Major export destinations of Thailand: evidence from copula-based simultaneous kink equation

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Abstract. This paper assesses the nonlinear relationship between selected economic factors and Thailand’s exports to its three major export partners namely the United States, Japan, and China by employing copula-based simultaneous kink equation (SKE) model. This is because there is an increase of empirical evidence of nonlinearities in regression models with macroeconomic time series. The practical result shows that there is a nonlinear relationship between the growth of Thai GDP and the growth of exports to Japan. The kink value in Thai GDP growth is 0.017, indicating that if Thai GDP growth is beyond 0.017%, the coefficient will be in the negative part which is 0.014. Thai exports to Japan will fall when Thai GDP growth moves across the kink point, which is a rather unexpected result. Overall, it refers that Thailand’s GDP is the most crucial determinant of Thailand’s exports since its significance obtains for Thailand’s exports to both China and Japan.

1. Introduction
Thailand’s exports account for almost 70% of its GDP compared to the world average of only 30%. Heavy reliance on trade thus has tremendous implications for the Thai economy. Major Thai export destinations consist of the United States (U.S.), China (CN), and Japan (JP). Since the beginning of 1997, the values of Thai exports to its top three destinations had increased continually until 2008 when the global financial crisis occurred, and the export values dropped dramatically. Then, Thai exports to these countries had recovered until the last five years, Thailand’s exports performance has been disappointing so far.

To understand the characteristics of the economic factors by explaining the trade volumes between Thailand and its top three main export destinations is essential for policymakers to enhance Thailand’s exports growth. Meanwhile, these topics have brought up a few attention in the economic literature. Another primary motivation of our study is to investigate the nonlinear impact of independent variables on Thailand’s exports. Since time series data of macroeconomic variables are often found in the form of nonlinearity Tong [1], Chan and Tsay [2] and Gonzalo and Wolf [3]. Then threshold models were introduced to model the dynamics in macroeconomic and financial time series. Thus, this paper attempts to fill the gap of the literature partially and to investigate the nonlinear relationship between Thailand’s exports to three main export destinations and the selected economic variables by using gravity trade model which was first introduced by Timbergen [4].
We estimate a system of three equations which represent Thailand’s exports to each country; therefore we employ the Seemingly Uncorrelated Equation (SUR) method (Zellner [5]). A significant benefit of SUR estimation is allowing for the correlation between the errors across equations. Moreover, we would like to investigate the nonlinear impact of independent variables on Thailand’s exports. A regression kink model can detect changes in the slope of the association between independent variables and the dependent variable. The regression function of kink model is continuous, where its slope discontinues at a threshold point. Card et al. [6] made the regression kink model well-known as a model of the regression discontinuity. Then Hansen [7] developed methods for estimation and inference in regression kink models which consider a change-point as an unknown parameter and also assume continuity of the regression model. If the relationship between them has a kink point in which the positive slope changes at the kink to a higher slope compared with the lower part, it will provide useful information to policymakers especially on the issues of how to boost Thailand’s exports.

Therefore, this paper employs the SUR estimation for estimating a system of three equations and applies the regression kink model to assess the nonlinear effects between Thailand’s exports to three main export destinations and the selected economic variables. Thus, the model becomes the simultaneous kink equation (SKE) model. One weakness of the SKE model is that the errors of all equations are assumed to be normal distributions which are a strong assumption and real data are usually not normally distributed. This strong assumption might lead to an inefficient specification. To overcome this issue, we employ copula to join marginal distribution functions in the SKE model. The essential advantages of using copula functions in modelling are capable of tail dependence, allowance to model not only linear but also nonlinear dependence, and even allowance to model with different distributions and non-normal distributions.

