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Common Components in Co-integrated System and Its Estimation and Application: Evidence from Five Stock Markets in Asia-Pacific Chinese Region

Hsiang-Hsi Liu[1*] and Chien-Kuo Tseng[2]

Abstract

Previous studies on co-integration focused on whether there is co-integration between variables, and might not explore which variables are caused when co-integration exists. This study is based on a multivariate factor model and apply Quah's decomposition theorem to derive common factors affecting long-run equilibrium, and use this common factor to explain which variables affect the formation of co-integration. Empirically, five stock markets in the Asian-Pacific Chinese region (Hong Kong, Singapore, Taiwan and China including Shanghai and Shenzhen stock markets) are the objects of analysis. According to the estimated common factor, the existence of the co-integration among the five stock markets is caused by the stock markets in Taiwan and Hong Kong. Therefore, when investing in these five stock markets, investors must incorporate and use the information of the two stock markets as a decisive factor in order to promote correct decision-making. That is, the policy authorities of these countries should promote the effective interaction and operation of the stock market. The decisive influence of stock market information in the two countries cannot be ignored.

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Keywords: Co-integration, Error Correction Model (ECM), Common Component, Quah's Decomposition Theorem.

[1] Distinguished Professor, Graduate Institute of International Business, National Taipei University, Taiwan.
[2] Master, Graduate Institute of International Business, National Taipei University, Taiwan.

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1 Introduction

Box-Jenkins' analysis of time series points out that stable (stationary) short-term time series have better predictive effects. However, the main general economic data are mostly non-stationary time series. It is not possible to directly use the Box-Jenkins model or causal correlation model to estimate or predict the original value. Instead, the original value is used for regression analysis, which will result in spurious regression. Although the differencing method can be used to transform an unstable series into a stable series and obtain short-term estimation or prediction results, long-term information may be ignored, it is still impossible to understand the interactive influence of the long-term information of the series on the related series. Granger (1986), Engle and Granger (1987) proposed the concept of co-integration, using a two-stage estimation method to estimate the co-integration vector, and endowing the two co-integration series with economic meaning, and making the unstable series also have long-term adjustment effects. Long-term analysis can also be carried out on a number of indicators (such as GNP, consumption, income, etc.) that require long-term forecasts in the overall economy (Chaudhuri and Smiles, 2004; Padilla and Garrido, 2018; Guntukula, 2018).

At that time, the research literature of Engle and Granger (1987) only applied to the analysis of co-integration between two variables, and did not analyze multiple variables at the same time. Therefore, Johansen (1988) and Johansen and Juselius (1990, 1992) proposed the method of maximum likelihood estimation (MLE) suitable for multivariate estimation of co-integration vector, the existence of co-integration can also be considered for multiple non-stationary time series, so that the interactive effects of variables related to the entire economic system can be considered at the same time. The results of such estimates and predictions will not cause deviations or biases in the analysis (Johansen and Juselius, 1990, 1992; Hasanov, Hunt and Mikayilov, 2016).

In the study of co-integration, we usually only explore whether there is a co-integration relationship between two variables or multiple variables, and then make empirical explanations. For example, whether there is room for arbitrage in the commodity markets (Figuerola-Ferretti and Gonzalo, 2010) or whether the stock markets of multiple countries react in the same direction without hedging risks (Rizwanullah, Liang, Yu, Zhou, Nasrullah and Ali, 2020) and other related issues such as price discovery (Yan and Zivot, 2010; Xu, 2018) . However, such empirical research only confirms the "whether there is" co-integration. Once the empirical result shows that co-integration exists, only the number of co-integration vectors is estimated or tested, and it is impossible to know which variables affect the long-term equilibrium. That is, when there is a disequilibrium, it is only known that there will be a long-term equilibrium between the variables through adjustment disequilibrium error via the error-correction, and it is impossible to know which variables will interact and adjust to promote the emergence of a long-term equilibrium (Mohanasundaram and Karthikeyan, 2015; Caporale, Gil-Alana and You, 2022). In view of the above problems, this research will establish a complete basic analysis framework through the methods of statistics and econometrics, so as to have a solid theoretical analysis concept for the above problems, and further use this model to detect the co-integration effect of stocks in order to verify the dominant or lead effect of implicit common factor model in the co-integration system (Gonzalo and Granger, 1995; Casoli and Lucchetti, 2021). Based on the multivariate factor model, this study uses Quah's (1992) decomposition theorem to deduce and estimate the common factors affecting long-term equilibrium. . It is hoped that our empirical results can highlight the contribution of this study.

As is known to all, the economic development of the Asia-Pacific Chinese Region (Mainland China, Hong Kong, Singapore and Taiwan) will become more and more important in the years to come. With frequent trade, capital flow and mutual investment between countries, the stock market in this region, which highlights a country's economic situation, has become the main research object of this study. The geographic proximity and homogeneous culture between the stock markets in Taiwan, Hong Kong, Singapore and Mainland China help smooth the flow of information between these markets. Therefore, the transmission of information between these markets should be more efficient. Because they share similar cultural and policy implementation characteristics and are closely related in terms of trade policies, stock price co-integration and return spillovers are thought to be more pronounced in countries operating in the close region. In this study, the analysis of stock price co-integration and return should not only take into account stock market information from its own market but also the interaction effects from neighboring countries and further detects the whether there is stock price co-integration or even to verify the dominant or lead effect of implicit common factor model in the co-integration system. Some literature (Yeh and Lee, 2000; Cheng and Glascock, 2005; Johansson and Ljungwall, 2009, Huang and Kuo, 2015 and Mitra and Iyer, 2017) depicted that information transmission between the greater China stock markets, indicating that stock information transmission has increased and the Chinese stock market is well linked to the neighboring markets of Taiwan, Hong Kong and Singapore. The evidence suggests that these markets are closely linked and increasingly integrated. In other words, it can be hypothesized or believed that if these markets are integrated, then unexpected events in one market will affect not only the co-integration of stock prices, but also the linkage of returns with other markets. To achieve our research purpose, five stock markets in Asia-Pacific Chinese Region as indicated above are chosen for empirical analysis.

