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How to obtain a better result of updating the I-O table from the MTT method

Jeerawadee Pumjaroen
Rajamangala University of Technology Thanyaburi

Tipat Sottiwan
Rajamangala University of Technology Thanyaburi

Abstract

Under the assumption of changes in economic structure, Matrix Transformation Technique (MTT) combines matrix transformation and forecasting techniques to update input-output (I–O) tables solving I-O timeliness. This research aims to improve the result of MTT by forecasting only the significant elements instead of forecasting all elements of a transformed-intersection matrix as the original propose. The forecasted elements are considered from their statistically significant trend and their correlation with the technical coefficient. The empirical evidence from updating the Thailand I-O table shows that the performance of MTT with forecasting only significant elements outperforms the result of MTT with forecasting all elements and the well-known method as the RAS approach. The assessment is considered from the updating results of the I-O table, technical coefficient, and multiplier matrices by common indices: Standardized Total Percentage Error (STPE), Theil's U (U), Standardized Weighted Absolute Difference (SWAD), and also Mean Absolute Percentage Error (MAPE).

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Contact: Jeerawadee Pumjaroen - jeerawadee_p@rmutt.ac.th, Tipat Sottiwan - tipat_s@rmutt.ac.th.
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1. Introduction

An I-O table is a vital tool describing the relationship of commodity flows between the sectors in the economy, developed by Leontief (1936). It has been used to analyze numerous topics and a wide range of fields. For instance, policymakers and analysts apply the I-O table for policy simulation, economic impact analysis, and identification of the key sectors in an economy. Consequently, these applications can help them deeper understand the potential problems and find out the possible solutions, which may avoid the difficulties or be more adequately prepared to confront them by virtue of being aware of their existence.

Nevertheless, there are some concerns about the I-O table. One of the major concerns of an I-O analysis is timeliness (Dietzenbacher et al., 2013; Miller & Blair, 2009). Generally, I-O tables are not arranged for each successive year but for every 4-5 years instead (Rao & Tommasino, 2014). Because of numerous requirements, an elaborate and accurate statistical apparatus including well-trained personnel are required to construct the I-O table; hence, there is a substantial time lag between the actual census period, construction, and publication of the survey-based tables. Besides, constructing I–O tables through surveys is sometimes highly costly. For instance, the survey-based Thailand I-O table of 2015 was not published until 2020, a five-year time lag (Office of the National Economic and Social Development Council of Thailand, 2020). Thus, the ones who apply the available I-O table will doubt whether that table still reflects the economy they are studying. Hence, to deal with the I-O timeliness, the common solution is to update them.

Several methods of updating the I-O table have been proposed categorized into three groups; survey, semi-survey, and non-survey methods (Deng, Zhang, Wang, Li, & Zhang, 2014). Regarding one of the core I-O analyses as a multiplier matrix, Stoeckl (2012) finds that the estimating method between a survey and a non-survey approach is similar. Due to the various conditions of the survey approach, the non-survey method has been developed and broadly applied (Zheng, Fang, Wang, Jiang, & Ren, 2018). The attention of the non-survey approach is to update the target I-O table by using the historical survey-based I-O table. The two popular non-survey methods are Naïve and RAS that has long been applied (Khan, 1993).

NAÏVE approach is based on the original I–O assumption of intertemporal stability of coefficients. The idea is applied from the initial framework of which Leontief (1936, 1951) proposed. Therefore, the target year's coefficient simply adopts from the base year's data. When there is no structural change in the economy, the Naïve method should be considered first because of its simplicity (Jalili, 2000). In the real world, however, the intertemporal instability of I–O coefficients is well-established, which recognizes the instability.

RAS is an iterative bi-proportional adjustment, made known by Stone (1961); Stone and Brown (1962). The method is a well-known and widely used method to update the I-O table without having to generate a completely new set of inter-industry data. Instead, the operation generates new I-O coefficients for the target year using only one prior year table in conjunction with the target year total intermediate industry inputs and outputs and total industry outputs. The basic idea is to minimize the dissimilarity between a prior table and a target table in addition to balance an initial estimate rather than pure updating. However, the procedure of RAS can be done with only a non-negative table.

Further, there are many other modification methods of RAS. For example, Generalized RAS (GRAS) is the alternative approach to update the table containing both positive and negative elements presented by Junius and Oosterhaven (2003). The method assumes that each row and column of the balanced matrix has at least one positive element. The procedure separates the matrix into two matrices—one with non-negative elements and the other with absolute values. Then, the rows and column adjustment will be performed for the sum of two matrices. The negative elements will adjust the result in the last step. More recently, the assumption of GRAS can be relaxed so that the method can balance a matrix that has a column(s) and/or a row(s) without any positive elements (Temurshoev, Miller, & Bouwmeester, 2013).

Cell-Correction of RAS (CRAS) is also a further evolution of RAS proposed by Mínguez, Oosterhaven, and Escobedo (2009). Instead of proceeding with a prior single matrix as RAS, CRAS applies multiple previous matrices to updates the new I-O table. The method involves two stages based on RAS. Firstly, the process uses the prior time-series tables to estimates coefficient variation distributions between the projected and the true I-O tables by the traditional RAS. Secondly, the matrix is modified by the distributions obtained from the previous stage to obtain the projected values of the target matrix. Since both stages are based on RAS, CRAS can work only with non-negative matrices.

