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Has the Accumulation of Foreign Reserves Protect the Thai Economy from Financial Crisis? : An Approach of Empirical Likelihood

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Abstract: In this article, we analyzed the effect of the accumulation of foreign reserves to economic growth in Thailand. In order to estimate of this impact, we employed a kink regression model which has an ability to capture a structure changed in the relationship between foreign reserves accumulation and economic growth as well as identify the kink point of their relationship. However, we concern that the assumption of normality may yield biased estimation for model parameters of interest and its difficulty to specify the correct error distribution of the model. Hence, the maximum likelihood estimation might not be accurate. In this paper, we investigate the use of Empirical likelihood approach as a solution to this problem. To examine the performance of this estimatin, we conduct a simulation and experiment studues. Then, the approach is applied to analyze the effect of the accumulation of foreign reserves to economic growth in Thailand.

Keyword: Foreign reserves, economic growth, econometric, empirical likelihood, kink regression

1. INTRODUCTION

Many economic research on emerging market crisis mentioned that countries with an insufficient level of foreign reserves will be suffered from crises (Bussière, *et al.*, 2015). Heller (1966) suggested that the advantage of holding foreign reserves is to avoid the reduction in output resulting from a deficit in the balance of payments. Therefore, if the country has enough foreign reserves, it will provide a form of self-insurance against the risk of rapid withdrawal of cross-border investment which may lead to a deep recession. However, there would be an opportunity cost arising from holding a large foreign reserves. McCauley (2007) argued that the holding a massive foreign reserves may raise deadweight loss for the economy. Most foreign reserves are financed by the domestic borrowing or liabilities, thus the difference between the yield paid on the foreign reserves and the domestic cost of borrowing lead a higher cost of foreign reserves holding.

In short, foreign reserve accumulation seem to play an important role in the economic growth since it can bring both benefit and loss to the economy. Therefore, this study aim to investigate the effect of foreign reserves to economic growth in the case of Thailand.

Thailand is the emerging economic country that had experienced growth decline during the financial crisis in 1997. Thailand was loudly hit by speculative attacks in Thai Baht currency from foreign investors in those periods. To keep the exchange rate fixed, the central bank was forced to contract the money supply by selling its foreign reserves to buy back Thai baht and take the baht out of circulation. However, with the weak economy, its foreign currency reserve was no longer enough to fight against the speculative forces. Hence, Thailand decided to switch to a flexible exchange rate regime. In those time, the crisis in Thailand drive a high interest rates form 7.25% to 14.59 and Thai government had to devalue the baht from 25.09 in 1994 to 47.247 in 1997 and thereby collapsing of Thai economy for the first time. A natural question arising from this observation is: Has the accumulation of foreign reserves protect the Thai economy from the financial crisis? To answer this question, this first object of this study is therefore to identify the effect of foreign reserve accumulation and economic growth in Thailand.

In addition, to identify the effect of foreign reserve accumulation and economic growth, our study employ a modern nonlinear model called Kink regression of Hansen (2015). The model has an ability to capture a structure change in the relationship between foreign reserve accumulation and economic growth as well as identify the kink point of their relationship. However, many researchers concerned that the limited data that bring about an underdetermined, or ill-posed problem for the observed data, and the traditional estimation techniques, namely example Ordinary least square, Bayesian, and Maximum likelihood estimators, are difficult to obtain the optimal solution (Sriboochitta, 2017). Button et al. (2013) suggested that when the sample is limited, it is often hard to get meaningful results. Moreover, Lourens, Zhang, Long, and Paulsen (2013) also confirm that the explanatory variable is also conditionally non-normal distribution in many applications thus the assumption of normality may then yield biased estimation for model parameters of interest. Thus, in this study, we proposed an alternative estimation called "Empirical likelihood (EL)" since it can relax a strong assumption of normality and the limited of data. This approach is viewed as an alternative to classical likelihood approaches and it was first proposed by Owen (1988). It has many interesting properties and efficient as parametric likelihood (Mykland, 1999; Variyath, Chen, and Abraham, 2010). The main idea of Empirical Likelihood is to use a maximum entropy discrete distribution supported on the observe data and constrained by nonlinear equations related with the parameters of the model. In short, it's a non-parametric likelihood, which is fundamental for the likelihood-based statistical methodology. A review of EP refers to the study of Chen and Van Keilegom (2009).