The rest of the research is organized as follows. Sections 2 discusses the basic model framework related to co-integration, error correction model and permanent-transitory decomposition method, while Section 3 depicts empirical results and analysis. Section 4 presents concluding remarks.

2 Basic Model Framework

As mentioned above, this research aims to explore the common factors implicit in the co-integration system. To achieve this research purpose, it is necessary to have a general understanding of the basic model framework, so as to facilitate the establishment of the model in empirical analysis. In this section, the co-integration theory and the error correction model-ECM since Granger (1986) are summarized, and the long-term and short-term term decomposition or so-called permanent-transitory decomposition (P-T decomposition) method to detect common component used in this study will be explained.

2.1 Co-integration Theory and Error Correction Model

Since Granger (1981) first proposed the concept of co-integration in 1981, he put forward verification and estimation in a complete manner in 1987. So far, the co-integration has achieved more specific application results in econometric regression (Engle and Granger, 1987; Phillips, 1991; Lieberman, Ben-Zion and Hauser, 1999; Niyimbanira, 2013; Barigozzi, Lippi and Luciani, 2016; Gulzar, Mujtaba Kayani, Xiaofen, Ayub, and Rafique, 2019; Maiti, Vukovic, Vyklyuk and Grubisic, 2022). The proposal of co-integration is mainly to solve the problem caused by spurious regression. Difference is the method to perform quantitative regression for non-stationary time series, but it will change some properties of the original series, for example, the series will lose long-term information. Therefore, when Engle and Granger (1987) published the mathematical derivation, statistical test and estimation method of co-integration in 1987, the study of this problem became an important field of econometric regression.

In general, time series can only be analyzed by econometric method if it is stationary-state. Otherwise, spurious regression will occur when OLS is used to estimate parameters. Now, the stationary series will be explained first. When a time series satisfies Equation (1), Equation (2) and Equation (3), the time series is called weak stationary or covariance stationary.

$$E(X_t)=\mu \tag{1}$$

$E(X_t - \mu)^2 = \sigma_0^2$ (2)

$E(X_t - \mu)(X_{t-k} - \mu) = \sigma_k^2$ (3)

The expected value and variance of X_t in equations (1) and (2) are constant and independent of time. Equation (3) shows that the auto-covariance of X_t and X_{t-k} is only related to the number of lag periods and has nothing to do with time.

Co-integration studies mainly focus on the same integration order among variables. If a low integration order can be obtained through linear combination, all variables have the property of co-integration. Granger((1988a, 1988b) has the following definition of integrated order and co-integration: If a non-stationary series is after d difference to be a stationary, invertible, non-deterministic trend ARMA series, then the series is called d-order integration, denoted as I(d), or $\Delta^d X_t$ ~I(0). Where d is the difference operator, $\Delta X_t = X_t - X_{t-1}$. If X_t is a vector of P×1, and each variable in X_t is I(d), and there is a vector ($\beta \neq 0$), such that $Z_t = \beta' X_t$ ~I(d-b), 0<b<d, then Z_t is called a co-integration series (d, b) and is denoted as CI(d, b), where β is called co-integration vector. The vector that may not be unique in the definition, it can also be a matrix.

Although the variables X_t and Z_t in the definition are I (d) and I (d-b) respectively, the non-stationary variables in general measurement are mostly I (1). Therefore, X_t and Z_t are mostly used as I(1) and I(0) respectively in empirical test, and the testing methods are mostly used for stationary series I(0) and non-stationary series I(1), because it is easier to identify and analyze. According to the definition of cointegration, when a p-dimensional non-stationary series can be related by a relation with a constant error term, it is called co-integration. In the long term, each variable's movements are random walk, it is difficult to predict its trend, but there is always a certain proportional relationship (β') between the variables. They do not become farther and farther away from each other as time passes, but move together as a group of variables through some common components. Co-integration analysis is one of the important methods to explore and find out this phenomenon.

Engle and Granger (1987) further explained with the error correction model (ECM) that when there is co-integration among variables, that is, when there is long-term equilibrium among variables, the relationship between variables can be expressed by the ECM.

The vector variable error correction model is expressed as follows:

$A(B)(1-B) X_t = -\alpha Z_{t-1} + \varepsilon_t$ (4)

Where ε_t is the stationary disturbance, i.e., white noise process, $\varepsilon_t \overset{iid}{\sim} (0, \sigma^2)$ and A(0)=I, $Z_t = \beta' X_t$ is the stationary series.

The above definition is mainly based on the concept of error correction mechanisms. When disequilibrium of variables in the current period can be adjusted in the next period, although there may be disequilibrium among variables in the short term, equilibrium can be achieved after long-term adjustment. Therefore, if we want to know whether there is co-integration among variables or whether there is long-term equilibrium among variables, we can get it by studying whether variables can be expressed as ECM, which is the importance of ECM.

Now, we try to make a simple explanation between two variables. Assuming that X_t and Y_t are co-integrated, and their error correction model can be written as:

$$\Delta Y_t = \alpha \Delta X_t + \lambda (Y_{t-1} - \beta X_{t-1}) + u_t \tag{5}$$

The above equation is a short-term dynamic adjustment equation, in which the change of Y_t (ΔY_t) comes from the immediate change of X_t (ΔX_t) and the adjustment of the equilibrium error of the previous period ($Y_{t-1} - \beta X_{t-1}$), and both short-term dynamic and long-term adjustment effects are considered. If X_t and Y_t are I(1), on the premise of co-integration (belonging to I(0)), all items in the error correction model are I(0). OLS can be used to estimate α and λ, which solves the problem of generating spurious regression.