Even though there are many updating methods, which are the modification of RAS, RAS is still the most accepted and applied method of bi-proportional technique (Szabó, 2015). In addition to RAS, Cross-Entropy (CE) by Golan, Judge, and Robinson (1994) has been proved to generate a solution equivalent to RAS (McDougall, 1999). CE is the procedure to estimate a new set of I-O coefficients by minimizing the entropy distance between an updating table and a prior table. The method advantage is the possibility of accounting for full use of and only using all available information.

More recently, Wang et al. (2015) propose the pure update I-O table named the Matrix Transformation Technique (MTT). Under the assumption of significantly changing an economic structure, MTT combines the time series forecasting and transformation matrix technique to update the I-O table for the current or ahead of the fiscal year. It is a non-iterative procedure using many available I–O tables to update the target I-O matrix.

If there are economic structure changes, we reckon MTT is one of the proper methods to update the I-O table. However, the structural change of the economy may not mean all sectors have a significant change. It might happen for some sectors in the economy.

This research aims to improve the result of updating the I-O table by MTT. Regarding the original MTT procedure based on the assumption that all elements have significant trends, it predicts all the transformed intermediate elements; however, we predict only some significant elements. To pursue the aim, the empirical analysis of updating Thailand's I-O tables is attempted. After updating the I-O table of Thailand by several models of the MTT, the results are assessed by comparing them with RAS--the most well-known and widely used method.

The paper is organized as follows. Later in this introduction, we introduce a simplification of an I-O table and its constraints to pave the way for understanding MTT and RAS. Then, Section 3 illustrates how to obtain a better result from the MTT method by the empirical analysis of Thailand's I-O table. Hereafter, Section 4 compares the updating results from both MTT and RAS methods, including eight models. Finally, the conclusion of the paper is presented in Section 5.

2. Updating Methods

This section shortly describes a generalized structure and the updating methods of an I-O table. We first illustrate the I-O table's transformation into a simplified I-O matrix and hereafter express the updating methods—MTT and RAS.

2.1 Simplification of the I-O Table to the I-O Matrix

The section simply describes the I-O table and its constraints. However, an understanding of the I-O structure is relevant for the discussion in the following sections.

The I-O table expresses the economic structure by applying a matrix framework to provide information on the purchase-sale relationships between sectors within an economy. The sectors indicated by the rows are thus producing commodities (output) that are the input of the sector indicated by the columns. The row totals thus signify the total sales of sectors, while the column totals are the total costs. The basic idea of the framework is to illustrate the relationship of the inputs used by a given sector related to the output by a linear and fixed coefficient production function.

Regarding the I-O table, as for n sectors in the economy, the first n rows and columns are for intermediate inputs and outputs. Besides, there are additional columns to indicate final demand and rows to indicate value-added. Therefore, the column totals together with the value-added must always equal the sum of the row totals and final demand for the I-O table to balance, as depicted in Figure 1.

		INTERMEDIATE OUTPUT		FINAL DEMAND		TOTAL OUTPUT
		$1 \cdots n$	TOTAL	C_i I_i G_i EX_i	TOTAL FINAL DEMAND	
INTERMEDIATE INPUT	1 $\vdots$ n	$x_{11} \cdots x_{1n}$ $\vdots \ \ddots \ \vdots$ $x_{n1} \cdots x_{nn}$	$\sum_{j=1}^{n} x_{1j}$ $\vdots$ $\sum_{j=1}^{n} x_{nj}$	c_1 i_1 g_1 ex_1 $\vdots$ $\vdots$ $\vdots$ $\vdots$ c_n i_n g_n ex_n	$x_{1(n+1)}$ $\vdots$ $x_{n(n+1)}$	$\sum_{j=1}^{n+1} x_{1j} = x_1$ $\vdots$ $\sum_{j=1}^{n+1} x_{nj} = x_n$
	TOTAL	$\sum_{i=1}^{n} x_{i1} \cdots \sum_{i=1}^{n} x_{in}$	$\sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij}$	$\sum_{i=1}^{n} c_i$ $\sum_{i=1}^{n} i_i$ $\sum_{i=1}^{n} g_i$	$\sum_{j=1}^{n} x_{(n+1)j} = \sum_{i=1}^{n} x_{i(n+1)}$	
VALUE ADDED	*wage* *surplus* *tag* *etc.*	$w_1 \cdots w_n$ $s_1 \ \ddots \ s_n$ $t_1 \cdots t_n$ $etc_1 \quad etc_n$				
	TOTAL VALUE-ADDED	$x_{(n+1)1} \cdots x_{(n+1)n}$				$\sum_{j=1}^{n+1} x_{(n+1)j} = x_{n+1}$
TOTAL INPUT		$\sum_{i=1}^{n+1} x_{i1} \cdots \sum_{i=1}^{n+1} x_{in}$				$\sum_{j=1}^{n+1} x_{(n+1)j} = \sum_{i=1}^{n+1} x_{i(n+1)}$