The second object of this study is therefore to propose an EL estimator to estimate the unknown parameters in the Kink regression model. Yet, to the best of our knowledge, the estimation of kink regression using EL estimator has not been proposed in the literature, and hence the study we conducted is the first concerned with applying the EL estimator to kink regression model.

The rest of the paper is organized as follows. Section 2, describes the methodology used. Section 3 presents the simulation study in order to demonstrate the finite sample performance of the EL estimators. In Section 4, we resents our main econometric analysis of the role of foreign reserves on economic growth in Thailand. In this last section, we offers a conclusion.

2. KINK REGRESSION MODEL

2.1. Model structure

In this study two regime kink regression model is considered and it rely on

$$Y_t = \beta_1^-(x'_{1,t} \le \gamma_1)_- + \beta_1^+(x'_{1,t} > \gamma_1)_+, ..., \beta_K^-(x'_{K,t} \le \gamma_K)_- + \beta_K^+(x'_{K,t} > \gamma_K)_+ + \alpha Z + \varepsilon_t, \tag{1}$$

where Y_t is $[T \times 1]$ sequence of response variable at time t, $x'_{k,t}$ is a matrix of $(T \times K)$ predictor variables at time t. Here the relationship of $x'_{k,t}$ with Y_t changes at the unknown location or kink point γ_K, thus β is a matrix of $(T \times K \times 2)$ unknown parameters where $(\beta_1^-, ..., \beta_K^-)$ and $(\beta_1^+, ..., \beta_K^+)$ are the coefficients with respect to variable $x'_{k,t}$ for value of $x'_{k,t} \le \gamma_k$ and with respect to variable $x'_{k,t}$ for value of $x'_{k,t} > \gamma_k$, respectively. Z is a vector of covariates whose relationship with Y_t is linear. Following, Hansen (2015), the predictor variables are subject to regime-change at unknown kink point or threshold variable $(\gamma_1, ..., \gamma_K)$ and thereby separating these regressors into two regimes. These threshold variables are compact and strictly in the interior of the support of $(x_{1,t}, ..., x_{K,t})$. In addition, the error term of the model ε_t is vector of error which is not assume any distribution, but we only assume $E(\varepsilon_t) = 0$.

2.2. Constructing Empirical likelihood

Since the distributions of errors ε_t in Eq.(1) is unspecified, the likelihood function is unavailable. Therefore, it is necessary to find an appropriate likelihood. In this study, we adopt empirical likelihood (EL) of Owen(1991) as an alternative parametric likelihood in our Bayesian estimation. In this section, we will briefly discuss the concept of empirical likelihood, its relationship with estimating functions.

Let $p_1, ..., p_k$ be the set of implied probability weights allocated to the data. It carries a lot of information about the stochastic properties of the data. The empirical likelihood for estimated parameter $\theta \in \{\beta_1^-, ..., \beta_K^-, \beta_1^+, ..., \beta_K^+, \alpha, \gamma_1, ..., \gamma_K\}$ in Eq.(1) , in the spirit of Owen (1991, 2001), is

$$EL(\theta) = \max \prod_{t=1}^{T} p_i. \tag{2}$$

By taking logarithm Eq.(2), we have

$$EL(\beta) = \max \sum_{t=1}^{T} \log p_t, \tag{3}$$

where the maximization is subject to the constraints

$$\sum_{t=1}^{T} p_t \frac{\partial m(\mathrm{X}_{it};\theta)}{\partial \theta}(y_t - m(\mathrm{X}_{it};\theta)) = 0, \tag{4}$$

$$\sum_{t=1}^{T} p_t = 1, \tag{5}$$

where, $m(X_{it};\theta) = \beta_1^-(x'_{1,t} \le \gamma_1)_- + \beta_1^+(x'_{1,t} > \gamma_1)_+, ..., \beta_K^-(x'_{K,t} \le \gamma_K)_- + \beta_K^+(x'_{K,t} > \gamma_K)_+ + \alpha Z$.