When discussing econometric time series, vector auto-regressive (VAR) model is closely related to error correction model (Engle and Granger, 1987; Granger, 1988a and 1988b), which is illustrated here. Let X_t be the I(1) vector time series of P×1, and its VAR(k) expression is:

$$X_t = \mu + \varphi D_t + \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \ldots + \Pi_k X_{t-k} + \varepsilon_t \tag{6}$$

Where ε_t is a vector white noise process with iid N(0,Λ), $X_{-k+t}, \ldots, X_0$ are known, μ is a constant vector of order P, and D_t is a seasonal dummy variable whose sum is zero after centering.

Equation (6) is simply derived:

$$X_t - X_{t-1} = \mu + \varphi D_t + \Pi_1 X_{t-1} - X_{t-1} + \Pi_2 X_{t-2} + \ldots + \Pi_k X_{t-k} + \varepsilon_t \tag{7}$$

$$\Delta X_t = \mu + \varphi D_t + (\Pi_1 - I)(X_{t-1} - X_{t-2}) + (\Pi_2 + \Pi_1 - I) X_{t-2} + \ldots + \Pi_k X_{t-k} + \varepsilon_t \tag{8}$$

The following error correction model (ECM) representation is obtained:

$$\Delta X_t = \mu + \Pi X_{t-k} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \varphi D_t + \varepsilon_t \tag{9}$$

$$\Gamma_i = -(I_p - \Pi_1 -, \ldots, - \Pi_i),\ i=1, ..., k-1$$

$$\Pi = -(I_p - \Pi_1 -, \ldots, - \Pi_k)$$

Where Δ represents the first difference lag operator. ΠX_{t-k} is error correction term, which measures the deviation from the long-term equilibrium and causes the correction of the equilibrium through its effect on ΔX_t. $\Pi = -(I_p - \Pi_1 -, \ldots, - \Pi_k)$ is called the long-term response matrix , where I_p is an identity matrix. It measures cumulative long-term effects.

According to ECM, there are two forces that can change ΔX_t, one is $\sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i}$, where ΔX_{t-i} has a short-term self-adjustment effect, Γ_i represents the short-run dynamics. The other is ΠX_{t-k}

, which represents the impact of previous disequilibrium on the current adjustment is a long-term relationship. Π is called impact matrix, and its rank has a key significance to the entire model and determines the properties of X_t, which are explained as follows:

(1) If rank (Π)=p, X_t is a stationary series, that is, $X_t \sim I(0)$. There are only short-term effects between variables, so there is no need to investigate co-integration.
(2) If rank (Π)=0, then X_t is a traditional non-stationary vector autoregressive moving average (k-1,1,0) or VARMA (k-1,1,0), there is no co-integration, that is, after short-term disequilibrium between variables appear, it cannot tend to long-term equilibrium.
(3) If 0 < rank (Π) = r < p, it implies that there are r co-integrated vectors between X_t, so that the linear combination of X_t becomes a stationary time series. The fundamental theorem of linear algebra shows that $\Pi=\alpha\beta'$, where α, β is a p×r full rank matrix. β is the co-integration vector of X_t which contains information on the long-run relationships among the variables, and α is the matrix that represents the speed of the adjustment to the equilibrium when the system is out of equilibrium.

Johansen and Juselius (1990) are the main researchers of co-integration research after Engle and Granger. In contrast to Engle and Granger's two-stage approach in co-integration estimation and test of multivariable variables, Johansen and Juselius (1990) proposed the maximum likelihood estimation (MLE) method to estimate the co-integration vector and verify the co-integration vector to determine whether the co-integration exists. Johansen (1991), Johansen and Juselius (1992) and Johansen (1994) provided some restricted tests for the co-integration vector and adjustment speed matrix and Johansen (1994) explained the method of co-integration dimension verification, to meet the needs of economic demonstration. The literature research of Johansen (1992, 1994) added nonlinear time trend term into the model, so that the research after the verification of co-integration existence and co-integration vector is more complete is focused on the application of empirical evidence.

2.2 Permanent-Transitory Decomposition Method

In general co-integration research, most literature usually only discuss whether there is a co-integration relationship between two variables or multiple variables, and then make empirical explanations, such as whether there is arbitrage space in the two commodity markets or whether the multi-country stock markets react in the same direction and cannot avoid risks. However, such empirical research only confirms the existence of co-integration. Once the empirical result is that co-integration exists, only the number of co-integration vectors is estimated or verified, and it is impossible to know which variables affect the long-term equilibrium, that is, when the equilibrium exists, it is only known that there will be a long-term equilibrium among the variables, and it is impossible to know which variables will interact and adjust to promote the emergence of a long-term equilibrium(Stock and Watson, 1988; Gonzalo and Granger, 1995; Hecq, Palm and Urbain, 2000; Barigozzi, Lippi and Luciani, 2016 and Casoli and Lucchetti, 2021). That is, when there is a disequilibrium between variables, it is only known that the variables will move towards long-term equilibrium, but it is impossible to know which variables will interact and adjust to promote the emergence of long-term equilibrium (Gonzalo and Granger, 1995; Hecq, Palm and Urbain, 2000 and Barigozzi, Lippi and Luciani, 2016; Kapar, Olmo and Ghalayini, 2020). Therefore, based on the multivariate factor model and using the decomposition theorem of Quah (1992), this study will deduce the common factor affecting long-term equilibrium, which is the so-called trend or force formed by dominant co-integration. It also highlights the biggest difference and contribution between this study and other papers. Basically, the purpose of this study is to estimate the long-run impact factors of a multivariate time series with co-integration. The research method first starts from the concept of co-integration, and then decomposes the long-run and short-run terms of a non-stationary time series according to the permanent-transitory decomposition (P-T decomposition) method proposed by Quah (1992). By using Johansen's maximum likelihood estimation method to estimate the long-run and short-run terms respectively, the content represented by the long-run term is the long-run impact factor affecting the entire co-integration system. In this way, we can not only test whether there is long-run equilibrium in the whole multivariable time series (whether there is co-integration or not), but also further explore which are the main influencing variables (common factor) and which are affected variables to understand the dynamic adjustment process of how short-run disequilibrium lead these variables together toward long-run equilibrium.

