}_t = \sum_{d=1}^{T} w_{td} \hat{s}_d \hat{s}_d^{'},$$

with $\hat{s}_t = I_{\{\hat{\varepsilon}_t \leq 0\}} - \tau$. Then, we obtain $\hat{A}_t = \hat{S}_t^{'} \hat{G}_t^{-1}$.

Step4 Use linear programming technique to solve the following moment condition:

$$\frac{1}{T} \sum_{t=1}^{T} \hat{A}_t (I_{\{y_t \leq x_t^{'} \beta\}} - \tau) = 0.$$

Finally the estimator $\hat{\hat{\beta}}$ is obtained by Newton step.

3.2 Monte Carlo Simulation

The data generating process of our experiment follows Jun and Pinkse (2009):

$$y_{it} = \beta_{i0} + \beta_{i1} x_{it1} + \beta_{i2} x_{it2} + \varepsilon_{it},\ i = 1, 2, \cdots, N, \quad t = 1, 2, \cdots, T,$$

where T is the sample size, N is the total number of equations, and $\beta_i = [\beta_{i0}\ \beta_{i1}\ \beta_{i2}]^{'} = [10\ -4\ 2]^{'}$. In addition, the regressors $x_{it1,z}$, $x_{it2,z}$ and $\varepsilon_{it,z}$ are generated using the following design:

$$x_{it1,z} = N_{it,z} + 0.2 U_{it,z}, \quad x_{it2,z} = 0.2 N_{it,z} + U_{it,z}, \quad \varepsilon_{it,z} = h_{i,z}(X_{t,z}) e_{it,z},$$

where $N_{it,z} \sim N(5, 9)$, $U_{it,z} \sim U(0, 4)$. In the homoskedastic experiments we set $h_{i,z} = 1$ and the heteroskedastic form used is

$$h_{i1,z}(X_{t,z}) = exp(|x_{t1,z}^{'} \beta_1 + x_{t2,z}^{'} \beta_2 + x_{t3,z}^{'} \beta_3|/10),$$
$$h_{i2,z}(X_{t,z}) = 1 + 3exp(-(x_{t1,z}^{'} \beta_1 + x_{t2,z}^{'} \beta_2 + x_{t3,z}^{'} \beta_3 + 10)^2/100),$$

where $x_{it,z} = [1\ x_{it1,z}\ x_{it2,z}]^{'}$. The number of replication is 1000. We calculate bias and root mean squared error (RMSE) for the three estimators. We list all the simulation results in the Appendix and provide more explanations in the future version of this paper.

4 Empirical Study

4.1 Data and Empirical Models

The data used in the paper is based on those in Frankel and Poonawala (2010). There are 10 advanced market currencies, including the Australian dollar, Canadian dollar, Danish krone, Euro, Japanese yen, New Zealand dollar, Norwegian krone, Swedish Krona, Swiss franc and UK pound. Also, there are 14 emerging market currencies, including the Czechoslovakia koruna, Hong Kong dollar, Hungarian forint, Indian rupee, Indonesia rupiah, Kuwaiti dinar, Mexican peso, Philippine peso, Saudi Arabian riyal, Singapore dollar, South African rand, Taiwan dollar, Thai baht and Turkish@lira. The monthly data of spot and 1-month forward exchange rate are collected over the period of December 31, 1998 to March 29, 2013, and from the Datastream.

Table 13 and Table 14 present descriptive statistics of our data. To test the normality of future change of currencies, we use Jarque-Bera test and the results are shown in Table 15. This table shows that most of the future change in the spot exchange rate of each currency is right-skewed and heavy-tailed. Therefore, the quantile regression should be considered to fully describe the distribution of future change in the spot exchange rate. In addition, the daily data are also considered. Table 16 and Table 17 present descriptive statistics and Table 18 show the results of Jarque-Bera test.

Our empirical study is based on the following model:

$$s_{t+1} - s_t = \alpha + \beta(f_t - s_t) + \varepsilon_{t+1},$$

where s_t is log of the spot exchange rate at time t, f_t is log of the forward exchange rate at time t, $s_{t+1} - s_t$ is the future change in the spot exchange rate, $f_t - s_t$ is the forward premium. The null hypothesis of unbiasedness is $\beta = 1$. The stacking quantile regression is applied to test this hypothesis.

4.2 Empirical Results

Figure 1 shows the average of $\hat{\beta}(\tau)$ for advanced and emerging market currencies under different quantiles. From Figure 1 we can see that the coefficients are smaller in absolute values in emerging countries than those in advanced market. The results are consistent with Frankel and Poonawala (2010) where they show a larger bias in

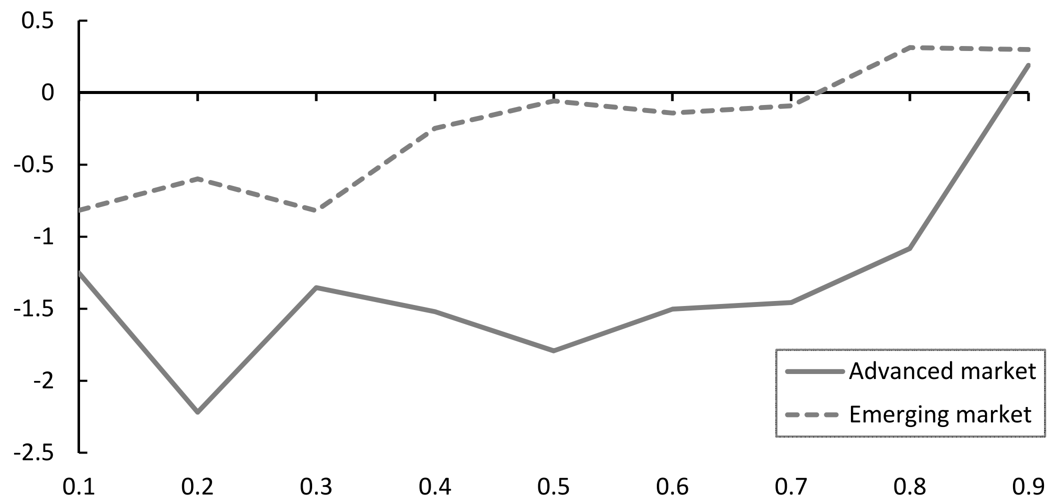

Figure 1: Spot on forward regression–monthly data

advanced market than in emerging market. In addition, the bias decreases along with quantiles in absolute value; which shows that the forward exchange rate is biased and the bias depends on the amount of the future change in the spot exchange rate. When the amount of the future change in the spot exchange is large, the bias is small and vice versa. Our empirical results are consistent with those in Huisman et al (1998). The empirical result of daily data are presented in Figure 2. We have similar conclusion for daily data.

5 Conclusions

In this paper, we propose a quantile regression method for SUR model. The Monte Carlo simulation is provided to show that the proposed method has better small sample performances. The empirical results show that a larger bias in advanced market than in emerging market, which is consistent with Frankel and Poonawala (2010). In addition, we also show that, when the amount of the future change in the spot exchange is large, the bias is small and vice versa. Our results do not support

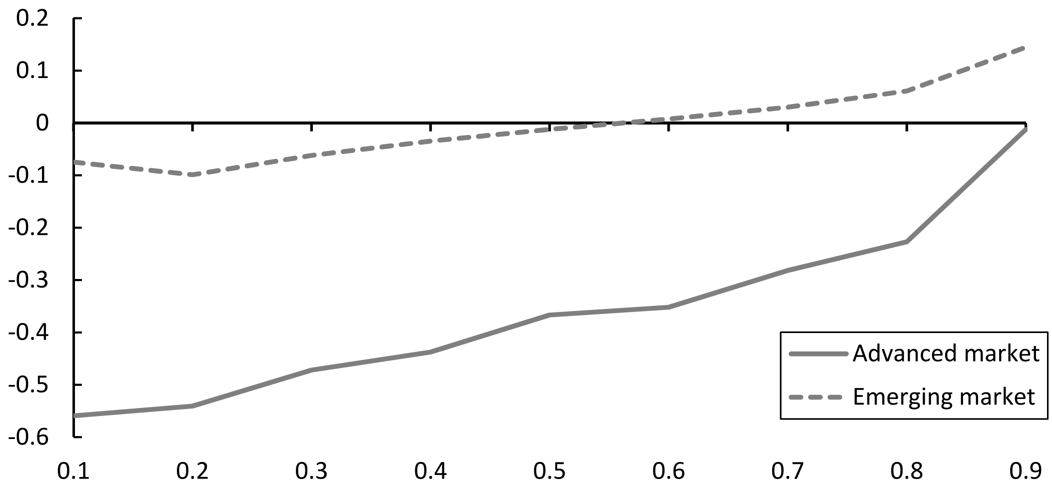

Figure 2: Spot on forward regression–daily data

the "forward rate unbiasedness hypothesis" and is consistent with Huisman et al (1998).