Thus, we have copula-based on Simultaneous Kink Equation (SKE) model. This model should improve the result of the estimated parameters of the Thai exports to its top three export destinations. This model was first introduced by Maneejuk et al. [8] to study the nonlinear relationship between economic growth and income inequality. To our best knowledge, this paper is the first attempt to apply gravity trade model with a copula-based SKE approach. This paper consists of five sections. The first section gives an introduction. The second section specifies the methodologies consisting of the Gravity model in international trade, the SKE model, Dependence Modelling with copulas, and estimation technique of copula-based SKE model. Section 3 is devoted to model specification and data. The estimation results are reported and analyzed in Section 4. In the final section, we formulate some concluding remarks.

2. Methodology
Card et al. [6] invented the regression kink model well-known as a model of the regression discontinuity. The regression function of kink model is continuous, where its slope discontinues at a threshold point. The regression kink involves estimating changes in the slope of the association between an independent variable and a dependent variable. Hence, it is useful for detection of change-point in slope. Since we have three equations, therefore we use the SKE model for this paper. Let’s assume that we have m-simultaneous equations. Thus, the SKE model can be written as follows:

\[ y_{i1} = \alpha_i + \sum_{j=1}^{G} \beta_{ij} (Y_{ij} - Y_{0j}) + \sum_{k=1}^{k} \phi_{ik} (X_{ij} - X_{0j}) + \sigma_i \varepsilon_{ij} \]

\[ \vdots \]

\[ y_{im} = \alpha_M + \sum_{j=1}^{M} \beta_{mj} (Y_{ij} - Y_{0j}) + \sum_{k=1}^{k} \phi_{mk} (X_{ij} - X_{0j}) + \sigma_M \varepsilon_{mj} \]

(1)

where \((y_{i1}, ..., y_{im})\) is \((T \times 1)\) a vector of dependent variable; \(X_{ij}\) is a \((T \times k)\) matrix of \(k\) explanatory variables; \(Y_{ij}\) is the \((T \times G)\) matrix of \(G\) dependent variables in the \(r^{th}\) equation; \((\varepsilon_{i1}, ..., \varepsilon_{im})\) are \((T \times 1)\) the vector of disturbances; \((\sigma_1, ..., \sigma_M)\) is the scale parameter of margin 1, ..., \(M\).
Following the regression kink model developed by Hansen [7], we consider change-point as an unknown parameter and also assume continuity of the regression model. The model consists of two parts separated into a negative and positive part. The negative part is \( a^- = \min(a,0) \), whereas the positive part is \( a^+ = \max(a,0) \) of a real number \( a \). In model (1) for the \( i^{th} \) equation, the coefficients with respect to the variables which are the RHS equal to \((\beta_{i1}, ..., \beta_{im})\) and \((\phi_{i1}, ..., \phi_{in})\) for a value of \( y_i \) and \( x_i \) less than \((\gamma_{i1}, ..., \gamma_{im})\) and \((\gamma_{i1}, ..., \gamma_{in})\), respectively. On the other hand, there are equal to \((\beta_{i1}', ..., \beta_{im}')\) and \((\phi_{i1}', ..., \phi_{in}')\) for value of \( Y_i \) and \( X_i \) greater than \((\gamma_{i1}', ..., \gamma_{im}')\) and \((\gamma_{i1}', ..., \gamma_{in}')\), respectively. The regression function is continuous in whole variables (Hansen [7]).

### 2.1. Dependence modelling with multivariate copulas

Sklar [9] shows that for any multivariate distribution function \( H \) with a marginal distribution \( F_j \) where \( j \in \{1, ..., d\} \), then \( C \) is a copula such that:

\[
H(x_1, ..., x_d) = C(F_1(x_1), ..., F_d(x_d))
\]  

There are two leading families of copulas; Elliptical copulas and Archimedean copulas. Let the function \( \Phi(.) \) is multivariate standard distribution function and \( \Phi^{-1} \) is the inverse of the univariate distribution function. \( \rho \) represents the dependence parameter for Elliptical copulas. The dependence parameter of the copula measuring the relationship between the marginal distributions. Then the corresponding Multivariate Elliptical copulas is:

\[
C(u_1, ..., u_n; \rho) = \Phi(\Phi^{-1}(u_1), ..., \Phi^{-1}(u_n); \rho)
\]