Sometime the high dimensionality of the parameter space $(\theta, p_1, ..., p_T)$ makes the above maximization problem difficult to solve, and leads to expressions which are hard to maximize. Instead of maximizing $EL(\theta)$ with respect to the parameters $(\theta, p_1, ..., p_T)$ jointly, we use a profile likelihood.

The empirical likelihood, Eq.(3), is essentially a constrained profile likelihood, with constraints Eq.(4) and Eq.(5). In getting the empirical likelihood at each candidate parameter value θ, this optimization problem can be solved for the optimal p_t. Suppose, we know θ, then we can write the empirical likelihood as

$$\mathrm{EL}(\theta, p_1, ..., p_t) = EL(p_1, ..., p_t). \tag{6}$$

We maximize this profile empirical likelihood to obtain $(p_1, ..., p_T)$. By conducting the Lagrange multipliers, we can maximize the empirical likelihood in Eq. (3) subject to the constraints in Eqs. (4) and (5) as

$$L(p, \lambda_0, \lambda_1) = \sum_{t=1}^{T} \log(p_t) + \lambda_0(\sum_{t=1}^{T} p_t - 1) + \lambda_1^T \sum_{t=1}^{T} p_t \frac{\partial m(X_{it};\theta)}{\partial A_k}(Y_t - m(X_{it};\theta)), \tag{7}$$

where $\lambda \in \mathbb{R}$ is the Lagrange multipliers. It is a straightforward exercise to show that the first order conditions for L with respect to p_t ,and setting the derivative to zero, we can find that $\lambda_0 = -n$, and by defining $\lambda = -n\lambda_1$, we obtain the optimal p_t as

$$p_t = \frac{1}{T}\left(\frac{\partial m(X_{it};\theta)}{\partial \theta}(Y_t - m(X_{it};\theta))\right)^{-1} \tag{8}$$

Then, substituting the optimal p_t into the empirical likelihood in Eq.(7) we obtain

$$\mathrm{EL}(\theta) = \sum_{t=1}^{T} \log(1 + \lambda \frac{\partial m(X_{it};\theta)}{\partial \theta}(y_t - m(X_{it};\theta)) - \mathrm{T}\log(\mathrm{T}). \tag{9}$$

The computation of $\mathrm{EL}(\theta)$ is easy, we can maximize $\mathrm{EL}(\theta)$ with respect to (θ) and it is typically carried out using a nonlinear optimization algorithm.

2.3. Empirical likelihood ratio Test for a Kink Effect

Since the EL estimator is proposed to estimate the unknown parameter in kink regression model, we develop an EL-ratio test to check whether the model exist a kink point or not. The idea of EL-ratio test is similar to the likelihood ratio test which is used to compare the goodness of fit between the constrained and unconstrained model. In this test, The null hypothesis of this test is that

$$\begin{aligned} \mathrm{H}_0 &= \beta_1 = \beta_1^- = \beta_1^+ \\ \mathrm{H}_A &= \beta_1^- \neq \beta_1^+ \end{aligned} \tag{10}$$