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Appendix

Table 1: Bias and RMSE for different sample size with homoskedasticity

	$i=1$	$\tau=0.1$		$\tau=0.5$		$\tau=0.9$	
	T	100	500	100	500	100	500
Weighted quantile regression							
$\hat{\beta}_1$	Bias	-0.0036	0.0001	-0.0016	0.0000	0.0006	-0.0010
	RMSE	0.0597	0.0255	0.0426	0.0190	0.0601	0.0263
$\hat{\beta}_2$	Bias	0.0054	0.0002	-0.0001	0.0007	-0.0012	-0.0004
	RMSE	0.1353	0.0566	0.0990	0.0435	0.1337	0.0590
Stacking quantile regression							
$\hat{\beta}_1$	Bias	-0.0029	0.0000	-0.0017	0.0000	0.0009	-0.0010
	RMSE	0.0586	0.0256	0.0423	0.0190	0.0598	0.0262
$\hat{\beta}_2$	Bias	0.0056	0.0003	0.0002	0.0007	-0.0010	-0.0006
	RMSE	0.1344	0.0562	0.0983	0.0435	0.1318	0.0588
Jun and Pinkse (2009)							
$\hat{\beta}_1$	Bias	-0.0014	-0.0002	-0.0018	0.0001	0.0003	-0.0011
	RMSE	0.0609	0.0260	0.0431	0.0191	0.0630	0.0265
$\hat{\beta}_2$	Bias	0.0071	0.0003	-0.0010	0.0003	-0.0014	-0.0004
	RMSE	0.1401	0.0578	0.0994	0.0437	0.1372	0.0599
	$i=2$	$\tau=0.1$		$\tau=0.5$		$\tau=0.9$	
	T	100	500	100	500	100	500
Weighted quantile regression							
$\hat{\beta}_1$	Bias	0.0001	0.0012	-0.0013	0.0006	-0.0016	0.0001
	RMSE	0.0600	0.0250	0.0438	0.0191	0.0603	0.0255
$\hat{\beta}_2$	Bias	0.0034	0.0003	-0.0009	0.0008	0.0050	0.0014
	RMSE	0.1376	0.0585	0.1007	0.0427	0.1408	0.0616
Stacking quantile regression							
$\hat{\beta}_1$	Bias	0.0000	0.0012	-0.0017	0.0006	-0.0019	0.0001
	RMSE	0.0593	0.0246	0.0438	0.0190	0.0586	0.0255
$\hat{\beta}_2$	Bias	0.0027	0.0001	-0.0001	0.0009	0.0055	0.0012
	RMSE	0.1353	0.0582	0.0991	0.0425	0.1384	0.0613
Jun and Pinkse (2009)							
$\hat{\beta}_1$	Bias	-0.0003	0.0014	-0.0012	-0.0010	-0.0011	0.0002
	RMSE	0.0618	0.0252	0.0442	0.0542	0.0608	0.0259
$\hat{\beta}_2$	Bias	0.0046	0.0006	-0.0000	-0.0000	0.0027	0.0013
	RMSE	0.1415	0.0585	0.1012	0.0583	0.1441	0.0628

Notes: $e_{it} \sim N(0,1)$, $\rho = 0$, replication=1000.

Table 2: Bias and RMSE for different error distribution with homoskedasticity

	$i=1$	$\tau=0.1$			$\tau=0.5$			$\tau=0.9$		
	e_{it}	$N(0,3)$	χ^2_3	$U(0,1)$	$N(0,3)$	χ^2_3	$U(0,1)$	$N(0,3)$	χ^2_3	$U(0,1)$
Weighted quantile regression										
$\hat{\beta}_1$	Bias	-0.0063	-0.0006	-0.0000	-0.0007	0.0055	0.0007	0.0009	-0.0096	0.0003
	RMSE	0.1034	0.0446	0.0106	0.0744	0.0853	0.0164	0.1004	0.2362	0.0104
$\hat{\beta}_2$	Bias	0.0093	-0.0009	-0.0010	0.0087	-0.0060	-0.0003	0.0078	-0.0022	-0.0010
	RMSE	0.2343	0.1068	0.0245	0.1755	0.2092	0.0390	0.2407	0.5139	0.0231
Stacking quantile regression										
$\hat{\beta}_1$	Bias	-0.0050	-0.0006	-0.0000	-0.0007	0.0045	0.0006	0.0006	-0.0055	0.0004
	RMSE	0.1015	0.0441	0.0105	0.0738	0.0855	0.0163	0.0995	0.2343	0.0103
$\hat{\beta}_2$	Bias	0.0097	0.0005	-0.0012	0.0072	-0.0065	-0.0003	0.0070	0.0009	-0.0010
	RMSE	0.2329	0.1043	0.0243	0.1727	0.2082	0.0385	0.2405	0.5127	0.0230
Jun and Pinkse (2009)										
$\hat{\beta}_1$	Bias	-0.0025	-0.0011	-0.0000	-0.0005	0.0046	0.0006	-0.0006	-0.0105	0.0003
	RMSE	0.1054	0.0464	0.0111	0.0757	0.0865	0.0166	0.1039	0.2420	0.0111
$\hat{\beta}_2$	Bias	0.0123	-0.0019	-0.0009	0.0067	-0.0066	-0.0004	0.0082	-0.0051	-0.0010
	RMSE	0.2427	0.1119	0.0255	0.1765	0.2105	0.0397	0.2466	0.5403	0.0249
	$i=2$	$\tau=0.1$			$\tau=0.5$			$\tau=0.9$		
	e_{it}	$N(0,3)$	χ^2_3	$U(0,1)$	$N(0,3)$	χ^2_3	$U(0,1)$	$N(0,3)$	χ^2_3	$U(0,1)$
Weighted quantile regression										
$\hat{\beta}_1$	Bias	0.0002	-0.0015	0.0000	-0.0003	-0.0049	0.0008	-0.0013	0.0015	-0.0006
	RMSE	0.1039	0.0477	0.0102	0.0763	0.0876	0.0165	0.0995	0.2228	0.0108
$\hat{\beta}_2$	Bias	0.0059	0.0034	0.0003	-0.0004	0.0052	0.0000	-0.0170	0.0145	0.0003
	RMSE	0.2383	0.1056	0.0239	0.1732	0.2073	0.0380	0.2330	0.5432	0.0236
Stacking quantile regression										
$\hat{\beta}_1$	Bias	0.0001	-0.0014	0.0000	-0.0003	-0.0045	0.0008	-0.0005	0.0037	-0.0005
	RMSE	0.1027	0.0479	0.0101	0.0752	0.0876	0.0164	0.0988	0.2208	0.0105
$\hat{\beta}_2$	Bias	0.0047	0.0033	0.0002	-0.0015	0.0075	0.0000	-0.0157	0.0141	0.0003
	RMSE	0.2344	0.1054	0.0239	0.1708	0.2062	0.0375	0.2315	0.5321	0.0233
Jun and Pinkse (2009)										
$\hat{\beta}_1$	Bias	-0.0006	-0.0026	-0.0001	-0.0014	-0.0045	0.0006	0.0004	0.0045	-0.0004
	RMSE	0.1070	0.0526	0.0107	0.0762	0.0894	0.0169	0.1025	0.2341	0.0112
$\hat{\beta}_2$	Bias	0.0077	0.0021	0.0005	0.0015	0.0040	-0.0000	-0.0191	0.0038	0.0001
	RMSE	0.2455	0.1169	0.0255	0.1730	0.2089	0.0381	0.2442	0.5614	0.0254

Notes: $T=100$, $\rho=0$, replication=1000.