On the other hand, the Archimedean copulas allow for plenty of different dependence structures. Therefore, we can capture different characteristics of tail dependences such as only lower tail dependence. The corresponding Multivariate Archimedean copulas are:

\[
C(u_1, ..., u_n|\theta) = \Phi\left(\sum_{j=1}^{n} \Phi^{-1}(u_j); \theta\right)
\]

where the term \( \Phi(.) \) is the Laplace transform. \( \theta \) denotes the dependence parameter for Archimedean copulas which is restricted to be in the range of \([0, +\infty)\) for Clayton copula, and \((0, \infty)\) for Frank copula.

### 2.2. Estimation technique of copula-based simultaneous kink equation (SKE) model

This study consists of three equations; Thailand exports to China, to Japan, and to the United States. The multivariate copula is employed to join the three equations. The parameters are estimated using the maximum likelihood. The log likelihood of this model can be written as:

\[
\log L(y_1, Y_1, y_2, Y_2, y_3, Y_3; u_1, u_2, u_3|\Theta_1, \Theta_2, \Theta_3, \theta) = \sum_{i=1}^{3} \left[ \log \left( y_i, Y_1, X_1 | \Theta_1 \right) + \log \left( y_2, Y_2, X_2 | \Theta_2 \right) + \log \left( y_3, Y_3, X_3 | \Theta_3 \right) + \log c(u_1, u_2, u_3|\theta) \right]
\]

where \( \Theta_1 = \{\alpha_1, \beta_1, \beta_{i1}', r_{i1}, \phi_{i1} \} \), \( \Theta_2 = \{\alpha_2, \beta_2, \beta_{i2}', r_{i2}, \phi_{i2} \} \), \( \Theta_3 = \{\alpha_3, \beta_3, \beta_{i3}', r_{i3}, \phi_{i3} \} \), \( \theta \) is the estimated parameters of exports to China, exports to Japan, and exports to the United States respectively. \( u_1, u_2, u_3 \) are the distributions of the marginal error term related to three exports equations of the model. Three different marginal distributions of the error term are considered in this study; Normal (n), Student-t (t), and skewed Normal distributions (sk). For the copulas, we consider Gaussian, Frank, Student-t, and Clayton to join pairs of three different marginal distributions. We use a one-step estimation of SKE model with copula likelihood. To select the best-fitted both copula function and marginal distribution of the error terms for our data, we employ the Akaike Information Criterion (AIC)
and Bayesian Information Criterion (BIC). Chen [10] confirmed that the AIC is appropriate for choosing the best-fit marginal distribution.

3. Model specification and data

3.1. Model specification

This paper considers top three trading destinations of Thailand namely China (CN), Japan (JP), and the United States (U.S.). Therefore, we have three equations of exports. The specification of gravity model for this paper can be written as:

\[ EX_{CN,t} = \alpha_1 + \beta_1 GDP_{TH,t} + \beta_2 GDP_{CN,t} + \beta_3 P_{CN,t} + \beta_4 D_{CN,t} + u_1 \]
\[ EX_{JP,t} = \alpha_2 + \beta_1 GDP_{TH,t} + \beta_2 GDP_{JP,t} + \beta_3 P_{TH,t} + \beta_4 P_{JP,t} + \beta_5 D_{JP,t} + u_2 \]
\[ EX_{US,t} = \alpha_3 + \beta_1 GDP_{TH,t} + \beta_2 GDP_{US,t} + \beta_3 P_{TH,t} + \beta_4 P_{US,t} + \beta_5 D_{US,t} + u_3 \]  

where \( EX_{CN,t}, EX_{JP,t}, \) and \( EX_{US,t} \) denote the value of Thai exports to CN, JP, and the US, respectively at time \( t \). \( GDP_{TH,t}, GDP_{CN,t}, GDP_{JP,t}, \) and \( GDP_{US,t} \) denote the gross domestic product which is a measure of the monetary value of all final goods and services of TH, CN, JP, and the US, respectively at time \( t \). \( P_{TH,t}, P_{CN,t}, P_{JP,t}, \) and \( P_{US,t} \) denote a number of population in TH, CN, JP, and the US, respectively at time \( t \). \( D_{CN,t}, D_{JP,t}, \) and \( D_{US,t} \) denote the distance between TH and CN, JP, and the US, respectively at time \( t \). \( u_1, u_2, u_3 \) are the distributions of the marginal error term related to three exports equations of the model.