The EL ratio is defined as follows

$$\text{EL-ratio} = 2\left| EL_A(\beta_1^-, \beta_1^+, \gamma | Y, X) - EL_0(\beta_1 | Y, X) \right| \quad (11)$$

where, $EL_A(\beta_1^-, \beta_1^+, \gamma | Y, X)$ is an the log empirical likelihood for alternative kink regression model and $EL_0(\beta_1 | Y, X)$ is the log empirical likelihood for null linear regression model. According to Wilks' theorem (Wilks, 1938), under certain regularity conditions, $\text{EL-ratio} \to \chi_F^2$ as $T \to \infty$. This property is maintained by the EL, as is demonstrated in Owen (1990) for the mean parameter. Therefore, the probability distribution of the test statistic is approximately a chi-squared distribution with degrees of freedom equal $F = \mathrm{df}_{\mathrm{H_A}} - \mathrm{df}_{\mathrm{H_0}}$. The *p*-value is then computed by $P(\chi^2_{df_A - df_0} \geq \text{EL-ratio})$. If the test is statistically significant, we can reject H_0, otherwise accept.

3. SIMULATION STUDY

In this section, we propose a simulation and experiment study to investigate the finite sample performance of the EL method and also compare the performance of EL estimation on kink regression model with the maximum likelihood (ML) estimation. In these simulations, we investigated the precision of the estimations under different sample sizes and error distributions. We consider three competing likelihood functions: normal, student-t and skewed student-t likelihood functions. To compare these methods, the study conduct a Mean Squared Error (MSE) approaches. In this simulation, we set

$$Y_t = \alpha + \beta_1^-(x'_{1,t} \leq \gamma_1)_- + \beta_1^+(x'_{1,t} > \gamma_1)_+ + \varepsilon_t \ , \ (12)$$

where β_0, β_1^-, and β_1^+ are set to be 1,0.5, and -2, respectively. threshold value is set to be γ_1= 6. We then simulate $x'_{1,t}$ from uniform distribution $Unif[-4,6]$. To make a comparison, ε_t are assumed to be i.i.d. random error which are generated from $skew-t(0,1,4,0.5)$, $N(0,1)$, $t(0,1,4)$, and $Unif(-2,2)$. In this Monte Carlo simulation, we consider sample size $n = 20$ and $n = 40$. Then, we assess the performance of our proposed method through the Bias and Mean Squared Error (MSE) of each parameter in which the MSE of each parameter is given by

$$MSE = N^{-1} \sum_{r=1}^{N} (\tilde{\phi}_r - \phi_r)^2,$$

where N =100 is the number of repetitions; and $\tilde{\phi}_r$ and ϕ_r are the estimated value and true value, respectively.

Table 1-4 report the results of the experiments for four different error distributions assumption namely uniform, normal, student-t and skewed student-t distributions, respectively. We can see that if we estimate the model under the correct specified likelihood distribution, the MLE based correct specified likelihood always show the lowest MSE on estimated parameters. Consider the EL estimator, we find that it perform well in all cases of error distribution assumption, especially uniform distribution assumption. In addition, the obtained MSE from EL estimator is sometime yield a lower MSE when compare with the misspecified ML estimators. Therefore, in this simulation study, these results confirm the advantage of the EL estimator, which performs well over a wide range of error distributions.

Table 1

Results of the Monte Carlo experiment for Kink regression with $\varepsilon_t \sim \mathrm{U}(-2,2)$

Sample sizes	*Parameter*	*Empirical likelihood*	*Normal likelihood*	*Student-t likelihood*	*Skew student-t likelihood*
N=100	$MSE(\beta_0)$	**0.0311**	0.0735	0.0812	0.0642
	$MSE(\beta_1^-)$	**0.0014**	0.0030	0.0037	0.0021
	$MSE(\beta_1^+)$	**0.0040**	0.0047	0.0056	0.0050
	$MSE(\gamma)$	**0.0015**	0.0331	0.0404	0.0235
N=200	$MSE(\beta_0)$	**0.0185**	0.0403	0.0596	0.0431
	$MSE(\beta_1^-)$	**0.0028**	0.0037	0.0053	0.0035
	$MSE(\beta_1^+)$	**0.0008**	0.0011	0.0015	0.0018
	$MSE(\gamma)$	**0.0001**	0.0098	0.0126	0.0118