Table 3: Bias and RMSE for different error correlation with homoskedasticity

	$i=1$	$\tau=0.1$			$\tau=0.5$			$\tau=0.9$		
	ρ	0.1	0.5	0.9	0.1	0.5	0.9	0.1	0.5	0.9
Weighted quantile regression										
$\hat{\beta}_1$	Bias	0.0027	-0.0003	0.0012	0.0003	0.0030	0.0030	0.0000	0.0023	0.0010
	RMSE	0.0613	0.0556	0.0584	0.0423	0.0430	0.0430	0.0591	0.0615	0.0593
$\hat{\beta}_2$	Bias	0.0018	0.0020	-0.0035	0.0020	-0.0015	-0.0015	0.0006	0.0006	-0.0006
	RMSE	0.1379	0.1368	0.1371	0.1016	0.0990	0.0990	0.1331	0.1372	0.1367
Stacking quantile regression										
$\hat{\beta}_1$	Bias	0.0027	-0.0002	0.0014	-0.0002	0.0028	0.0028	-0.0001	0.0020	0.0013
	RMSE	0.0607	0.0556	0.0571	0.0423	0.0427	0.0427	0.0585	0.0598	0.0578
$\hat{\beta}_2$	Bias	0.0026	0.0010	-0.0032	0.0016	-0.0020	-0.0020	0.0001	-0.0003	-0.0001
	RMSE	0.1348	0.1338	0.1351	0.1009	0.0974	0.0974	0.1321	0.1358	0.1349
Jun and Pinkse (2009)										
$\hat{\beta}_1$	Bias	0.0024	-0.0006	0.0038	-0.0000	0.0024	0.0018	0.0008	-0.0008	0.0010
	RMSE	0.0633	0.0574	0.0541	0.0426	0.0405	0.0317	0.0606	0.0624	0.0537
$\hat{\beta}_2$	Bias	0.0025	0.0042	-0.0031	0.0012	-0.0028	-0.0026	0.0013	0.0049	0.0017
	RMSE	0.1444	0.1396	0.1251	0.1037	0.0959	0.0733	0.1401	0.1381	0.1245

	$i=2$	$\tau=0.1$			$\tau=0.5$			$\tau=0.9$		
	ρ	0.1	0.5	0.9	0.1	0.5	0.9	0.1	0.5	0.9
Weighted quantile regression										
$\hat{\beta}_1$	Bias	-0.0019	-0.0003	-0.0007	-0.0016	-0.0020	-0.0007	0.0003	-0.0018	0.0017
	RMSE	0.0593	0.0587	0.0585	0.0428	0.0425	0.0447	0.0601	0.0588	0.0605
$\hat{\beta}_2$	Bias	0.0073	0.0068	-0.0011	0.0060	-0.0009	0.0032	-0.0068	0.0013	0.0040
	RMSE	0.1341	0.1383	0.1388	0.0981	0.0976	0.0985	0.1313	0.1376	0.1349
Stacking quantile regression										
$\hat{\beta}_1$	Bias	-0.0017	-0.0006	-0.0004	-0.0014	-0.0021	-0.0006	0.0003	-0.0019	0.0018
	RMSE	0.0582	0.0585	0.0570	0.0422	0.0426	0.0442	0.0588	0.0585	0.0595
$\hat{\beta}_2$	Bias	0.0081	0.0052	-0.0023	0.0052	-0.0012	0.0022	-0.0071	0.0027	0.0044
	RMSE	0.1330	0.1363	0.1362	0.0974	0.0958	0.0974	0.1295	0.1364	0.1335
Jun and Pinkse (2009)										
$\hat{\beta}_1$	Bias	-0.0008	-0.0009	0.0005	-0.0010	-0.0023	-0.0015	0.0008	-0.0006	-0.0006
	RMSE	0.0604	0.0619	0.0531	0.0431	0.0407	0.0322	0.0616	0.0606	0.0523
$\hat{\beta}_2$	Bias	0.0087	0.0049	0.0031	0.0053	-0.0013	-0.0019	-0.0059	0.0002	0.0008
	RMSE	0.1405	0.1369	0.1212	0.1000	0.0946	0.0729	0.1359	0.1430	0.1202

Notes: $T=100$, $(e_{1t}, e_{2t}) \sim BN(0,0,1,1,\rho)$, replication=1000.

Table 4: Bias and RMSE for different sample size with heteroskedasticity

	$i=1$	$\tau=0.1$		$\tau=0.5$		$\tau=0.9$	
	T	100	500	100	500	100	500
Weighted quantile regression							
$\hat{\beta}_1$	Bias	-1.1977	-0.9784	0.0198	-0.0003	1.1954	0.9917
	RMSE	1.5308	1.0345	0.2135	0.0847	1.5108	1.0489
$\hat{\beta}_2$	Bias	0.5778	0.4380	-0.0073	0.0002	-0.4334	-0.4156
	RMSE	2.0535	0.8928	0.3269	0.1302	2.0456	0.8760
Stacking quantile regression							
$\hat{\beta}_1$	Bias	-1.8793	-1.7471	0.0154	-0.0013	1.8847	1.7818
	RMSE	2.3091	1.8120	0.2255	0.0958	2.3023	1.8480
$\hat{\beta}_2$	Bias	1.0065	0.9287	-0.0171	0.0015	-0.9898	-0.9121
	RMSE	2.6784	1.3307	0.3446	0.1373	2.3032	1.2923
Jun and Pinkse (2009)							
$\hat{\beta}_1$	Bias	-0.6831	-0.5912	0.0166	-0.0098	0.6993	0.5740
	RMSE	0.9306	0.6375	0.2167	0.3063	0.9333	0.6210
$\hat{\beta}_2$	Bias	0.4397	0.3124	-0.0179	0.0876	-0.3661	-0.2982
	RMSE	1.4003	0.5611	0.3385	0.2717	1.3149	0.5573
	$i=2$	$\tau=0.1$		$\tau=0.5$		$\tau=0.9$	
	T	100	500	100	500	100	500
Weighted quantile regression							
$\hat{\beta}_1$	Bias	0.0298	0.0398	-0.0013	-0.0010	-0.0326	-0.0423
	RMSE	0.1888	0.1030	0.0574	0.0249	0.1916	0.1038
$\hat{\beta}_2$	Bias	0.0377	-0.0224	0.0036	-0.0008	0.0166	0.0136
	RMSE	0.3857	0.1910	0.1612	0.0716	0.3785	0.1819
Stacking quantile regression							
$\hat{\beta}_1$	Bias	0.0277	0.0356	-0.0015	-0.0012	-0.0297	-0.0369
	RMSE	0.1786	0.0936	0.0575	0.0250	0.1814	0.0930
$\hat{\beta}_2$	Bias	-0.0396	-0.0190	0.0035	-0.0010	0.0085	0.0108
	RMSE	0.3800	0.1939	0.1603	0.0725	0.3773	0.1823
Jun and Pinkse (2009)							
$\hat{\beta}_1$	Bias	0.0074	0.0035	-0.0016	-0.0031	-0.0081	-0.0041
	RMSE	0.1912	0.0975	0.0581	0.0612	0.1965	0.1000
$\hat{\beta}_2$	Bias	-0.0320	-0.0045	0.0028	-0.0004	-0.0010	-0.0037
	RMSE	0.3797	0.1820	0.1614	0.0760	0.3812	0.1735

Notes: The heteroskedastic form for $i=1$ is $h_1(X_t)=exp(|x_{t1}^{'}\beta_1+x_{t2}^{'}\beta_2|/10)$. The heteroskedastic form for $i=2$ is $h_2(X_t)=1+3exp(-(x_{t1}^{'}\beta_1+x_{t2}^{'}\beta_2+10)^2/100)$. $e_{it}\sim N(0,1)$, $\rho=0$, replication=1000.