In this section, a brief description of statistical factor analysis is given before discussing the decomposition of the long-run and short-run terms in the time series. Factor analysis has been developed in statistics for many years. Its main purpose is to represent the original data structure in fewer dimensions while preserving most of the information provided by the original data structure. Basically, it explores the complex combination of variables in multivariate data, conducts exploratory research to find potential features for future experiments or conducts relevant empirical analysis. Factor analysis (Geweke, 1977; Forni, Hallin, Lippi and Reichlin, 2000) assumes that the response of a sample unit to a variable is composed of two parts: one is the part common to all variables, called the common factor, and the other is the part unique to each variable, called the unique factor. The common factors are not related to the unique factors and the factors formed by other residual terms. In general, factor analysis can be expressed as the following model:

$$X_1 - \mu_1 = \ell_{11} F_1 + \ell_{12} F_2 + \ldots + \ell_{1m} F_m + \varepsilon_1$$

$$X_2 - \mu_2 = \ell_{21} F_1 + \ell_{22} F_2 + \ldots + \ell_{2m} F_m + \varepsilon_2$$

$$\vdots$$

$$X_p - \mu_p = \ell_{p1} F_1 + \ell_{p2} F_2 + \ldots + \ell_{pm} F_m + \varepsilon_p \quad (10)$$

In the model, $X_1, X_2, \ldots, X_p$ are observable P variables, $F_1, F_2, \ldots, F_m$ are common factors. Factor analysis is to use m common factors to capture the characteristics of P-dimensional samples, and use this factors of lower dimensions to analyze the characteristics between the original variables ($X_1, X_2, \ldots, X_p$) for the purposes of factor analysis.

Assuming that Y_t, X_t are I(1) random process, Y_t, X_t can be expressed as follows respectively:

$$Y_t = \mathrm{A} f_t + \tilde{Y}_t \quad (11)$$

$$X_t = f_t + \tilde{X}_t \quad (12)$$

Where Y_t, X_t, f_t ~I(1) and $\tilde{Y}_t, \tilde{X}_t \sim$ I(0)

The above two expressions are based on the fact that the two variables have a common factor f_t, then Z_t is the linear combination of Y_t and X_t.

$$Z_t = Y_t - \mathrm{A} X_t = \tilde{Y}_t - \mathrm{A} \tilde{X}_t \sim \mathrm{I}(0)$$

According to the definition of co-integration, if Y_t and X_t are I(1) random processes, also there is A such that $Z_t = Y_t$ -A X_t is an I(0) random process, then Y_t and X_t have co-integration. According to this, both Y_t and X_t variables are I(1) random processes, if there is a common factor f_t between these two variables, then the two variables are co-integrated. Conversely, if the two variables have co-integration, there must be a common factor f_t.

It can also be expressed as the factor model of Equation (13) to indicate whether co-integration exists (Stock and Watson, 1988; Gonzalo and Granger, 1995):

$$\begin{bmatrix} Y_t \\ X_t \end{bmatrix} = \begin{bmatrix} A \\ 1 \end{bmatrix} f_t + \begin{bmatrix} \tilde{Y}_t \\ \tilde{X}_t \end{bmatrix} \tag{13}$$

Where Y_t, X_t, f_t~I(1) and $\tilde{Y}_t, \tilde{X}_t \sim$I(0)

To explore whether Y_t and X_t are co-integrated, we can obtain it by exploring whether Y_t -A X_t is A random process of I(0). Since the linear combination of I(1) random processes is still an I(0) random process, Y_t -A $X_t = \tilde{Y}_t$ -A $\tilde{X}_t \sim$I(0) in the factor model, it can be known that Y_t and X_t have co-integration, that is, if Y_t and X_t can be expressed as the above factor model, then Y_t and X_t have co-integration.

In general, co-integration studies mostly estimate and verify the co-integration vector (1, A), that is, the existence of co-integration and the dimension of co-integration vector are estimated and verified. According to Equation (13), it can be seen that the existence of co-integration is closely related to the existence of common factor f_t. In Equation (5), B and its variable can be expressed as Equation (13), i.e., f_t exists, then co-integration exists, and the component represented by f_t is the main factor causing long-term equilibrium in the co-integration system. Therefore, if we can know the existence of f_t and the estimate f_t. Therefore, not only can the existence of co-integration be verified, but also the reasons for the formation of long-term equilibrium can be further understood from the information of common factor f_t, and the study of long-term equilibrium can have more thorough results.

In order to estimate the common factor f_t, some constraints must be added to facilitate mathematical estimation. First, assume that

$$f_t = B_1 X_t \tag{14}$$

That is, f_t is a linear combination of variable X_t. This assumption is of great significance, because such an assumption makes a certain connection between the common factors f_t and variable X_t, which is conducive to analyzing the long-term equilibrium between variables only after estimating f_t. The P-T decomposition proposed by Quah (1992) is used to estimate f_t. Now, the concept and mathematical derivation process of P-T decomposition are explained as follows:

If $X_t \sim I(1)$ and we want to decompose X_t into two random processes P (long-run term) and T (short-run term), the following four points in the P-T decomposition should be met (Quah, 1992; Gonzalo and Granger, 1995):

(1) $P_t \sim I(1), T_t \sim I(0)$

(2) var (ΔP_t) and var(T_t)>0

(3) $X_t = P_t + T_t$

(4) Let the AR expression of ($\Delta P_t, T_t$) be:

$$H^*(L)\begin{bmatrix}\Delta P_t \\ T_t\end{bmatrix} = \begin{bmatrix}u_{P_t} \\ u_{T_t}\end{bmatrix}$$, u_{P_t} and u_{T_t} are not correlated

and (a) $\lim_{h\to\infty} \frac{\partial E_t(X_{t+h})}{\partial u_{P_t}} \neq 0$

(b) $\lim_{h\to\infty} \frac{\partial E_t(X_{t+h})}{\partial u_{T_t}} = 0$

Where E_t is the conditional expectation with respect to the previous information.