Figure 1: A general structure of an I-O table

To simplify the I-O matrix for n sectors, we leave the intermediate transaction of input and output as the same as the I-O table and apply the summation of final demand and the summation of value-added instead, as depicted in Figure 2.

$$\left[\begin{array}{ccc:c|c|c}
x_{11} & \cdots & x_{1n} & \sum_{j=1}^{n} x_{1j} & x_{1(n+1)} & \sum_{j=1}^{n+1} x_{1j} \\
\vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\
x_{n1} & \cdots & x_{nn} & \sum_{j=1}^{n} x_{nj} & x_{n(n+1)} & \sum_{j=1}^{n+1} x_{nj} \\
\hdashline
\sum_{i=1}^{n} x_{i1} & \cdots & \sum_{i=1}^{n} x_{in} & \sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij} & & \\
\hline
x_{(n+1)1} & \cdots & x_{(n+1)n} & & \sum_{j=1}^{n} x_{(n+1)j} = \sum_{i=1}^{n} x_{i(n+1)} & \\
\hline
\sum_{i=1}^{n+1} x_{i1} & \cdots & \sum_{i=1}^{n+1} x_{in} & & &
\end{array}\right]
=
\left[\begin{array}{c:c|c:c}
X & SO & FD & TO \\
\hdashline
SI & & & \\
\hline
VA & & \mu & \\
\hline
TI & & &
\end{array}\right]$$

Figure 2: The simplification of an I-O matrix from an I-O table of $n \times n$ sectors

Let X is the matrix of the intermediate transaction of the I-O table, a vector of SI and SO serve as the sector's summation intermediate input and output. Whereas VA and FD sequentially represent a vector of the sector's total value-added and total final demand. Additionally, TI and TO denote the sector's total input and output, respectively.

I-O table is a balanced table with distinct characteristics. It requires constraints in both columns and rows, which make each element in the table interdependency, as for the following:

Total input = Total output: $\sum_{j}^{n}\sum_{i}^{n+1} x_{ij} = \sum_{i}^{n}\sum_{j}^{n+1} x_{ij}$ (1)

Total sector's input of sector i = total sectors' output of sector j for i=j:

$$\sum_{i=1}^{n+1} x_{ij} = \sum_{j=1}^{n+1} x_{ij};\ \forall i = j;\ i, j = 1,2,\ldots,n \qquad (2)$$

The total value-added =Total final demand): $\sum_{j=1}^{n} x_{(n+1)j} = \sum_{i=1}^{n} x_{i,(n+1)} = \mu$ (3)

2.2 MTT Method

The MTT method of Wang et al. (2015) is the combination of the transformation matrix technique and time series forecasting to update the target I-O table. The process requires just the value-added of each sector and the total value-added (or the total final demand) of the target year. With a non-iterative procedure, the MTT result can fulfill the I-O table constraints that the summation of rows equals the summation of columns. Nonetheless, forecasting each element in the I-O table cannot be done directly due to the constraints. Hence, MTT relieves the constraints by transforming the I-O matrix to be the new matrix without constraints. Given a series of each element from an unconstrained matrix, we can update or forecast them independently. Hereafter, the approach back-transforms the forecasting matrix to the original form of the I-O table. In Brief, the explanation of the MTT procedure is as the following.

As for $n \times n$ sectors of the I-O table, the MTT requires an I-O matrix of $(n+1)\times(n+1)$.

$$X=\left[\begin{array}{ccc|c} x_{11} & \cdots & x_{1n} & x_{1(n+1)} \\ \vdots & \ddots & \vdots & \vdots \\ x_{n1} & \cdots & x_{nn} & x_{n(n+1)} \\ \hline x_{(n+1)1} & \cdots & x_{(n+1)n} & \sum_{j=1}^{n} x_{(n+1)j} \end{array}\right]=\begin{bmatrix} X_{n\times n} & FD_{n\times 1} \\ VA_{1\times n} & \mu \end{bmatrix} \quad (4)$$

Given T tables available of the I-O matrices, MTT uses a series of the I-O matrices, $X^1, X^2, \ldots, X^T$, to update the target I-O matrices; $\widehat{X}^{T+1}, \widehat{X}^{T+2}, \ldots$. First, the approach transforms the I-O matrices $(X^1, X^2, \ldots, X^T)$ by removing the I-O constraints to be the matrixes with unconstraints $(Y^1, Y^2, \ldots, Y^T)$. Afterward, the method forecasts the elements of transformed I-O matrices $(\widehat{Y}^{T+1}, \widehat{Y}^{T+2}, \ldots)$, and restores them to the original form of I-O matrices $(\widehat{X}^{T+1}, \widehat{X}^{T+2}, \ldots)$.