Table 5: Bias and RMSE for different error distribution with heteroskedasticity

	$i=1$	$\tau=0.1$			$\tau=0.5$			$\tau=0.9$		
	e_{it}	$N(0,3)$	χ^2_3	$U(0,1)$	$N(0,3)$	χ^2_3	$U(0,1)$	$N(0,3)$	χ^2_3	$U(0,1)$
Weighted quantile regression										
$\hat{\beta}_1$	Bias	-2.0745	0.1020	0.0185	-0.0045	0.8667	0.1504	1.9924	10.0146	1.7349
	RMSE	2.6514	0.2320	0.0467	0.3757	1.0589	0.1848	2.4885	11.2324	1.9330
$\hat{\beta}_2$	Bias	1.0008	-0.0548	-0.0157	0.0367	-0.0049	-0.0725	-0.9236	-4.0179	-0.7684
	RMSE	3.5568	0.3645	0.0777	0.5722	1.2673	0.2036	3.4217	12.7989	2.1770
Stacking quantile regression										
$\hat{\beta}_1$	Bias	-3.2550	0.3198	0.0563	0.0104	2.0084	0.3784	3.2230	13.7380	2.4019
	RMSE	3.9995	0.4063	0.0737	0.4124	2.1994	0.4138	3.9199	15.5850	2.7168
$\hat{\beta}_2$	Bias	1.7433	-0.1496	-0.0297	0.0104	-0.9800	-0.1846	-1.8316	-6.4192	-1.1273
	RMSE	4.6391	0.4280	0.0869	0.6177	1.7651	0.3099	4.6092	15.8461	2.7815
Jun and Pinkse (2009)										
$\hat{\beta}_1$	Bias	-1.1832	0.4739	0.0747	0.0088	1.7295	0.3245	1.1428	5.6706	0.9667
	RMSE	1.6118	0.6057	0.0997	0.3910	1.9137	0.3563	1.5475	6.6785	1.1215
$\hat{\beta}_2$	Bias	0.7616	-0.2318	-0.0383	0.0291	-0.8214	-0.1492	-0.5264	-2.7015	-0.4820
	RMSE	2.4254	0.5368	0.1050	0.5927	1.5812	0.2701	2.2712	8.4454	1.3061
	$i=2$	$\tau=0.1$			$\tau=0.5$			$\tau=0.9$		
	e_{it}	$N(0,3)$	χ^2_3	$U(0,1)$	$N(0,3)$	χ^2_3	$U(0,1)$	$N(0,3)$	χ^2_3	$U(0,1)$
Weighted quantile regression										
$\hat{\beta}_1$	Bias	0.0516	-0.0096	-0.0016	-0.0019	-0.0342	-0.0071	-0.0488	-0.2406	-0.0299
	RMSE	0.3270	0.0677	0.0145	0.1046	0.1928	0.0271	0.3245	0.9004	0.1227
$\hat{\beta}_2$	Bias	-0.0652	-0.0078	0.0017	-0.0035	0.0345	0.0071	-0.0007	0.0178	0.0075
	RMSE	0.6681	0.1723	0.0396	0.2801	0.4318	0.0679	0.7017	1.6350	0.2079
Stacking quantile regression										
$\hat{\beta}_1$	Bias	0.0479	-0.0088	-0.0015	-0.0008	-0.0310	-0.0065	-0.0487	-0.2265	-0.0271
	RMSE	0.3093	0.0670	0.0146	0.1045	0.1840	0.0256	0.3107	0.8288	0.1093
$\hat{\beta}_2$	Bias	-0.0686	0.0054	0.0013	-0.0032	0.0336	0.0074	-0.0041	0.0128	0.0052
	RMSE	0.6581	0.1727	0.0389	0.2807	0.4255	0.0686	0.7003	1.6474	0.2030
Jun and Pinkse (2009)										
$\hat{\beta}_1$	Bias	0.0129	-0.0083	-0.0016	-0.0034	0.0533	0.0073	-0.0075	-0.0589	0.0069
	RMSE	0.3312	0.0740	0.0159	0.1042	0.2040	0.0291	0.3372	0.8783	0.1167
$\hat{\beta}_2$	Bias	-0.0555	-0.0068	0.0017	-0.0000	-0.0146	-0.0015	-0.0372	-0.0600	-0.0078
	RMSE	0.6577	0.1921	0.0426	0.2815	0.4342	0.0662	0.6836	1.6591	0.2031

Notes: The heteroskedastic form for $i=1$ is $h_1(X_t) = exp(|x'_{t1}\beta_1 + x'_{t2}\beta_2|/10)$. The heteroskedastic form for $i=2$ is $h_2(X_t) = 1 + 3exp(-(x'_{t1}\beta_1 + x'_{t2}\beta_2 + 10)^2/100)$. $T=100$, $\rho=0$, replication=1000.

Table 6: Bias and RMSE for different error correlation with heteroskedasticity

	$i=1$	$\tau=0.1$			$\tau=0.5$			$\tau=0.9$		
	ρ	0.1	0.5	0.9	0.1	0.5	0.9	0.1	0.5	0.9
Weighted quantile regression										
$\hat{\beta}_1$	Bias	-1.1485	-1.1675	-1.1485	0.0084	-0.0015	-0.0010	1.2058	1.1418	1.2040
	RMSE	1.4757	1.4982	1.4757	0.2076	0.2037	0.2148	1.5131	1.4671	1.5109
$\hat{\beta}_2$	Bias	0.5221	0.5214	0.5221	0.0019	0.0204	-0.0051	-0.5666	-0.4597	-0.4482
	RMSE	1.9686	1.9796	1.9686	0.3199	0.3284	0.3318	1.9733	1.9941	1.8870
Stacking quantile regression										
$\hat{\beta}_1$	Bias	-1.8772	-1.8286	-1.8772	0.0026	0.0033	0.0021	1.9096	1.8413	1.9597
	RMSE	2.3258	2.2469	2.3258	0.2306	0.2348	0.2374	2.3137	2.2439	2.3762
$\hat{\beta}_2$	Bias	0.9840	0.9594	0.9840	-0.0004	0.0028	0.0007	-1.0196	-0.8523	-0.9668
	RMSE	2.5722	2.6336	2.5722	0.3372	0.3586	0.3497	2.5876	2.6251	2.5684
Jun and Pinkse (2009)										
$\hat{\beta}_1$	Bias	-0.6652	-0.6611	-0.6833	0.0039	0.0042	0.0041	0.7357	0.6759	0.6768
	RMSE	0.9118	0.9190	0.9300	0.2210	0.2131	0.1797	0.9712	0.9192	0.9601
$\hat{\beta}_2$	Bias	0.3726	0.3076	0.3877	0.0030	0.0037	0.0028	-0.3841	-0.3085	-0.4004
	RMSE	1.3694	1.3052	1.3743	0.3302	0.3341	0.2615	1.3574	1.2810	1.3289
	$i=2$	$\tau=0.1$			$\tau=0.5$			$\tau=0.9$		
	ρ	0.1	0.5	0.9	0.1	0.5	0.9	0.1	0.5	0.9
Weighted quantile regression										
$\hat{\beta}_1$	Bias	0.0150	0.0336	0.0141	-0.0009	-0.0019	0.0056	-0.0322	-0.0346	-0.0305
	RMSE	0.1975	0.1902	0.1900	0.0592	0.0609	0.0564	0.1982	0.1857	0.1858
$\hat{\beta}_2$	Bias	-0.0116	-0.0048	0.0109	0.0008	0.0123	-0.0052	0.0022	-0.0023	0.0111
	RMSE	0.3778	0.3773	0.3951	0.1691	0.1636	0.1584	0.4074	0.3892	0.3847
Stacking quantile regression										
$\hat{\beta}_1$	Bias	0.0144	0.0324	0.0139	-0.0008	-0.0026	0.0056	-0.0290	-0.0324	-0.0284
	RMSE	0.1834	0.1809	0.1794	0.0595	0.0607	0.0568	0.1864	0.1753	0.1762
$\hat{\beta}_2$	Bias	-0.0137	-0.0024	0.0138	0.0006	0.0109	-0.0059	-0.0018	0.0021	0.0088
	RMSE	0.3773	0.3820	0.3983	0.1718	0.1626	0.1576	0.4077	0.3882	0.3903
Jun and Pinkse (2009)										
$\hat{\beta}_1$	Bias	-0.0008	0.0301	0.0300	-0.0009	-0.0023	0.0056	-0.0094	-0.0302	-0.0472
	RMSE	0.2029	0.1970	0.2073	0.0609	0.0585	0.0497	0.1981	0.1962	0.2034
$\hat{\beta}_2$	Bias	0.0114	-0.0145	0.0052	0.0003	0.0110	-0.0047	-0.0078	0.0026	0.0137
	RMSE	0.3792	0.3817	0.3993	0.1717	0.1580	0.1266	0.4048	0.3852	0.3809