3.2. Data

This empirical study uses quarterly data on Thailand, China, Japan, and the United States over the period quarter 1, 1997 to quarter 4, 2015. The variables include Thailand’s exports, GDP, and distance from Thailand to the other countries. The data are obtained from Thomson Reuter DataStream, except for distance which is collected from the CEPII Geodist dynamic dataset [11]. All time-series data are transformed into the growth form for making the series stationary. We check the stationarity of the time series with Augmented Dickey-Fuller (ADF) unit root test. The results are not provided here but they indicate that all the time series variables are stationary.

4. Empirical results

4.1. Testing for a threshold

To check the existence of a kink effect, we employ the likelihood ratio test (LR-test). The null hypothesis for the test is that the kink effect does not exist. LR test value of Thai GDP and Thai exports to Japan equation is 2354.438 which is significant at 1% level. As a result, the null hypothesis is rejected indicating that there is a kink effect between Thailand’s GDP and Thailand’s exports to Japan. Therefore, this implies that the linear regression will not be suitable for this study due to the nonlinearity created by the kink effect.

Let \( \gamma_1 \) is the kink point parameter. The form of kink effect in the SKE model for Thailand’s exports to Japan equation can be shown as:

\[ EX_{JP,t} = \alpha_2 + \beta_2 \left( GDP_{TH,t} - \gamma_1 \right) + \beta_5 \left( GDP_{TH,t} - \gamma_1 \right) + \beta_2 GDP_{JP,t} + \beta_3 P_{TH,t} + \beta_4 P_{JP,t} + \beta_5 D_{JP,t} + \sigma_2 e_2 \]  

4.2. The criteria for selecting the copulas for SKE model

The empirical results show that Clayton copula with Student-t margin for exports to the U.S., Normal margin for exports to China, and Normal margin for exports to Japan turn out to be the best-fit copula since it provides the minimum values by both AIC and BIC which are 486.066 and 543.807 respectively as shown in table 1. The Clayton copula indicates that there is a strong left tail dependence. This refers that Thai exports to top three main trading partners are strongly correlated at low growth but less correlated at high growth.
Table 2 relatively shows the estimated parameters from copula-based on SKE model. The first step, we focus on the estimated results of Thailand’s exports to China. Thailand’s GDP and China’s GDP are significantly at 1% level. Both of them are found to be positively related to Thailand’s exports to China. An increase in both Thailand’s GDP growth and China’s GDP growth by 1% leads to increase in growth of Thailand’s exports to China by 0.948% and 0.359%, respectively.

Table 1. The criteria to select the best-fit copula model.