Step 1: Transformation:

The MTT transforms the historical I-O matrices $(X^1, X^2, \ldots, X^T)$ to break down their constraints, obtaining the unconstrained matrices $(Y^1, Y^2, \ldots, Y^T)$ so that we can freely forecast their elements. The procedure transforms two times. Firstly, it discharges the constraints (1) and (2) by transforming the I-O matrix as $y_{ij} = \dfrac{x_{ij}}{x_{i(n+1)}}; i = 1, 2, \ldots, n+1$. Even though $Y_{n\times n}$ is unconstraint, there is a constraint in the matrix from $\sum_{j=1}^{n} y_{(n+1)j} = 1$ due to (3). Since MTT makes a second transformation of $VAT_{1\times n}$ by $z_j = \dfrac{y_{(n+1)j}}{y_{(n+1)n}}; j = 1, 2, \ldots, n$. The result of the unconstraint-matrix, Y, of which elements can be freely forecast, written as;

$$\left[\begin{array}{ccc|c} y_{11} & \cdots & y_{1n} & 1 \\ \vdots & \ddots & \vdots & \vdots \\ y_{n1} & \cdots & y_{nn} & 1 \\ \hline y_{(n+1)1} & \cdots & y_{(n+1)n} & 1 \end{array}\right]=\begin{bmatrix} Y_{n\times n} & I_{n\times 1} \\ VAT_{1\times n} & 1 \end{bmatrix} \rightarrow \left[\begin{array}{cccc|c} y_{11} & \cdots & y_{1(n-1)} & y_{1n} & 1 \\ \vdots & \ddots & \vdots & \vdots & \vdots \\ y_{n1} & \cdots & y_{n(n-1)} & y_{nn} & 1 \\ \hline z_1 & \cdots & z_{n-1} & 1 & 1 \end{array}\right]=\begin{bmatrix} Y_{n\times n} & I_{n\times 1} \\ Z_{1\times n} & 1 \end{bmatrix}=Y$$

Step 2: Time series forecasting

This step forecasts the elements of $\widehat{Y}_{n\times n}^{T+1}, \widehat{Y}_{n\times n}^{T+2}, \ldots$ from the time series of unconstraint-matrices $(\widehat{Y}_{n\times n}^{1}, \widehat{Y}_{n\times n}^{2}, \ldots, \widehat{Y}_{n\times n}^{T})$.

Step 3: Back-transformation

The method restores $\hat{Y}^{T+1}, \hat{Y}^{T+2}, \ldots$ to be $\hat{X}^{T+1}, \hat{X}^{T+2}, \ldots$ to obtain the target I-O table.

Firstly, MTT makes a back-transformation of $Z_{1\times n}$ to $VAT_{1\times n}$ as the following.

$$y_{(n+1)j} = \frac{z_j}{\sum_{j=1}^{n} z_j} = \frac{z_j}{\sum_{j=1}^{n-1} z_j + 1} \quad \text{because of } \sum_{j=1}^{n} y_{(n+1)j} = 1\text{; now we get } \begin{bmatrix} Y_{n\times n} & I_{n\times 1} \\ VAT_{1\times n} & 1 \end{bmatrix}$$

Secondly, the process restores $VAT_{1\times n}$ to $VA_{1\times n}$. As for, we set μ as an exogenous variable such as GDP of the target year, this step can be the following.

$$x_{(n+1)j} = \mu \bullet y_{(n+1)j};\ j = 1,2,\ldots,n \quad \text{because of (3); now we get } \begin{bmatrix} Y_{n\times n} & I_{n\times 1} \\ VA_{1\times n} & \mu \end{bmatrix}$$

Thirdly, It restores $I_{n\times 1}$ to $FD_{n\times 1}$.

$$x_{i(n+1)} = B^{-1} Tran(x_{(n+1)j})$$

$$B = Diag(1 + \sum_{j=1}^{n} y_{1j}, 1 + \sum_{j=1}^{n} y_{2j}, \cdots, 1 + \sum_{j=1}^{n} y_{nj}) - Tran(Y_{n\times n})$$

Finally, MTT restores $Y_{n\times n}$ to $X_{n\times n}$.

$$x_{ij} = y_{ij} \bullet x_{i(n+1)};\ i, j = 1,2,\cdots,n$$

2.3 RAS Method

RAS is the well-known and widely used method to update the I-O table without generating a completely new set of inter-industry data, made known by Stone (1961); Stone and Brown (1962). The method is an iterative bi-proportional adjustment with the basic idea to minimize the dissimilarity between a prior table and a target table. The operation generates new I-O coefficients for the target year using only one from the previous year tables in conjunction with the target year total intermediate industry inputs $(SI_{1\times n})$ and outputs $(SO_{n\times 1})$, and total industry outputs $(TO_{n\times 1})$ (Jackson & Murray, 2004; Pavia, Cabrer, & Sala, 2009). However, a major defect of RAS is that it can only address non-negative tables.

3. Empirical Analysis

As for empirical analysis, we apply the time series of Thailand's I-O tables expressed in producers' prices containing 16 sectors. The aim is to identify the model among several models updating by MTT and RAS, which obtains the closest estimate to the actual 2015 I-O table. To achieve the task, we update the I-O matrix of 2015 via MTT for seven models and one from RAS.

Then, compare their updating results with the actual survey I-O table of 2015 to determine the relative performance of the updating methods.