Source: Calculation

Table 2

Results of the Monte Carlo experiment for Kink regression with $\varepsilon_t \sim \mathrm{N}(0,0.5)$

Sample sizes	*Parameter*	*Empirical likelihood*	*Normal likelihood*	*Student-t likelihood*	*Skew student-t likelihood*
N=100	$MSE(\beta_0)$	0.0560	**0.0172**	0.0736	0.0172
	$MSE(\beta_1^-)$	0.0439	**0.0011**	0.0053	0.0010
	$MSE(\beta_1^+)$	0.0439	**0.0004**	0.0033	0.0005
	$MSE(\gamma)$	0.0147	**0.0084**	0.0389	0.0061
N=200	$MSE(\beta_0)$	0.0025	**0.0068**	0.0268	0.0108
	$MSE(\beta_1^-)$	0.0003	**0.0003**	0.0014	0.0003
	$MSE(\beta_1^+)$	0.0023	**0.0003**	0.0012	0.0003
	$MSE(\gamma)$	0.0020	**0.0017**	0.0082	0.0023

Source: Calculation

Table 3
Results of the Monte Carlo experiment for Kink regression with $\varepsilon_t \sim t(0,1,4)$

Sample sizes	*Parameter*	*Empirical likelihood*	*Normal likelihood*	*Student-t likelihood*	*Skew student-t likelihood*
N=100	$MSE(\beta_0)$	0.0558	0.0494	**0.0420**	0.0657
	$MSE(\beta_1^-)$	0.0139	0.0026	**0.0019**	0.0027
	$MSE(\beta_1^+)$	0.0001	0.0021	**0.0009**	0.0013
	$MSE(\gamma)$	0.0492	0.0112	**0.0101**	0.0135
N=200	$MSE(\beta_0)$	0.0327	0.0304	**0.0078**	0.0335
	$MSE(\beta_1^-)$	0.0021	0.0012	**0.0008**	0.0014
	$MSE(\beta_1^+)$	0.0003	0.0007	**0.0006**	0.0007
	$MSE(\gamma)$	0.0215	0.0049	**0.0086**	0.0108

Source: Calculation

Table 4
Results of the Monte Carlo experiment for Kink regression with $\varepsilon_t \sim \text{skewt}(0,1,4,0.5)$

Sample sizes	*Parameter*	*Empirical likelihood*	*Normal likelihood*	*Student-t likelihood*	*Skew student-t likelihood*
N=100	$MSE(\beta_0)$	0.0175	0.0365	0.0458	**0.0255**
	$MSE(\beta_1^-)$	0.0017	0.0029	0.0009	**0.0012**
	$MSE(\beta_1^+)$	0.0034	0.0036	0.0012	**0.0013**
	$MSE(\gamma)$	0.0091	0.0151	0.0062	**0.0081**
N=200	$MSE(\beta_0)$	0.0073	0.0091	0.0299	**0.0065**
	$MSE(\beta_1^-)$	0.0018	0.0006	0.0006	**0.0003**
	$MSE(\beta_1^+)$	0.0055	0.0006	0.0006	**0.0003**
	$MSE(\gamma)$	0.0073	0.0074	0.0075	**0.0051**

Source: Calculation

4. APPLICATION STUDY

4.1. Data and model analysis

Table 5
Data Description

	FR Growth	*GDP Growth*
Mean	0.023169	0.016913
Median	0.023414	0.016678
Maximum	0.257449	0.107358
Minimum	-0.15007	-0.0831
Std. Dev.	0.054383	0.025234
Skewness	0.589845	-0.51427
Kurtosis	6.405468	7.10179
J-B Probability	0.0000	0.0000
ADF-Probability	0.0000	0.0000