Notes: The heteroskedastic form for $i=1$ is $h_1(X_t) = exp(|x_{t1}^{'}\beta_1 + x_{t2}^{'}\beta_2|/10)$. The heteroskedastic form for $i=2$ is $h_2(X_t) = 1 + 3exp(-(x_{t1}^{'}\beta_1 + x_{t2}^{'}\beta_2 + 10)^2/100)$. $T=100$, $(e_{1t}, e_{2t}) \sim BN(0,0,1,1,\rho)$, replication=1000.

Table 7: Bias and RMSE in the SUR model with three equations

		Homoskedasticity		Heteroskedasticity 1		Heteroskedasticity 2	
	T	100	500	100	500	100	500
$i = 1$							
$\hat{\beta}_1$	Bias	0.0004	0.0001	0.0067	-0.0016	0.0004	-0.0000
	RMSE	0.0433	0.0180	0.3020	0.1007	0.0576	0.0237
$\hat{\beta}_2$	Bias	-0.0006	0.0007	0.0124	0.0039	-0.0021	0.0023
	RMSE	0.0972	0.0433	0.4544	0.1786	0.1445	0.0637
$i = 2$							
$\hat{\beta}_1$	Bias	0.0006	0.0001	0.0153	-0.0012	-0.0004	0.0003
	RMSE	0.0417	0.0190	0.2748	0.1060	0.0565	0.0252
$\hat{\beta}_2$	Bias	-0.0013	-0.0002	0.0207	-0.0019	-0.0007	-0.0003
	RMSE	0.0960	0.0428	0.4860	0.1821	0.1403	0.0634
$i = 3$							
$\hat{\beta}_1$	Bias	-0.0035	0.0008	0.0079	0.0043	-0.0053	0.0010
	RMSE	0.0433	0.0188	0.2885	0.1122	0.0590	0.0248
$\hat{\beta}_2$	Bias	-0.0028	-0.0006	-0.0025	0.0032	-0.0064	-0.0017
	RMSE	0.0959	0.0424	0.4718	0.1836	0.1425	0.0611

Notes: $e_{it} \sim N(0,1)$, $\tau = 0.5$, $\rho = 0$, replication=1000.

Table 8: Bias and RMSE for different error distribution for three equations on RDQR

		Homoskedasticity			Heteroskedasticity 1			Heteroskedasticity 2		
	e_{it}	$N(0,3)$	χ^2_3	$U(0,1)$	$N(0,3)$	χ^2_3	$U(0,1)$	$N(0,3)$	χ^2_3	$U(0,1)$
$i = 1$										
$\hat{\beta}_1$	Bias	-0.0010	0.0017	-0.0001	-0.0158	3.6987	0.6649	-0.0016	-0.0898	-0.0156
	RMSE	0.0716	0.0862	0.0155	0.4811	4.1105	0.7307	0.0961	0.1771	0.0276
$\hat{\beta}_2$	Bias	0.0125	-0.0037	0.0014	0.0511	-1.9517	-0.3461	0.0188	0.0425	0.0105
	RMSE	0.1736	0.2086	0.0374	0.8073	3.4659	0.6208	0.2641	0.3712	0.0585
$i = 2$										
$\hat{\beta}_1$	Bias	0.0028	0.0034	-0.0009	0.0220	3.9043	0.6941	0.0027	-0.0985	-0.0158
	RMSE	0.0729	0.0896	0.0162	0.4779	4.3211	0.7690	0.0990	0.1812	0.0271
$\hat{\beta}_2$	Bias	-0.0071	0.0001	-0.0008	-0.0469	-2.0155	-0.3430	-0.0088	0.0522	0.0094
	RMSE	0.1691	0.2050	0.0389	0.8186	3.4652	0.6069	0.2476	0.3916	0.0558
$i = 3$										
$\hat{\beta}_1$	Bias	0.0025	0.0017	0.0006	0.0144	3.7128	0.6821	0.0009	-0.1027	-0.0162
	RMSE	0.0761	0.0871	0.0159	0.5293	4.1513	0.7548	0.1009	0.1842	0.0285
$\hat{\beta}_2$	Bias	0.0003	0.0101	-0.0001	-0.0241	-1.8736	-0.3454	0.0007	0.0334	0.0068
	RMSE	0.1637	0.2092	0.0360	0.8375	3.4150	0.6299	0.2430	0.3709	0.0550

Notes: $T = 100$, $\tau = 0.5$, $\rho = 0$, replication=1000.

Table 9: Bias and RMSE for different error correlation for three equations on RDQR

		Homoskedasticity			Heteroskedasticity 1			Heteroskedasticity 2		
	ρ	0.1	0.5	0.9	0.1	0.5	0.9	0.1	0.5	0.9
$i = 1$										
$\hat{\beta}_1$	Bias	-0.0006	-0.0006	0.0019	0.0036	0.0030	0.0085	-0.0009	0.0013	0.0018
	RMSE	0.0414	0.0414	0.0421	0.2827	0.2893	0.2913	0.0555	0.0582	0.0570
$\hat{\beta}_2$	Bias	0.0072	0.0072	0.0003	0.0019	-0.0117	-0.0020	0.0109	-0.0001	0.0012
	RMSE	0.1002	0.1002	0.0979	0.4783	0.4727	0.4654	0.1525	0.1477	0.1453
$i = 2$										
$\hat{\beta}_1$	Bias	0.0009	0.0017	-0.0003	0.0013	0.0030	0.0058	0.0014	-0.0021	-0.0007
	RMSE	0.0421	0.0425	0.0409	0.2882	0.2826	0.2716	0.0577	0.0563	0.0544
$\hat{\beta}_2$	Bias	-0.0044	-0.0071	-0.0014	-0.0044	-0.0484	-0.0187	-0.0052	-0.0039	-0.0027
	RMSE	0.0988	0.0943	0.0929	0.4692	0.4726	0.4684	0.1427	0.1468	0.1390
$i = 3$										
$\hat{\beta}_1$	Bias	0.0003	0.0018	0.0000	-0.0292	-0.0108	0.0091	0.0003	-0.0034	0.0004
	RMSE	0.0432	0.0418	0.0429	0.2941	0.2859	0.2725	0.0582	0.0584	0.0575
$\hat{\beta}_2$	Bias	-0.0011	-0.0014	-0.0022	0.0511	-0.0212	-0.0234	-0.0021	0.0142	-0.0016
	RMSE	0.0948	0.0970	0.0959	0.4707	0.4708	0.4824	0.1407	0.1476	0.1423

Notes: $T = 100$, $\tau = 0.5$, $(e_{1t}, e_{2t}) \sim BN(0, 0, 1, 1, \rho)$, replication=1000.