| Marginal Distribution | Gaussian AIC | Gaussian BIC | Frank AIC | Frank BIC | Student AIC | Student BIC | Clayton AIC | Clayton BIC |
|-----------------------|--------------|--------------|-----------|-----------|-------------|-------------|-------------|-------------|
| n n n                 | 505.536      | 558.088      | 507.504   | 560.055   | 510.577     | 565.318     | 493.017     | 545.569     |
| n n t                 | 512.875      | 567.616      | 511.034   | 565.773   | 516.530     | 573.461     | 505.181     | 559.923     |
| n n sk                | 509.205      | 566.136      | 510.924   | 567.856   | 518.713     | 577.834     | 509.057     | 565.988     |
| n t n                 | 507.605      | 562.347      | 503.119   | 557.860   | 512.417     | 569.348     | 494.405     | 549.446     |
| n t t                 | 514.418      | 571.349      | 510.449   | 567.380   | 519.139     | 578.260     | 508.799     | 565.730     |
| n t sk                | 517.161      | 576.282      | 513.545   | 572.666   | 517.111     | 578.421     | 512.810     | 571.931     |
| n sk n                | 510.000      | 566.931      | 511.047   | 567.978   | 515.606     | 574.727     | 496.196     | 553.127     |
| n sk t                | 517.026      | 576.146      | 515.241   | 574.361   | 519.462     | 580.773     | 509.906     | 569.027     |
| n sk sk               | 512.443      | 573.753      | 513.646   | 574.957   | 523.858     | 587.358     | 513.953     | 575.263     |
| t n n                 | 506.307      | 561.048      | 508.486   | 563.227   | 511.129     | 568.060     | 489.066*    | 543.807*    |
| t n t                 | 513.112      | 570.043      | 512.552   | 569.483   | 514.361     | 573.481     | 502.786     | 559.717     |
| t n sk                | 515.122      | 574.243      | 512.476   | 571.597   | 517.769     | 579.080     | 509.702     | 568.823     |
| t t n                 | 508.659      | 565.590      | 509.787   | 566.718   | 513.322     | 572.443     | 492.725     | 549.656     |
| t t t                 | 515.036      | 574.157      | 513.785   | 572.906   | 518.688     | 579.998     | 505.664     | 564.785     |
| t t sk                | 517.171      | 578.482      | 510.169   | 571.480   | 518.524     | 582.024     | 512.523     | 573.834     |
| t sk n                | 511.345      | 570.466      | 512.125   | 571.246   | 515.559     | 576.869     | 494.544     | 553.665     |
| t sk t                | 517.894      | 579.204      | 517.400   | 578.710   | 521.922     | 585.422     | 501.659     | 565.969     |
| t sk sk               | 520.145      | 583.645      | 512.264   | 575.764   | 520.147     | 585.837     | 506.414     | 569.914     |
| sk n n                | 509.901      | 566.832      | 508.322   | 565.253   | 513.506     | 572.627     | 493.470     | 550.401     |
| sk n t                | 516.205      | 575.326      | 510.776   | 569.897   | 518.487     | 579.797     | 505.658     | 564.778     |
| sk n sk               | 517.841      | 579.151      | 518.472   | 579.782   | 521.902     | 585.402     | 512.466     | 573.456     |
| sk t n                | 512.469      | 571.589      | 509.797   | 568.918   | 516.601     | 577.912     | 506.695     | 568.006     |
| sk t t                | 519.145      | 580.455      | 514.686   | 575.996   | 521.087     | 584.587     | 506.695     | 568.006     |
| sk t sk               | 521.037      | 584.537      | 514.501   | 578.001   | 516.126     | 581.816     | 509.125     | 572.625     |
| sk sk n               | 514.473      | 575.783      | 514.119   | 575.430   | 516.601     | 577.912     | 507.211     | 570.711     |
| sk sk t               | 521.714      | 585.214      | 514.511   | 578.011   | 525.033     | 590.723     | 507.211     | 570.711     |
| sk sk sk              | 512.014      | 576.113      | 517.456   | 583.146   | 514.710     | 582.589     | 512.017     | 577.707     |