Source: Calculation

To answer our research question: Has the accumulation of foreign reserves protect the Thai economy from the financial crisis? In this section, our proposed method is applied to study the effect of foreign reserve to the GDP. Therefore, our study model can be written as

$$GDP_t = \beta_1^-(\mathrm{FR}_t \leq \gamma_1)_- + \beta_1^+(\mathrm{FR}_t > \gamma_1)_+ + \varepsilon_t ,$$

where GDP_t is the growth of Gross Domestic product and FR_t is the growth of foreign exchange reserves of Thailand. The data were taken form Thomson Reuter DataStream. The data is quarterly time series data and the sample period is Q1/1993-Q4/2016. Note that the method of estimation is Empirical likelihood estimator. To allow a nonlinear effect of FR_t to GDP_t, a kink regression model is applied. Prior to estimating the kink regression model, we concern about the non-stationary data and nonlinear behavior in our model. In this study, we conduct a unit root test as well as nonlinear structure test for our data. The unit root test in the time series is tested by Augmented Dickey Fuller test where the null hypothesis of the test is the existence of a unit root. Test results are shown in Table 5 and the results confirm that our data is stationary. Then, to check whether there exists a kink or threshold effect in our model or not. The study conducted an Empirical likelihood ratio test as discussed in section 2.3 and the result is shown in Table 6. We can observe that the Empirical likelihood ratio test statistic show a significant at 1 % level. This result allow us to reject the null hypothesis of linear regression (EL_{linear}) for the relationship between GDP_t and FR_t for Thai economy, which means that the kink regression model is preferred in this study.

Table 6
Kink regression application result

	EL_{linear}	EL_{kink}	*EL Ratio*
Regime 1 vs. Regime 2	-12.32087	-0.849459	22.94282***

Source: Calculation

Note: "***" is significant at 1% level

4.2. Application result

The results of the kink regression model is shown in Table 6. We can observe a different sign effect of FR on the GDP_t in both two regimes. In this study, we denote regime 1 and 2 as low foreign reserve accumulation and high foreign reserve accumulation regimes, respectively. Based on the coefficients shown in Table 6, we find that in the case of Thailand, the growth of foreign exchange reserves show the positive statistically significant impact to economic growth in the first regime at 10% level while a negative statistically significant impact at 10% level is obtained in regime 2. Consider the kink or threshold point, we can observe that there exists a statistically significant kink effect at a significance level of 1% and the fitted kink regression line is plotted in Figure 1. The result illustrates a steep positive slope for foreign reserve, with a kink or threshold point (γ_1) around 2.34%, switching to a low negative slope foreign reserve above that point. For low foreign reserve accumulation $(\mathrm{FR}_t \leq 2.34\%)$, the growth of FR by one percentage point is found to increase the growth rate of GDP by 0.1755 percentage point. This result indicate the usefulness of foreign reserve during the crisis if the growth rate of foreign reserve is less than 2.34%. On the contrary, the growth of FR by one percentage point is found to decrease the growth rate of GDP by 0.0037 percentage point, when $\mathrm{FR}_t > 2.34\%$. We expect that

Table 7
Coefficients (standard errors) from Kink regression

Parameter	*GME*
	0.0397***
β_1^- (regime 1)	**0.1755***
	(0.0896)
β_1^+ (regime 2)	**-0.0037***
	(0.0016)
γ_1	0.0234***
	(0.0012)
λ_1	91.0165***
	(2.3731)
λ_2	-919.8528***
	(114.0875)
λ_3	-66.5134***
	(20.0582)
λ_4	74.9303***
	(2.5144)
Empirical Likelihood	**-0.849459**

Source: Calculation

Note: "***","**","*" are significant at 1% , 5%, and 10% level, respectively.
And () is standard error.