Table 10: Bias and RMSE for different sample size for five equations on RDQR

		Homoskedasticity		Heteroskedasticity 1		Heteroskedasticity 2	
	T	100	500	100	500	100	500
$i = 1$							
$\hat{\beta}_1$	Bias	-0.0011	-0.0005	0.0023	0.0047	-0.0011	-0.0013
	RMSE	0.0412	0.0185	0.4909	0.1457	0.0537	0.0235
$\hat{\beta}_2$	Bias	0.0067	0.0005	-0.0106	-0.0083	0.0044	-0.0028
	RMSE	0.0955	0.0424	0.8265	0.2793	0.1243	0.0564
$i = 2$							
$\hat{\beta}_1$	Bias	0.0023	-0.0000	0.0062	0.0036	0.0025	0.0000
	RMSE	0.0443	0.0186	0.4708	0.1520	0.0533	0.0236
$\hat{\beta}_2$	Bias	0.0007	-0.0007	-0.0044	0.0016	-0.0018	0.0031
	RMSE	0.0984	0.0431	0.8226	0.2725	0.1267	0.0578
$i = 3$							
$\hat{\beta}_1$	Bias	-0.0014	-0.0009	-0.0462	0.0020	0.0004	0.0008
	RMSE	0.0424	0.0192	0.5005	0.1523	0.0524	0.0228
$\hat{\beta}_2$	Bias	-0.0051	0.0004	0.0247	-0.0027	-0.0063	-0.0012
	RMSE	0.1016	0.0452	0.8649	0.2809	0.1275	0.0567
$i = 4$							
$\hat{\beta}_1$	Bias	-0.0005	0.0002	0.0222	0.0042	0.0021	0.0004
	RMSE	0.0441	0.0182	0.4918	0.1577	0.0560	0.0238
$\hat{\beta}_2$	Bias	-0.0005	0.0016	0.0014	-0.0035	0.0013	-0.0014
	RMSE	0.0995	0.0434	0.9038	0.2813	0.1285	0.0572
$i = 5$							
$\hat{\beta}_1$	Bias	-0.0010	-0.0006	-0.0278	-0.0023	-0.0014	-0.0016
	RMSE	0.0418	0.0188	0.5047	0.1545	0.0527	0.0237
$\hat{\beta}_2$	Bias	-0.0033	0.0002	0.0347	-0.0068	0.0033	0.0010
	RMSE	0.0976	0.0418	0.8402	0.2773	0.1301	0.0544

Notes: $e_{it} \sim N(0,1)$, $\tau = 0.5$, $\rho = 0$, replication=1000.

Table 11: Bias and RMSE for different error distribution for five equations on RDQR

		Homoskedasticity			Heteroskedasticity 1			Heteroskedasticity 2		
	e_{it}	$N(0,3)$	χ_3^2	$U(0,1)$	$N(0,3)$	χ_3^2	$U(0,1)$	$N(0,3)$	χ_3^2	$U(0,1)$
$i=1$										
$\hat{\beta}_1$	Bias	-0.0018	0.0020	-0.0007	0.0023	12.0246	2.2043	-0.0024	-0.0897	-0.0157
	RMSE	0.0711	0.0846	0.0164	0.8721	13.8380	2.5299	0.0895	0.1610	0.0255
$\hat{\beta}_2$	Bias	-0.0010	-0.0024	-0.0010	0.0371	-5.5198	-1.0310	0.0016	0.0411	0.0097
	RMSE	0.1713	0.2035	0.0362	1.5737	12.3472	2.1311	0.2176	0.3151	0.0488
$i=2$										
$\hat{\beta}_1$	Bias	0.0000	-0.0019	-0.0003	0.0058	12.4915	2.1290	0.0001	-0.0930	-0.0153
	RMSE	0.0726	0.0859	0.0162	0.9033	14.5672	2.4466	0.0908	0.1606	0.0258
$\hat{\beta}_2$	Bias	-0.0045	-0.0054	0.0025	0.1412	-5.9430	-1.1250	-0.0069	0.0386	0.0051
	RMSE	0.1656	0.2112	0.0366	1.5777	12.1974	2.1772	0.2121	0.3180	0.0487
$i=3$										
$\hat{\beta}_1$	Bias	-0.0000	-0.0023	-0.0003	-0.0071	12.3931	2.1597	-0.0002	-0.0896	-0.0160
	RMSE	0.0731	0.0920	0.0160	0.9092	14.3181	2.4882	0.0925	0.1601	0.0258
$\hat{\beta}_2$	Bias	0.0023	-0.0101	0.0005	-0.0267	-6.3941	-0.9930	0.0029	0.0715	0.0085
	RMSE	0.1720	0.2006	0.0375	1.4581	12.5587	2.1182	0.2195	0.3039	0.0485
$i=4$										
$\hat{\beta}_1$	Bias	-0.0031	-0.0028	0.0005	-0.0200	12.5119	2.1433	-0.0030	-0.0888	-0.0146
	RMSE	0.0746	0.0908	0.0167	0.8823	14.4012	2.4677	0.0935	0.1582	0.0248
$\hat{\beta}_2$	Bias	0.0040	0.0092	0.0001	-0.0253	-6.1826	-1.0128	0.0020	0.0359	0.0075
	RMSE	0.1703	0.2017	0.0370	1.5708	12.5563	2.1759	0.2215	0.2998	0.0494
$i=5$										
$\hat{\beta}_1$	Bias	0.0035	-0.0001	-0.0005	0.0165	12.5495	2.1569	0.0046	-0.0882	-0.0141
	RMSE	0.0750	0.0882	0.0161	0.8363	14.6029	2.5037	0.0948	0.1528	0.0247
$\hat{\beta}_2$	Bias	0.0045	0.0023	0.0005	0.0119	-6.5410	-1.1390	0.0049	0.0386	0.0112
	RMSE	0.1653	0.2008	0.0389	1.5814	13.0492	2.2205	0.2185	0.3045	0.0485

Notes: $T = 100$, $\tau = 0.5$, $\rho = 0$, replication=1000.

Table 12: Bias and RMSE for different error correlation for five equations on RDQR

		Homoskedasticity			Heteroskedasticity 1			Heteroskedasticity 2		
	ρ	0.1	0.5	0.9	0.1	0.5	0.9	0.1	0.5	0.9
$i=1$										
$\hat{\beta}_1$	Bias	-0.0010	0.0010	0.0010	0.0067	0.0208	0.0142	-0.0014	0.0009	0.0011
	RMSE	0.0410	0.0423	0.0439	0.5057	0.5004	0.4837	0.0517	0.0529	0.0537
$\hat{\beta}_2$	Bias	-0.0006	0.0026	-0.0006	0.0441	0.0296	0.0002	0.0009	0.0044	0.0019
	RMSE	0.0989	0.0959	0.0973	0.9156	0.9036	0.8421	0.1256	0.1181	0.1309
$i=2$										
$\hat{\beta}_1$	Bias	-0.0002	0.0013	0.0026	-0.0180	0.0126	0.0108	-0.0008	0.0020	0.0010
	RMSE	0.0416	0.0412	0.0433	0.5265	0.4914	0.4701	0.0524	0.0527	0.0546
$\hat{\beta}_2$	Bias	-0.0026	0.0041	0.0003	-0.0285	-0.0102	0.0088	-0.0032	0.0053	-0.0065
	RMSE	0.0963	0.0996	0.0960	0.8761	0.8523	0.8783	0.1231	0.1290	0.1255
$i=3$										
$\hat{\beta}_1$	Bias	0.0001	0.0009	-0.0014	-0.0190	0.0166	-0.0270	-0.0003	0.0009	0.0022
	RMSE	0.0424	0.0439	0.0432	0.5202	0.4726	0.4792	0.0533	0.0567	0.0545
$\hat{\beta}_2$	Bias	0.0007	-0.0019	-0.0010	0.0173	0.0373	0.0088	0.0010	-0.0028	0.0001
	RMSE	0.0989	0.0964	0.0978	0.9377	0.8027	0.8340	0.1265	0.1234	0.1268
$i=4$										
$\hat{\beta}_1$	Bias	-0.0015	-0.0007	0.0004	-0.0231	0.0386	0.0073	-0.0022	-0.0004	-0.0002
	RMSE	0.0429	0.0427	0.0412	0.5027	0.4863	0.4478	0.0542	0.0536	0.0550
$\hat{\beta}_2$	Bias	-0.0000	-0.0044	0.0118	0.0134	-0.0294	0.0614	-0.0005	-0.0052	-0.0057
	RMSE	0.0957	0.0990	0.0975	0.9288	0.8726	0.8323	0.1250	0.1269	0.1251
$i=5$										
$\hat{\beta}_1$	Bias	0.0022	-0.0002	-0.0004	0.0103	-0.0175	0.0072	0.0032	-0.0005	-0.0017
	RMSE	0.0435	0.0422	0.0419	0.5410	0.5075	0.4957	0.0547	0.0537	0.0539
$\hat{\beta}_2$	Bias	0.0038	0.0041	0.0013	0.0006	0.0218	-0.0336	0.0039	0.0063	-0.0013
	RMSE	0.1011	0.0970	0.1013	0.8823	0.8300	0.7983	0.1263	0.1271	0.1226

Notes: $T = 100$, $\tau = 0.5$, $(e_{1t}, e_{2t}) \sim BN(0, 0, 1, 1, \rho)$, replication=1000.