The time series of I-O tables for 1975, 1980, 1985, 1990, 1995, 2000, 2002, and 2010 are applied as eight benchmarks to update the I-O table of 2015 of MTT. For the target year, we proceed only with the total value-added—the gross domestic product at a market price of 2015 from the national account published by the Office of the National Economic and Social Development Council of Thailand. Regarding the value-added of each sector of the target year, we would apply them for the analysis if they were available. However, when we compare the historical data of the I-O tables and the national account series, they are rather different. One of the reasons for the difference is the sector classification; the national account classifies the sectors by activities; on the other hand, the sectors of the I-O table are classified regarding commodities. Therefore, we forecast them. Instead of forecasting the value-added of each sector, we forecast $z_1, z_2, \cdots z_{n-1}$ similar to forecast $Y_{n \times n}$.

3.1 Structural Change

Before proceeding with the MTT to update the Thailand I-O table of 2015, we have to ensure that Thailand has had structural changes. Hence, we apply the trend analysis to test each time series element of the technical coefficient and also the transform matrixes—$Y_{n \times n}$. The most widely used to detect the straight-line trends in time series is the least-squares linear regression (Hanke, Reitsch, & Wichern, 2001). The research applies a conventional linear regression model for trend analysis to test the linear trend of each specific element, like the following,

$$data = \beta_0 + \beta_1 T + \varepsilon \quad (5)$$

Where $data_i$ denotes the tested element while T is the time variable. The parameter β_1 represents the rate of change of $data$ for the time, and β_0 is the intercept. ε is the error term. The results of the trend analysis are shown in Figures 3 to 4 ("T" means significant trend at $\alpha = 0.05$, "No T" represents the otherwise). The result shows 107 from 256 of the technical coefficient and 59 from 256 of transformed data, which have a significant trend. Therefore, this evidence could confirm an economic structure changing occurring in Thailand so that we can apply the MTT to update the Thailand I-O table of 2015.

Although many of the elements show evidence of a significant trend, it is not all of them. According to the assumption of Wang et al. (2015); Zheng et al. (2018), they assume all elements have a significant trend so that they forecast all elements of $Y_{n \times n}$.

Sector	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	FD
01	NO T	NO T	T	T	T	NO T	NO T	NO T	NO T	T	T	NO T	T	NO T	T	T	-
02	T	NO T	NO T	T	T	NO T	NO T	T	T	NO T	T	NO T	NO T	NO T	NO T	NO T	-
03	NO T	NO T	T	NO T	NO T	NO T	NO T	T	NO T	T	NO T	NO T	T	NO T	NO T	NO T	-
04	NO T	T	T	T	NO T	T	NO T	T	T	T	T	T	T	T	NO T	T	-
05	NO T	NO T	NO T	T	NO T	NO T	NO T	T	T	T	NO T	T	T	NO T	NO T	NO T	-
06	T	NO T	NO T	NO T	T	NO T	T	NO T	NO T	T	NO T	NO T	NO T	NO T	T	NO T	-
07	T	T	T	NO T	T	NO T	T	NO T	NO T	NO T	T	NO T	T	NO T	T	NO T	-
08	NO T	NO T	NO T	NO T	NO T	NO T	T	NO T	NO T	NO T	T	T	T	T	T	T	-
09	T	NO T	T	NO T	T	NO T	NO T	NO T	T	T	NO T	NO T	NO T	NO T	T	NO T	-
10	NO T	T	NO T	T	T	NO T	NO T	NO T	T	T	T	T	NO T	NO T	T	NO T	-
11	T	NO T	T	T	T	NO T	NO T	T	NO T	NO T	NO T	NO T	T	T	T	NO T	-
12	T	T	NO T	NO T	T	T	T	NO T	NO T	NO T	NO T	NO T	T	NO T	T	NO T	-
13	T	NO T	NO T	T	T	T	NO T	NO T	NO T	T	NO T	NO T	NO T	NO T	NO T	NO T	-
14	NO T	NO T	NO T	NO T	NO T	NO T	NO T	T	NO T	NO T	T	NO T	T	T	T	NO T	-
15	T	T	T	T	NO T	T	NO T	NO T	NO T	NO T	T	T	NO T	T	T	NO T	-
16	NO T	T	NO T	T	NO T	NO T	NO T	NO T	NO T	T	NO T	NO T	NO T	NO T	NO T	NO T	-
VA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Figure 3: The results of the trend analysis for technical coefficient elements

Sector	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	FD
01	NO T	NO T	NO T	NO T	NO T	T	T	NO T	NO T	NO T	T	NO T	NO T	T	NO T	NO T	NO T
02	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T
03	NO T	NO T	T	NO T	NO T	NO T	T	T	NO T	NO T	NO T	NO T	NO T	T	NO T	NO T	NO T
04	T	NO T	T	T	NO T	T	NO T	NO T	T	NO T	NO T	T	NO T	T	NO T	NO T	NO T
05	NO T	NO T	NO T	T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	T	T	NO T	NO T	T	NO T
06	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T
07	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T
08	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T
09	T	NO T	NO T	NO T	T	T	NO T	NO T	NO T	NO T	NO T	T	T	NO T	NO T	NO T	NO T
10	NO T	T	T	NO T	NO T	NO T	NO T	NO T	T	T	T	NO T	T	NO T	NO T	NO T	NO T
11	NO T	NO T	T	NO T	T	NO T	NO T	NO T	NO T	NO T	NO T	T	NO T	NO T	NO T	T	NO T
12	T	T	NO T	NO T	T	T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T
13	NO T	T	T	NO T	NO T	NO T	T	NO T	T	T	NO T	NO T	NO T	NO T	NO T	NO T	NO T
14	NO T	NO T	NO T	NO T	NO T	NO T	T	NO T	T	T	T	NO T	T	T	T	T	NO T
15	NO T	T	NO T	NO T	NO T	T	T	NO T	T	NO T	T	NO T	NO T	T	T	NO T	NO T
16	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T
VA	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	NO T	