According to the above definition (Quah, 1992), if a variable is to conform to P-T decomposition, T_t cannot have a long-run effect on X_t, for example:

$$X_t = P_t + T_t \tag{15}$$

$$\Delta P_t = a_1 T_{t-1} + u_{1t} \tag{16}$$

$$T_t = b_1 \Delta P_{t-1} + u_{2t} \tag{17}$$

Where X_t, $P_t \sim I(1)$ and $T_t \sim I(0)$

If X_t is to conform to the connotation of P-T decomposition, a_1 must be equal to zero in Equation (16). If a_1 is not equal to zero, even if $T_t \sim I(0)$, T_t can affect ΔP_t and then X_t, thus it cannot be P-T decomposition.

According to the above connotation of P-T decomposition, in the representation of error correction model (ECM) (please see Equation (9) :

$$\Delta X_t = \mu + \Pi X_{t-k} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \varphi D_t + \varepsilon_t$$

If rank(Π)=r(Π=α β'), where α, β are all full-rank matrices of p×r, it can be seen that $Z_t = \beta' X_t$ belongs to I(0) as a short-run term in ECM. In order to comply with the P-T decomposition, the linear combination of X_t needs not to be affected by Z_t , then it can be known from the ECM that only the following relationship exists, which is not affected by $\beta' X_t$ in the linear combination of X_t :

$$f_t = \alpha'_\perp X_t \tag{18}$$

According to the result of the above derivation, $f_t = \alpha'_\perp X_t$, we can use Engle and Granger's two-stage estimation method or Johansen and Juselius's maximum likelihood estimation (MLE) method to estimate $\alpha'_\perp$, β and further obtain the common factor (f_t). In this way, empirical analysis can be carried out according to the characteristics of f_t to understand which factors contribute to the achievement of long-run equilibrium situation in the whole co-integrated system.

3 Results and Findings

Based on the aforementioned basic model framework and relevant measurement methods, this section conducts an empirical study on the stock market in the Asian-Pacific Chinese region. Since the purpose of this study is to estimate the common factors implied in the co-integration system, it is the first step to test whether there is co-integration among variables. If there is co-integration, the common factors (components) can be further estimated, and the reasons for the existence of co-integration of five stock markets in the Asian-Pacific Chinese region can be explained by this common factor. In the Subsection 3.1, the characteristics of the data will be explained, and in the Subsection 3.2, the unit root test of the variables will be carried out to verify whether each variable is a stationary time series, and the co-integration vectors will be estimated by Johansen-Juselius's MLE method, and the number of co-integration vectors will be verified. The Subsection 3.3 uses the estimates in the Subsection 3.2 to find common components (factors) in the co-integration system and analyze them.

3.1 Data Sources and Data Descriptions

3.1.1 Data Sources

The economic development of the in the Asian-Pacific Chinese region has become increasingly important, International trade, funds flow and investment in each other are frequent between countries. Therefore, the stock market, which highlights the state of a country's economy, has become the main research object of economists. Regarding the variables of stock price, this study will use the data of Taiwan Stock Exchange Weighted Index, Hong Kong Hang-Seng Index, Singapore Straits Times Index, Shanghai B-Share Index and Shenzhen B-Share Index for empirical analysis. All the data includes cross-border FX transactions data come from the Taiwan Economic Journal (TEJ) database. The study period is from January 11, 1997 to March 18, 2000. The analysis is based on weekly data (the closing index of the current week). This period is chosen to avoid the abnormal influences of rare occurrences of less special events, and to clearly examine common factor to explain which variables affect the formation of co-integration, i.e., the purpose of this study can be revealed during the research period, and the research results can be highlighted. Generally, investors are concerned with returns instead of closing prices, the stock market returns examined in this study are measured as the logarithm of changes in closing index levels from one trading week to the next such as, $R_{i,t} = \left(lnP_{i,t} - lnP_{i,t-1}\right)$ X 100. Where, $R_{i,t}$ is the weekly return of stock market i on week t. $P_{i,t}$ is the closing price index of stock market i on week t. $P_{i,t-1}$ is the closing price index of stock market i on week $t-1$.

3.1.2 Data Descriptions

The descriptive statistics for stock price indexes and stock price index return series, including mean, standard deviation, maximum, minimum, skewness and kurtosis are presented in Table 1. Since investors are concerned with stock returns instead of closing stock prices, the descriptive statistics of the stock market returns are only discussed in this section. As presented in Table 1, Taiwan and Hong Kong have the highest mean stock price return (0.0953, 0.0711) while Singapore has the lowest value of mean (0.0013) in stock price return. With regards to stock risk that is presented by standard deviation, Shenzhen and Shanghai B-Share markets show the highest standard deviation (2.3073 and 2.2340). Hong Kong have the lowest (0.3681) standard deviation in stock price return. The measures for skewness show that the distribution of stock index returns for these 5 markets are left-skewed distribution (less than 0), especially in Singapore and Hong Kong stock markets. The negative skewness implies that large negative returns tend to occur more often than large positive ones. Return rates of these 5 stock markets demonstrate the phenomenon of leptokurtic or fatter tails than normal distribution since their kurtosis coefficients are greater than 3.