Table 13: Descriptive statistics

	Mean	First quartile	Median	Third quartile	Standard deviation	Minimum	Maximum
Australian dollar							
spot	1.3712	1.1093	1.3187	1.5783	0.3132	0.9104	2.0479
forward	1.3735	1.1160	1.3220	1.5765	0.3127	0.9136	2.0500
Canadian dollar							
spot	1.2420	1.0329	1.1886	1.4739	0.2144	0.9489	1.6045
forward	1.2422	1.0334	1.1887	1.4734	0.2145	0.9495	1.6048
Danish krone							
spot	6.3021	5.5300	5.9073	6.9995	1.0884	4.7063	8.7967
forward	6.3015	5.5260	5.9081	6.9867	1.0885	4.7113	8.8041
Euro							
spot	0.8464	0.7430	0.7931	0.9421	0.1464	0.6311	1.1812
forward	0.8462	0.7425	0.7926	0.9400	0.1464	0.6317	1.1819
Japanese yen							
spot	105.4624	93.2675	109.1525	118.0700	15.0360	76.2500	133.8250
forward	105.2136	93.2523	108.7489	117.5664	14.9069	76.2271	133.6140
New Zealand dollar							
spot	1.6433	1.3511	1.4954	1.9099	0.3811	1.1444	2.5195
forward	1.6466	1.3556	1.4967	1.9082	0.3806	1.1424	2.5116
Norwegian krone							
spot	6.7982	5.8801	6.5109	7.5328	1.1740	5.0818	9.3665
forward	6.8063	5.8890	6.5101	7.5576	1.1788	5.0948	9.3902
Swedish Krona							
spot	7.7756	6.8325	7.4840	8.4900	1.2481	5.9300	10.8854
forward	7.7753	6.8233	7.4887	8.4835	1.2480	5.9388	10.8892
Swiss franc							
spot	1.2611	1.0503	1.2322	1.4782	0.2608	0.7882	1.7981
forward	1.2592	1.0500	1.2280	1.4752	0.2598	0.7878	1.7966
UK pound							
spot	0.6059	0.5520	0.6195	0.6430	0.0616	0.4814	0.7110
forward	0.6063	0.5535	0.6199	0.6439	0.0615	0.4818	0.7118
Czechoslovakia koruna							
spot	25.4086	19.0382	22.8309	30.9600	7.4921	15.1721	41.1380
forward	25.4122	19.0466	22.7918	30.9932	7.5019	15.1896	41.0910
Hong Kong dollar							
spot	7.7788	7.7582	7.7789	7.7991	0.0205	7.7438	7.8263
forward	7.7763	7.7568	7.7754	7.7972	0.0197	7.7408	7.8183

Table 14: Descriptive statistics@(continued)

	Mean	First quartile	Median	Third quartile	Standard deviation	Minimum	Maximum
Hungarian forint							
spot	220.8675	195.1490	216.2053	238.9750	35.6554	149.0466	310.6299
forward	221.9705	195.8940	217.1385	240.7950	35.9471	149.7766	312.0149
Indian rupee							
spot	46.1539	43.8400	45.9175	47.9400	3.4378	39.3235	56.1575
forward	46.3113	43.8994	46.0763	48.1031	3.4995	39.3835	56.5025
Indonesia rupiah							
spot	9497.5760	8824.2500	9133.2500	9521.2500	857.3468	6825.0000	12025.0000
forward	9421.0920	9108.7500	9745.0000	9745.0000	778.3940	6860.5000	12195.0000
Kuwaiti dinar							
spot	0.2915	0.2818	0.2920	0.3020	0.0117	0.2650	0.3085
forward	0.2916	0.2818	0.2920	0.3022	0.0117	0.2646	0.3084
Mexican peso							
spot	11.1604	9.9500	10.9645	12.3386	1.4259	9.0128	15.0812
forward	11.2188	10.1074	11.0003	12.3685	1.4157	9.0608	15.1862
Philipine peso							
spot	47.8223	43.1250	47.8475	52.4250	5.3911	37.9750	56.3300
forward	47.9819	43.2030	47.9873	52.6540	5.4483	38.1485	56.6920
Saudi Arabian riyal							
spot	3.7501	3.7502	3.7503	3.7505	0.0030	3.7150	3.7610
forward	3.7503	3.7499	3.7505	3.7515	0.0043	3.7050	3.7615
Singapore dollar							
spot	1.5593	1.3983	1.6220	1.7250	0.1926	1.2023	1.8465
forward	1.5576	1.3986	1.6205	1.7221	0.1917	1.2021	1.8460
South African rand							
spot	7.5523	6.6650	7.3038	8.0545	1.2791	5.6338	11.9950
forward	7.5954	6.6949	7.3582	8.1115	1.2950	5.6595	12.0800
Taiwan dollar							
spot	32.2387	31.0400	32.3885	33.3525	1.6929	28.6385	35.1050
forward	32.2025	30.9900	32.3485	33.3360	1.7034	28.6330	35.1690
Thai baht							
spot	37.0654	33.1300	37.5150	41.1675	4.6760	29.2850	45.7000
forward	37.1051	33.1485	37.5625	41.1925	4.6811	29.3405	45.8500
Turkish@lira							
spot	1.3366	1.2774	1.4308	1.5704	0.3860	0.3154	1.8886
forward	1.3224	1.2224	1.4482	1.5850	0.4123	0.3396	1.9019

Table 15: The normality test of future change in the spot exchange rate

Currencies	Skewness	Kurtosis	J-B	Currencies	Skewness	Kurtosis	J-B
Australian dollar	0.8071	5.6374	68.1248***	Hungarian forint	1.0904	6.2294	108.1913***
Canadian dollar	0.7185	7.0825	133.4633***	Indian rupee	0.2803	5.9100	62.5741***
Danish krone	0.1606	3.7663	4.9191*	Indonesia rupiah	-0.7640	8.8201	257.9872***
Euro	0.1687	3.7493	4.8119*	Kuwaiti dinar	1.5351	17.0912	1481.915***
Japanese yen	0.2598	3.2408	2.3374	Mexican peso	1.0996	7.2913	165.6672***
New Zealand dollar	0.5008	4.8157	30.6374***	Philipine peso	0.9358	6.5089	112.6827***
Norwegian krone	0.5021	4.3095	19.4022***	Saudi Arabian riyal	3.0610	65.3975	28007.8400***
Swedish Krona	0.1393	3.4662	2.1019	Singapore dollar	0.8212	6.2256	93.3510***
Swiss franc	-0.1353	4.6977	21.0583***	South African rand	0.5615	3.7348	12.8334***
UK pound	0.4159	4.5760	22.6257***	Taiwan dollar	0.0038	4.0598	8.0028**
Czechoslovakia koruna	0.4011	3.4786	6.2155**	Thai baht	0.1764	4.1431	10.1963***
Hong Kong dollar	-1.0816	10.3988	423.3821***	Turkish@lira	2.0430	14.3612	1038.6280***

Notes: J-B is the statistic of Jarque-Bera normality test. *, ** and *** indicate the significant leves of 10%, 5% and 1% respectively.