Figure 4: The results of the trend analysis for the transformed elements

3.2 Correlation Between Technical Coefficients and Transformed Elements of the I-O Matrix

Due to the I-O matrix constraints, instead of directly forecasting the target I-O matrix ($X_{n\times n}$), we forecast the elements of the transformed matrix—$Y_{n\times n}$. However, the ultimate goal of the updating is not the best result of a transformed matrix of $Y_{n\times n}$; it is the best result of the I-O matrix (matrix of X, technical coefficient, and multiplier). Therefore, we check the trend of's element and the correlation between's element and the technical coefficient element. Pearson's correlation is applied to measure the association between each element of $Y_{n\times n}$ and the technical coefficient matrix. Based on our assumption that the higher correlation between them is, the better result of updating the I-O table we will obtain. Hence, the level of Pearson's correlation over 0.5, 0.6, 0.7, 0.8, and 0.9 are considered.

3.3 Updating the I-O Table by MTT

After relaxing the constraints of I-O benchmarks, we obtain $Y^1, Y^2, \ldots, Y^T$ from $X^1, X^2, \ldots, X^T$. Then, for the years between the public benchmark I-O tables, the linear interpolation method is applied. Hereafter, ARIMA models are used to forecast each element of $Y_{n\times n}^{2015}$ and $z_1, z_2, \cdots z_{n-1}$. Finally, we restore the transformed matrix to be the I-O table.

We proceed with seven models of MTT considering of's forecasting elements: (1) forecast all elements of $Y_{n\times n}^{2015}$, (2) forecast only elements of $Y_{n\times n}^{2015}$ having a statistically significant trend, (3-7) forecast only elements of $Y_{n\times n}^{2015}$ having a statistically significant trend, and correlating with technical coefficient series at 0.5, 0.6, 0.7, 0.8, and 0.9 respectively.

4. Empirical Results

Identification of the outstanding models for updating the Thailand I-O table involves comparing the target year's updating matrix and the actual survey I-O matrix of Thailand in 2015. Even the closeness of updating and the actual survey-based of the I-O table is the crux of the matter; however, a decision should consider the estimated technical coefficient and multiplier matrices (Jalili, 2006; Stoeckl, 2012) because they are the core of the I-O analysis. Since the target

I-O table for the research contains 16 sectors, $(n+1)\times(n+1)=17\times17=289$ elements are assessed for the I-O table (including the component of value-added, final demand, and the total value-added), and $n\times n=16\times16=256$ elements are checked for the technical coefficient and the multiplier matrices.

The four common indices used for this task are employed: Standardized Total Percentage Error (Miller & Blair, 1985), Theil's U (Theil, 1971), Standardized Weighted Absolute Difference (Lahr, 1998), and Mean Absolute Percentage Error (Butterfield & Mules, 1980).

Standardized Total Percentage Error (STPE): $$STPE=\frac{100\sum_{i=1}^{m}\sum_{j=1}^{m}\left|\hat{x}_{ij}-x_{ij}\right|}{\sum_{i=1}^{m}\sum_{j=1}^{m}x_{ij}} \quad (6)$$

Theil's U (Theil): $$U=\sqrt{\frac{\sum_{i=1}^{m}\sum_{j=1}^{m}\left(\hat{x}_{ij}-x_{ij}\right)^2}{\sum_{i=1}^{m}\sum_{j=1}^{m}x_{ij}^2}} \quad (7)$$

Standardized Weighted Absolute Difference (SWAD): $$SWAD=\frac{100\sum_{i=1}^{m}\sum_{j=1}^{m}x_{ij}\left|\hat{x}_{ij}-x_{ij}\right|}{\sum_{i=1}^{m}\sum_{j=1}^{m}x_{ij}^2} \quad (8)$$

Mean Absolute Percentage Error (MAPE): $$MAPE=\frac{1}{(m)^2}\sum_{i=1}^{m}\sum_{j=1}^{m}\left|\frac{\hat{x}_{ij}-x_{ij}}{x_{ij}}\right| \quad (9)$$

Let $\hat{x}_{ij}$ is the updating value, and x_{ij} is the benchmark value (the actual value from the survey). While m is the number of the updating elements of which the I-O table is $m=n+1$, otherwise $m=n$. Additionally, regarding MAPE, for x_{ij} is zero, the particular value is out of the calculation (Butterfield & Mules, 1980; Wang et al., 2015)

As for the performance evaluation, the negative I–O coefficients are considered meaningless. Hence, the updating methods that estimate a higher number of negative coefficients are viewed as the model's weakness (Jalili, 2000). The empirical experiment presents MTT by forecasting all elements (Model 1) containing 13-negative technical coefficients and 10-negative multipliers, indicating the model's meaninglessness. Hence, we will not consider it as a candidate.