Table 1: Descriptive Statistics of Original Stock Price Indexes and Index Returns

	Stock Price **SZ**	**SH**	**TW**	**HK**	**SG**
Mean	97.9147	50.0552	7981.1056	12253.3286	1707.5328
Std. Dev.	35.4736	36.6324	356.9243	236.3455	83.8346
Maximum	181.1000	94.1310	10161.0500	17831.8600	2479.5800
Minimum	44.8200	22.5770	5710.1800	7018.4100	805.0400
Skewness	-0.6424	-0.7412	-0.2864	-0.8498	-0.9527
Kurtosis	0.5651	0.5674	0.2172	0.0783	-0.3324
	Stock Return **SZ**	**SH**	**TW**	**HK**	**SG**
Mean	0.0662	0.0571	0.0953	0.0711	0.0013
Std. Dev.	2.3073	2.2340	1.5281	1.2316	0.8712
Maximum	8.2570	7.4010	4.0510	6.0721	3.5831
Minimum	-9.8103	-10.2341	-4.0437	-4.2110	-5.1326
Skewness	-0.5651	-0.6342	-0.4152	-0.1417	-0.3156
Kurtosis	5.3214	5.3557	6.4534	7.2234	5.6567

Notes: SZ: Shenzhen B-Share Index; SH: Shanghai B-Share Index; TW: Taiwan Stock Exchange Weighted Index; HK: Hong Kong Hang-Seng Index; SG: Singapore Straits Times Index

In this subsection, we also draw the logarithmic trend charts (Figures 1-5) of the series of Shenzhen B-Share Index (SZ), Shanghai B-share Index (SH), Taiwan Stock Exchange Weighted Index (TW), Hong Kong Hang Seng Index (HK) and Singapore Straits Times Index (SG) of five stock markets in the Asian-Pacific Chinese region. By comparing the trend relations of these five markets from Figures 1-5, it can be found that during the study period, the trend of the price indexes of the five markets almost moves together to have co-movement effect, so there should be a correlation (co-movement) to some extent. We may get a clearer picture of the co-integration relationship among these five stock markets, whether there is a long-run equilibrium relationship among them, i.e., co-integration among them still needs to be confirmed by the subsequent statistical tests of this research.

Figure1: The Time Plot of the Log of Shenzhen B-Share Index (SZ)

Figure2. The Time Plot of the Log of Shanghai B-Share Index (SH)

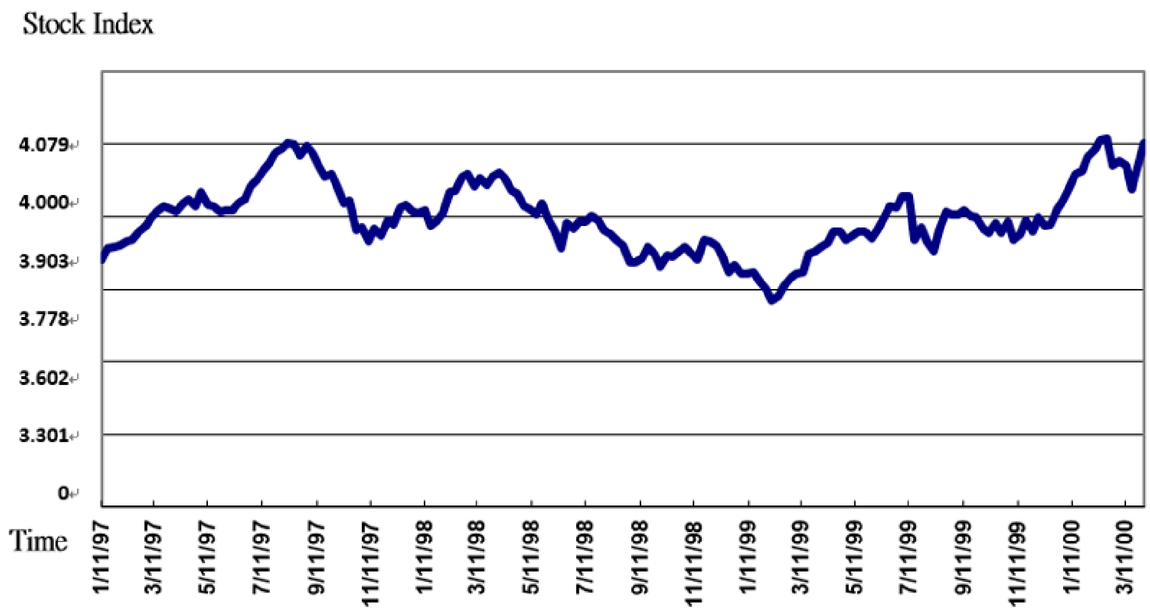

Figure3: The Time Plot of the Log of Taiwan Weighted Stock Index (TW)