Source: Calculation, Note:* = the lowest AIC, BIC

The second step is to consider the kink point. As is shown in figure 1, the existence of kink point in Thailand’s exports to Japan growth due to Thai GDP growth's effect. The kink regression provides the nonlinear impact of Thai GDP on Thailand’s exports to Japan which Thai GDP effect can be divided into two parts namely positive and negative part. The vertical axis represents Thailand’s GDP growth, while the horizontal axis represents the growth of export to Japan. We can see that the fitted regression displays a steeply positive slope for low Thailand’s GDP growth, then it switches at a kink point at 0.017% to an almost slightly remain constant positive slope for Thai GDP growth. The coefficient of this positive or first part is 1.129 which means an increase in Thailand’s GDP growth by 1% will lead to an increase in growth of Thailand’s exports to Japan 1.129%. On the other hand, if Thai GDP growth is above a kink point at 0.017%, the coefficient will be in the negative or second part which is 0.014%. It indicates that the effect of Thai GDP growth in the second part is much less than the first part. Therefore, if Thai GDP growth is over 0.017%, Thailand’s export to Japan will decrease from 1.129% to 0.014% indicating that Thai exports to Japan will fall when Thai GDP growth moves across the kink point. Since we aim to boost Thailand’s exports, this result seems to be unexpected. The dependence parameter (θ) is 0.719, then we use this value to compute Kendall’s tau value which equals to 0.264. This tau indicates
that the relationship between dependent variables of three equations is positive and relatively small (0.264). Lastly, the evidence shows that none of the variables is significant on Thailand’s exports to the United States.

**Table 2.** Estimated results of copula-based SKE model.

| Country | Variable | Coefficient | S.E. | P-value |
|---------|----------|-------------|------|---------|
| CHINA   | $\alpha_1$ | 0.082       | 0.530 | 0.877   |
|         | $\beta_{11}$ | 0.948***    | 0.367 | 0.010   |
|         | $\beta_{12}$ | 0.359***    | 0.134 | 0.007   |
|         | $\beta_{13}$ | 0.099       | 33.009 | 0.998 |
|         | $\beta_{14}$ | 0.099       | 206.248 | 1.000 |
|         | $\beta_{15}$ | -0.014      | 0.106 | 0.897   |
|         | $\sigma_1$   | 0.118***    | 0.011 | 0.000   |
| JAPAN   | $\alpha_2$  | -0.052      | 0.330 | 0.875   |
|         | $\beta_{21}$ | 1.129***    | 0.306 | 0.000   |
|         | $\beta_{22}$ | 0.014       | 0.060 | 0.332   |
|         | $\beta_{23}$ | 0.733       | 0.831 | 0.378   |
|         | $\beta_{24}$ | 0.039       | 0.146 | 0.792   |
|         | $\beta_{25}$ | 0.164       | 16.629 | 0.992 |
|         | $r_{1}$      | 0.017       | 0.052 | 0.740   |
|         | $\sigma_2$   | 0.067***    | 0.007 | 0.000   |
| The US  | $\alpha_3$  | -0.452      | 0.473 | 0.339   |
|         | $\beta_{31}$ | 0.464       | 0.286 | 0.104   |
|         | $\beta_{32}$ | 0.377       | 2.243 | 0.867   |
|         | $\beta_{33}$ | 0.077       | 21.128 | 0.997 |
|         | $\beta_{34}$ | 0.129       | 43.359 | 0.998 |
|         | $\beta_{35}$ | 0.077       | 0.072 | 0.281   |
|         | $\sigma_3$   | 0.107***    | 0.024 | 0.000   |
| Joint Estimates | Dependency (\(\theta\)) | 0.719 | 0.244 | 0.003 |

Note: ***, ** and * indicate significance at the 0.01, 0.05 and 0.1 levels, respectively.

**Figure 1.** The kink point in Thailand’s exports to Japan growth.
5. Conclusions
This paper focuses on Thailand’s exports to its top three trading destinations which are the United States, Japan, and China. The primary motivation of our study is to investigate the nonlinear impact of independent variables on Thailand’s exports. Copula-based on simultaneous kink equation (SKE) model is consequently employed in this study. If there is a change in slope which switches to a higher positive slope, it will provide useful information to policymakers especially on the issues of how to boost Thailand’s exports. The empirical result shows that there is a nonlinear effect of Thai GDP on Thai exports to Japan. The kink value in Thai GDP is 0.017, indicating that if Thai GDP growth is beyond 0.017%, the coefficient will be in the negative part, which is 0.014. This number implies that the effect of Thai GDP growth in the second part is less than the first part, which is shown as an unexpected result. Overall, it indicates that Thailand’s GDP is the most important determinant of Thailand’s exports since its significance on Thailand’s exports to both China and Japan is obtained.

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