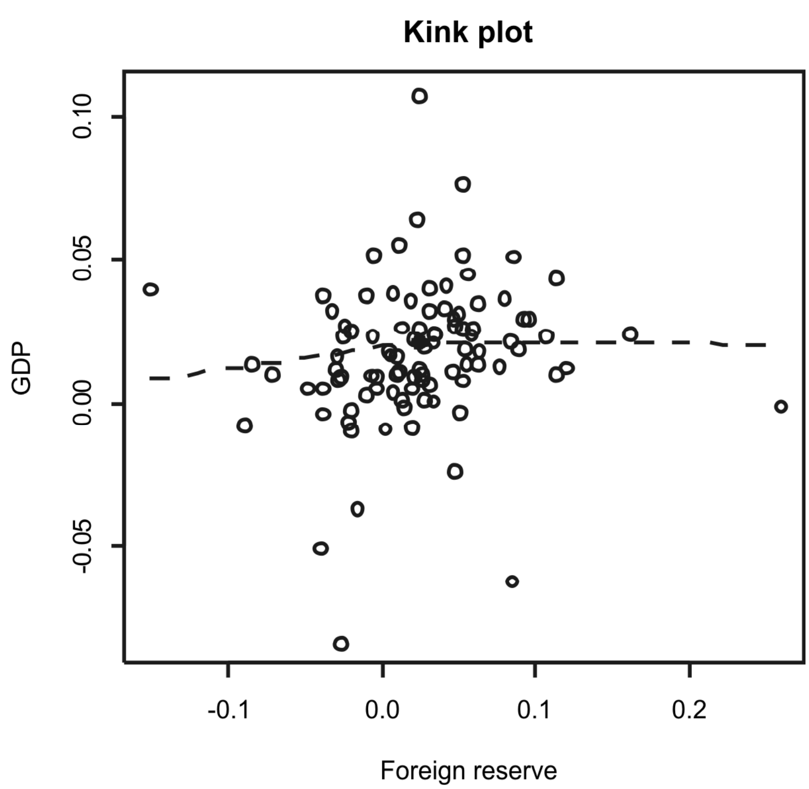

Figure 1: Kink plot of GDP and Foreign reserve growth

increases in foreign reserves in this regime can reduce domestic savings and thereby decreasing domestic investment and economic growth.

For the estimates λ_1, λ_2, λ_3, and λ_4, which are the Lagrange multipliers of each constraint of the optimization, we find that all Lagrange multipliers how the statistically significant at 1% level. Hence, this indicate that our estimation satisfy all constraints.

This result led us to conclude that if the growth foreign reserve is greater than 2.34% the increase in foreign reserve will harm the economic growth since an increases in foreign reserves can reduce domestic savings and have a negative impact domestic investment and economic growth. However, if the growth foreign reserve is less than 2.34%, it can be used as a tool for mitigate the effect of crisis.

5. CONCLUSION

Foreign reserves seem to have played a role in the economic growth in the last two decades. It was found to have both advantage and disadvantage to the economic growth. The foreign reserve accumulation has an ability to offset the effect of the crisis, however, some studies argued that the holding a massive foreign reserves may raise deadweight loss for the economy. To answer our research question: Has the accumulation of foreign reserves protect the Thai economy from the financial crisis? We employ a kink regression model find the effect of foreign reserve on the economic growth in the nonlinear context.

This paper also introduced a new approach for the estimation of kink regression model using Empirical likelihood (EL) estimator. To examine the performance of this estimation, we apply it in the simulation study. The main contribution of this estimation shows that it can relax a strong assumption of normality and the limited of data. This approach viewed as an alternative to classical likelihood approaches. The results of experiment presented in this study provide an evidence about the robust performance of the EL compared with the traditional estimation by Maximum likelihood (ML). We also found that it performs well in all cases of error distribution assumption, especially when the error is assumed to be uniform distribution. In addition, the obtained MSE from EL estimator is sometime yield a lower MSE when compare with the misspecified ML estimators. Therefore, in this simulation study, these results confirmed the advantage of the EL estimator, which performs well over a wide range of error distributions.

We then apply a kink regression model to study the effect of foreign reserves on the economic growth and found that foreign reserves provide both positive and negative effect on economic growth for expansion and recession regimes, respectively. To answer our research question, we found that foreign reserves seem to have played a role in offsetting the effect of the crisis when the growth rate of foreign reserves is less than 2.34%.

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