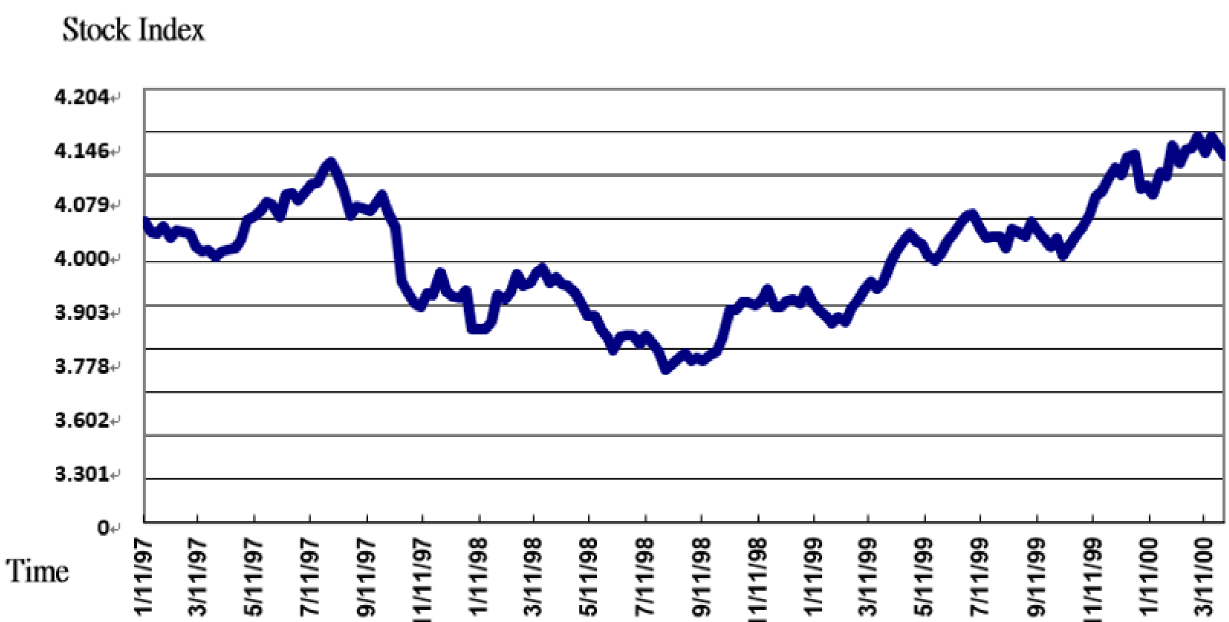

Figure4: The Time Plot of the log of Hong Kong Hang Seng Index (HK)

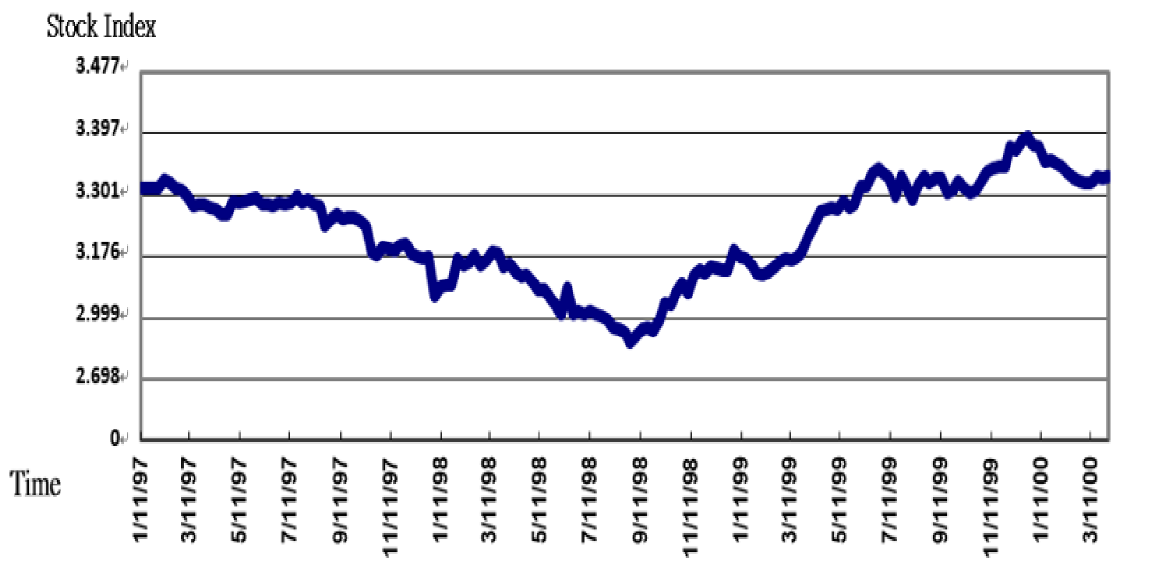

Figure5: The Time Plot of the Log of Singapore Straits Times Index (SG)

3.2 Unit Root Tests

In order to determine whether the variables are stationary series, it is necessary to conduct a unit root test before the co-integration test. In this study, the stock price indexes and index returns data of Shenzhen, Shanghai, Taiwan, Hong Kong and Singapore stock markets are tested by means of ADF (Augmented Dickey-Fuller (Dickey and Fuller, 1979, 1981)) and PP (Phillips-Perron (Phillips and Perron, 1988)) tests. However, before using the test methods of ADF and PP, the lag terms of the auto-correlation of each variable must be confirmed first. Therefore, this study adopts the SBC (Schwarz Bayesian information criterion) to select the optimal number of lagging periods and takes into account the problem of residual term correlation.

Table 2 shows the results of the ADF and PP test for the original weekly stock price indexes and price index return rate series (first difference of log series) of these 5 stock markets under three regression models with intercept term, with intercept and trend term, and without intercept and trend term. It can be found that the original weekly stock price index series cannot reject the null hypothesis (i.e., there is a unit root), which means that they are all non-stationary series. Next, this study converts the logarithm of the original weekly stock price index data into the return type by the first-order difference. The results of the ADF and PP tests support the rejection of the null hypothesis of a unit root at the 1% significance level, indicating that there do not exist the unit root for these 5 stock price index returns. It means that all series of stock price index returns have met the characteristics of the stationary series. As a result, these series (all index levels) are integrated of order one, I (1), all of our variables are first-order integrals, on the one hand, which means that any shock to the variable is only temporary. Again, if this random trend is common in the variables, then the above shocks dissipate and return to the long-term mean. On the other hand, further analysis can be done by co-integration, i.e. we can perform co-integration analysis on these indexes since they are all integrated in the same order required for co-integration.