On the other hand, the updating matrices' results of MTT by forecasting only some element of $Y_{n\times n}$, they do not present the negative coefficients both technical coefficients and multiplier.

According to Table 1, considering only the first three indices (STPE, U, and SWAD) MTT, forecasting only some elements with significant trends and highly correlated with the technical coefficient $(e.g.\ r\geq0.8)$ is outstanding. The results of updating the I-O, technical coefficient, and multiplier matrices by MTT of Model 6 and Model 7 are outperformed Model 8 by RAS (except only in updating the I-O matrix considering by STPE, RAS obtains the better result).

However, considering MAPE, MTT shows poorer performance than RAS. The poor result stems from some specific elements. For example, $y_{1,8}$, $y_{2,4}$, $y_{4,5}$ are the cause of the low performance of updating the I-O and technical coefficient matrices; whereas, the low performance of updating the multiplier matrix is mostly caused by $y_{4,5}$, $y_{4,16}$, $y_{5,6}$. Nevertheless, according to Moreno, Pol, Abad, and Blasco (2013); Tayman and Swanson (1999), MAPE is an error overstatement when the actual values are small; in addition, a few outlying errors easily influence it.

Table 1: Results of performance evaluation for I-O updating in 2015

		MTT Method							8. RAS Method
		1. Forecast $Y_{n\times n}$	2. y_{ij} has a trend	y_{ij} has a trend					
				3. $cor \geq 0.5$	4. $cor \geq 0.6$	5. $cor \geq 0.7$	6. $cor \geq 0.8$	7. $cor \geq 0.9$	
No. of Negative Value	Technical coefficient	13	0	0	0	0	0	0	0
	Multiplier	10	0	0	0	0	0	0	0
No. of forecast y_{ij}		256	59	36	36	34	30	17	-
STPE	I-O value	18.1160	16.8522	16.2998	16.2998	16.2985	15.6345	15.5582	**15.4255**
Theil_U		0.1056	0.1378	0.1348	0.1348	0.1349	0.1277	**0.1273**	0.1280
SWAD		5.3371	7.9109	7.7806	7.7806	7.7804	7.4444	**7.4312**	7.4587
MAPE		61.8219	50.2901	49.7689	49.7689	49.7708	49.7196	49.4911	**47.4645**
STPE	Technical coefficient	23.7706	12.2979	12.2237	12.2237	12.2118	**11.5195**	11.6277	11.6554
Theil_U		0.2264	0.1249	0.1234	0.1234	0.1234	0.1197	**0.1195**	0.1199
SWAD		14.3126	7.8872	7.9398	7.9398	7.9369	**7.3850**	7.4042	7.6127
MAPE		68.4596	40.9719	40.8202	40.8202	40.8212	40.5876	40.5988	**38.5159**
STPE	Multiplier	13.5807	6.7564	6.3700	6.3700	6.3680	5.9725	**5.9687**	6.0138
Theil_U		0.1071	0.0561	0.0534	0.0534	0.0534	0.0488	**0.0486**	0.0491
SWAD		4.7262	3.0677	2.9070	2.9070	2.9075	2.6765	**2.6578**	2.8184
MAPE		38.1124	16.6863	16.3320	16.3320	16.3655	16.2108	16.0950	**15.9867**

Since Model 7 by MTT and Model 8 by RAS are outstanding, we show, the comparable I-O value contains 16 sectors (including 256 elements) between Model 7, Model 8, and the actual I-O for 2015 in Figure 5. Most results of MTT and RAS do not show extremely different directions, accept $\hat{y}_{1,13}$, $\hat{y}_{2,5}$, $\hat{y}_{3,9}$. As for $\hat{y}_{1,13}$ and $\hat{y}_{2,5}$, MTT is closer to the actual value; however, RAS is closer for $\hat{y}_{3,9}$.