Table 16: Descriptive statistics–daily data

	Mean	First quartile	Median	Third quartile	Standard deviation	Minimum	Maximum
Australian dollar							
spot	1.3683	1.1027	1.3225	1.5691	0.3085	0.9066	2.0648
forward	1.3708	1.1065	1.3240	1.5698	0.3080	0.9114	2.0710
Canadian dollar							
spot	1.2404	1.0289	1.1894	1.4727	0.2130	0.9161	1.6155
forward	1.2406	1.0293	1.1889	1.4725	0.2130	0.9161	1.6159
Danish krone							
spot	6.3039	5.5459	5.9166	6.9962	1.0773	4.6702	8.9828
forward	6.3034	5.5420	5.9129	6.9914	1.0774	4.6753	8.9742
Euro							
spot	0.8466	0.7446	0.7944	0.9410	0.1449	0.6258	1.2067
forward	0.8464	0.7442	0.7941	0.9396	0.1448	0.6266	1.2051
Japanese yen							
spot	105.4834	93.1050	108.4150	117.8050	14.9203	75.7600	134.8300
forward	105.2402	93.0801	108.0755	117.4260	14.7920	75.7329	134.6417
New Zealand dollar							
spot	1.6394	1.3454	1.4975	1.8932	0.3744	1.1429	2.5400
forward	1.6427	1.3487	1.5014	1.8941	0.3740	1.1424	2.5526
Norwegian krone							
spot	6.7969	5.8752	6.5073	7.5305	1.1596	4.9584	9.5675
forward	6.8051	5.8820	6.5060	7.5617	1.1643	4.9733	9.5731
Swedish Krona							
spot	7.7726	6.8315	7.4775	8.4400	1.2288	5.8486	11.0318
forward	7.7744	6.8319	7.4515	8.3470	1.2338	5.9556	11.0718
Swiss franc							
spot	1.2608	1.0520	1.2338	1.4723	0.2579	0.7275	1.8090
forward	1.2589	1.0516	1.2308	1.4700	0.2570	0.7265	1.8174
UK pound							
spot	0.6067	0.5520	0.6196	0.6462	0.0613	0.4743	0.7316
forward	0.6072	0.5530	0.6198	0.6466	0.0612	0.4748	0.7320
Czechoslovakia koruna							
spot	25.3739	19.1077	22.9496	31.0475	7.4557	14.4979	42.0380
forward	25.3778	19.1170	22.9196	31.0825	7.4654	14.5149	41.9930
Hong Kong dollar							
spot	7.7797	7.7592	7.7811	7.7993	0.0207	7.7098	7.8294
forward	7.7772	7.7577	7.7772	7.7976	0.0199	7.7033	7.8220
Hungarian forint							
spot	221.0492	195.4264	216.2077	238.0915	35.1216	144.2562	317.1250
forward	222.1533	196.1369	217.1289	239.5915	35.4051	144.9563	318.5549

Table 17: Descriptive statistics–daily data (continued)

	Mean	First quartile	Median	Third quartile	Standard deviation	Minimum	Maximum
Indian rupee							
spot	46.1923	43.8450	45.8100	47.9800	3.4490	39.2700	57.1862
forward	46.3518	43.9050	45.9225	48.1810	3.5112	39.3137	57.5662
Indonesia rupiah							
spot	9196.5420	8850.0000	9140.0000	9490.0000	844.7454	6575.0000	12150.0000
forward	9420.4410	9110.5000	9745.0000	9745.0000	763.5583	6665.0000	12360.0000
Kuwaiti dinar							
spot	0.2914	0.2821	0.2920	0.3021	0.0116	0.2644	0.3089
forward	0.2915	0.2822	0.2919	0.3023	0.0116	0.2643	0.3089
Mexican peso							
spot	11.1533	9.9650	10.9445	12.3810	1.4100	8.9280	15.3835
forward	11.2105	10.0764	10.9770	12.4089	1.3999	9.0045	15.4938
Philipine peso							
spot	47.7928	43.1850	47.6800	52.3750	5.3529	37.5500	56.4600
forward	47.9502	43.2750	47.8290	52.6060	5.4086	37.7415	56.8380
Saudi Arabian riyal							
spot	3.7502	3.7502	3.7503	3.7505	0.0024	3.7110	3.7650
forward	3.7504	3.7498	3.7505	3.7514	0.0033	3.7015	3.7676
Singapore dollar							
spot	1.5590	1.3944	1.6214	1.7234	0.1914	1.2008	1.8536
forward	1.5574	1.3943	1.6197	1.7203	0.1906	1.2004	1.8532
South African rand							
spot	7.5917	6.6858	7.3350	8.1010	1.2935	5.6208	13.4700
forward	7.6351	6.7171	7.3734	8.1586	1.3102	5.6488	13.5650
Taiwan dollar							
spot	32.2366	30.9615	32.3945	33.4000	1.6857	28.5100	35.1800
forward	32.2043	30.8970	32.3545	33.4050	1.6945	28.5040	35.2850
Thai baht							
spot	37.0210	33.0000	37.4750	41.0695	4.6844	28.6150	45.8000
forward	37.0589	33.0495	37.5225	41.0900	4.6870	28.6725	46.1250
Turkish@lira							
spot	1.3436	1.2848	1.4315	1.5714	0.3831	0.3154	1.9181
forward	1.3268	1.2357	1.4447	1.5829	0.4104	0.3374	1.9304

Table 18: The normality test of future change in the spot exchange rate–daily data

Currencies	Skewness	Kurtosis	J-B	Currencies	Skewness	Kurtosis	J-B
Australian dollar	0.4081	2.1147	225.9162***	Hungarian forint	0.5948	2.8227	225.3814***
Canadian dollar	0.2961	1.5662	374.8991***	Indian rupee	0.7239	3.8335	434.7692***
Danish krone	0.8348	2.5450	466.5587***	Indonesia rupiah	0.3634	5.1192	781.9446***
Euro	0.8262	2.5268	460.2508***	Kuwaiti dinar	-0.2894	2.2267	145.3651***
Japanese yen	-0.4771	2.1231	261.6328***	Mexican peso	0.3963	2.2228	191.9617***
New Zealand dollar	0.8063	2.4624	450.1979***	Philipine peso	0.0131	1.7783	232.6352***
Norwegian krone	0.7150	2.4534	365.1591***	Saudi Arabian riyal	-8.5340	134.2793	2730340***
Swedish Krona	0.8410	2.8546	444.0083***	Singapore dollar	-0.3945	1.7823	327.9775***
Swiss franc	0.3559	2.1335	195.9192***	South African rand	1.1781	4.2100	1093.0010***
UK pound	-0.2714	2.0785	178.2072***	Taiwan dollar	-0.3025	2.2332	148.6346***
Czechoslovakia koruna	0.6420	2.0443	399.1380***	Thai baht	0.0277	1.7372	248.8927***
Hong Kong dollar	-0.0964	1.7289	257.5064***	Turkish@lira	-1.2280	3.7110	1018.4720***

Notes: J-B is the statistic of Jarque-Bera normality test. *, ** and *** indicate the significant leves of 10%, 5% and 1% respectively.

科技部補助計畫衍生研發成果推廣資料表

日期:2015/10/22

<table>
<tr><td rowspan="3">科技部補助計畫</td><td>計畫名稱: 近似無關分量迴歸</td></tr>
<tr><td>計畫主持人: 林馨怡</td></tr>
<tr><td>計畫編號: 103-2410-H-004-014- 學門領域: 數理與數量方法</td></tr>
<tr><td colspan="2">無研發成果推廣資料</td></tr>
</table>

103年度專題研究計畫研究成果彙整表

計畫主持人：林馨怡			計畫編號：103-2410-H-004-014-				
計畫名稱：近似無關分量迴歸							
成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數（含實際已達成數）	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	1	1	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	1	1	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	1	1	100%		
國外	論文著作	期刊論文	0	1	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
其他成果（無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。）		無。					

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

科技部補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

   ■達成目標

   □未達成目標（請說明，以100字為限）

   　　□實驗失敗

   　　□因故實驗中斷

   　　□其他原因

   說明：

2. 研究成果在學術期刊發表或申請專利等情形：

   論文：□已發表 □未發表之文稿 ■撰寫中 □無

   專利：□已獲得 □申請中 ■無

   技轉：□已技轉 □洽談中 ■無

   其他：（以100字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以500字為限）

   本研究計劃提出之方法可以應用到各種總體或產業實證。另外，本計劃對遠期外匯不偏性假說此一議題的實證研究，提供更完整的分析。