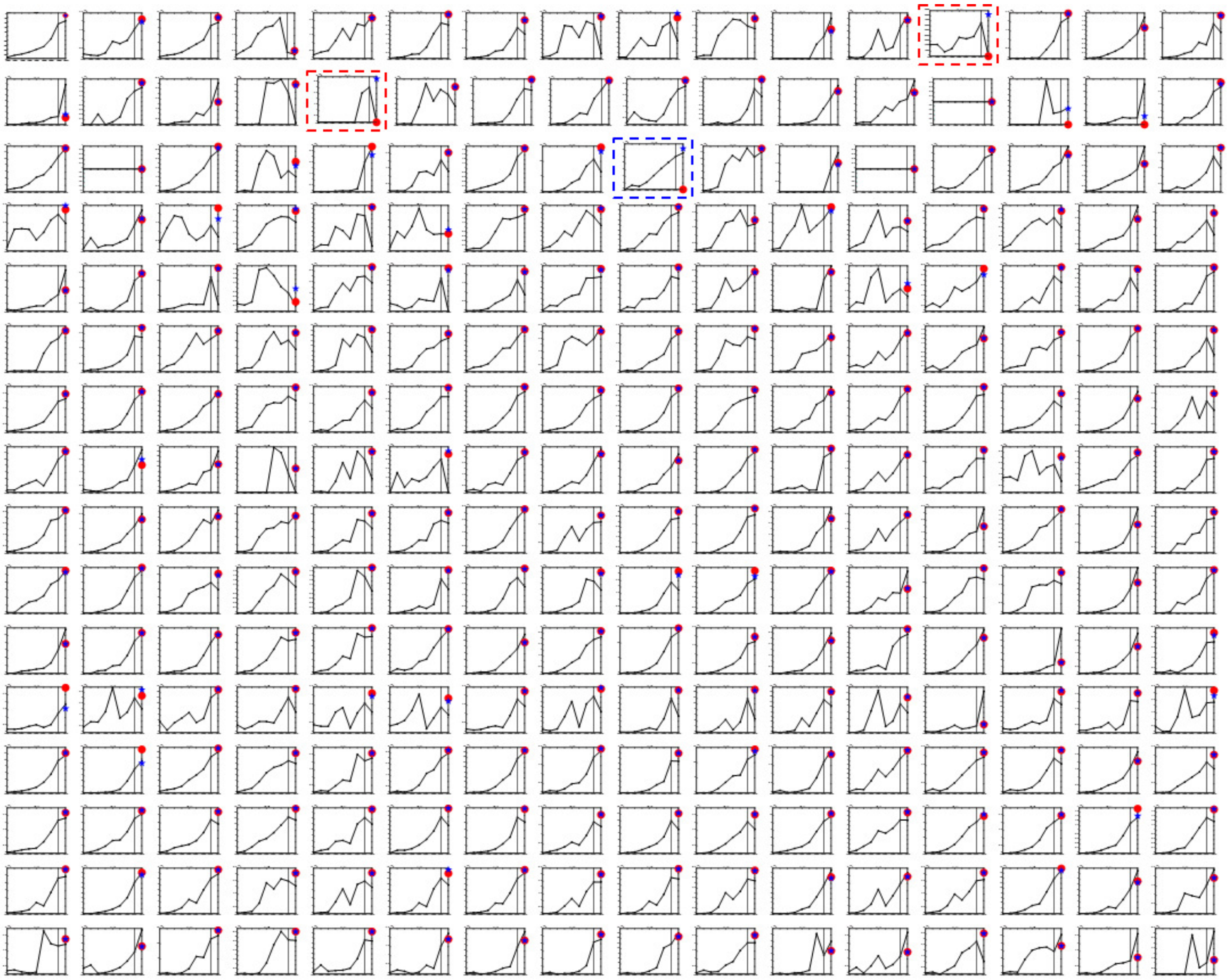

Figure 5: Comparison of 256 elements of I-O matrix between Model 7 by MTT, Model 8 by RAS, and the actual values from the survey of 2015.

Note: -* the actual values from the survey; ● Model 7 by MTT; ★ Model 8 by RAS

MTT is closer to the actual value; RAS is closer to the actual value

5. Conclusion

On particular importance of the research is how to obtain a better result of updating the I-O table from the MTT method. The MTT procedure combines the techniques of matrix transformation and time series forecasting. Later unchain the I-O's constraints by matrix transformation, freely forecast each element of the matrix can be done. Under the assumption of economic structural changes, MTT is suitable for updating the target I-O table. Regarding the original proposed by Wang et al. (2015), and later applied for updating China's I-O table by Zheng et al. (2018), illustrates the structural change by showing graphs of technical coefficient, transaction value, and transform-value. Assuming all the I-O time-series intersection elements have a statistically significant trend, they predict all of the target's transformed intersection elements. Considering the whole updating I-O table, not including the technical coefficient and multiplier matrix, they conclude that the MTT method is preferable to the alternative updating approaches.

Instead of forecasting all transformed intersection elements, we forecast only significant elements. Our empirical result of updating the Thailand I-O table shows that MTT obtains a better result when we forecast only the transformed elements having a significant trend and correlating with a technical coefficient. The work of MTT by predicting all elements contains some negative technical coefficients and negative multipliers, which indicates the model's meaninglessness; however, MTT with forecast only significant elements is not.

Besides, we also compare the well-known method of RAS to MTT with forecast only significant elements. Considering four evaluation indices—STPE, U, SWAD, and MAPE, MTT shows the superior work of three from four indices for updating the technical coefficient and multiplier matrices. However, MTT gains two indices equal to RAS for updating the I-O table. Please noted that MAPE overstates the error because a few outlying errors easily influence it, and while the actual values are small (Moreno et al., 2013; Tayman & Swanson, 1999; Wang et al., 2015). In case considering only three indices exclude MAPE, MTT is the most outstanding.

In conclusion, if there is a significant economic structural change, we recommend considering the MTT method to update the target I-O matrix by forecasting only the transformed elements of a significant trend and high correlate with a technical coefficient. Nevertheless, no one is perfect, reminding that the pure-MTT method cannot assure a generation of non-negative coefficients in the updating procedure; on the contrary, the RAS does not contain negative coefficients in either direct or inverse instances. Moreover, even RAS is still the most accepted and applied method of bi-proportional technique (Szabó, 2015). We hope to see the comparison of MTT and CRAS instead of only RAS for updating I-O products because Mínguez et al. (2009) confirm that CRAS outperforms RAS when evidencing economic structural change.

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