Table 2: Unit Root Tests

	Stock Market Indexes	With Intercept Term	With Intercept and Trend Term	Without Intercept and Trend Term
ADF(Augmented Dickey-Fuller)Test				
	SZ	-2.8013[2]	-2.2013[2]	2.5623[2]
Original	SH	-1.7183[2]	-1.7924[2]	1.7627[2]
Stock Price	TW	-0.9403[1]	-0.8909[1]	0.9612[1]
Index Series	HK	-2.5213[1]	-2.4930[1]	2.5337[1]
	SG	-1.6771[1]	-1.6107[1]	1.6283[1]
	SZ	-62.5566***[2]	-62.8266***[2]	-62.3114***[2]
Stock Price	SH	-59.6713***[2]	-59.5676***[2]	-59.5975***[2]
Index Return	TW	-32.4891***[1]	-32.4743***[1]	-32.4731***[1]
Series	HK	-52.9547***[1]	-52.9565***[1]	-52.9685***[1]
	SG	-55.8333***[1]	-55.8793***[1]	-55.8987***[1]
PP(Phillips-Perron) Test				
	SZ	-1.8055[2]	-1.8756 [2]	1.7435 [2]
Original	SH	-2.7283 [2]	-2.8814[2]	2.7132 [2]
Stock Price	TW	-0.9452 [1]	-0.9412[1]	0.9154 [1]
Index Series	HK	-2.7313 [1]	-2.7564[1]	2.7491 [1]
	SG	-1.7781 [1]	-1.7107 [1]	1.7293 [1]
	SZ	-62.4425***[2]	-62.9123***[2]	-62.4654***[2]
Stock Price	SH	-59.5543***[2]	-59.5721***[2]	-59.4125***[2]
Index Return	TW	-59.4329***[1]	-59.4675***[1]	-59.4456***[1]
Series	HK	-52.8500***[1]	-52.8435***[1]	-52.8545***[1]
	SG	-55.6533***[1]	-55.7493***[1]	-55.7487***[1]

Notes: 1. The values in [.] are the most fitting lags determined by the SBC criterion. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively. The critical value is based on the research of Davidson and Mackinnon (1993). The software used is Eviews7.
2. SZ: Shenzhen B-Share Index; SH: Shanghai B-Share Index; TW: Taiwan Stock Exchange Weighted Index; HK: Hong Kong Hang-Seng Index; SG: Singapore Straits Times Index

3.3 Johansen-Juselius Co-integration Test

The test of co-integration and the estimation of co-integration vector are mainly based on the error correction model shown above (please see equation (9)):

$$\Delta X_t = \mu + \Pi X_{t-k} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \varphi D_t + \varepsilon_t$$

In this equation, we can estimate and test co-integration vectors, but before Π can correctly estimate, we must confirm the k of VAR (k). In this study, we use Ljung-Box Q statistic to test the residuals, starting from k=1 and stop until the residuals term has no serial correlation. After estimating and testing VAR (k) among these 5 stock market index returns, the estimated residuals of VAR have no serial correlation when k=2, so k=2 is selected as the optimal lag items. The matrix Π can be written as a form of the matrix of adjustment parameters α with the matrix of co-integrating vectors β : Π=α β' . As indicated above Subsection 2.1, the number of co-integrating vectors is identical to the number of stationary relationships in the Π-matrix or the rank of Π matrix. As proposed by Johansen and Juselius (1990), Trace and Maximum Eigenvalue tests are commonly used to identify the existence of co-integrating relationships. After selecting the k=2 lag term, the eigenvalues, $\hat{\beta}$ and $\hat{\alpha}_{\perp}$ of the estimates are obtained by using Johansen-Juselius's maximum likelihood method, which are listed in Table 3 respectively. Johansen-Juselius's Maximum Eigenvalue and Trace statistic corresponding LR statistic (likelihood ratio statistic) are also used to test the number of co-integration vectors, and the results are listed in Table 4. Because Johansen-Juselius's LR test is a nested test, that is, the test of the lower co-integration vector dimension is included in the test of the higher co-integration vector dimension, Johansen and Juselius (1990) shows that when the lower test dimensions all reject the null hypothesis, then the first test dimension that does not reject the null hypothesis is the dimension of the co-integration vector estimate. In Table 4, when the number of co-integration vectors of the null hypothesis is r=0, the test result rejects the null hypothesis, and when the next test of the null hypothesis is r=1, the null hypothesis is not rejected, indicating that there is a co-integration vector and only one co-integration vector exists, that is, there is co-integration among Shenzhen, Shanghai, Taiwan, Hong

Table 3: Estimates of Co-integration Related Parameters

Eigenvalue					
(0.601421 0.432179 0.341842 0.271420 0.101142)					
$\hat{\beta}$					
SZ	2.3412	-0.032	0.0148	-0.0162	0.4012
SH	-0.9712	-0.9124	-0.3105	0.2768	-0.6969
TW	-1.3214	0.7028	0.6124	-0.7102	-0.1412
HK	-0.3412	-0.3428	0.9438	0.3591	-0.4271
SG	0.8245	-0.9675	0.0162	0.1824	0.4458
$\hat{\alpha}_{\perp}$					
SZ	-1.1912	-0.4012	0.4635	-0.1384	0.3631
SH	1.3015	0.1589	0.5012	0.0905	0.1715
TW	0.0565	0.2671	-0.3614	0.6091	0.8816
HK	0.1624	0.1459	-0.3815	-1.0821	0.4712
SG	-0.1347	-1.3411	-0.0309	0.6215	-0.3815

Table 4: Tests for the Number of Co-integrated Vectors

Null Hypothesis	**Max-Eigen Statistics**	**5% Critical Value**	**Trace Statistics**	**5% Critical Value**
r=0	40.120*	36.4	81.736*	77.7
r≤1	16.310	30.3	34.251	54.6
r≤2	13.000	23.8	18.241	34.6
r≤3	6.050	16.9	77.310	18.2
r≤4	0.172	3.71	0.262	3.71

Note：*indicates statistical significance at the 5% level. The critical value is based on the research of MacKinnon, Haug and Michelis (1999).

Kong and Singapore stock markets, and only one co-integration vector exists, and the estimated value of the co-integration vector is (2.0142, -0.9658, -1.3147, -0.3124, 0.9218). As to whether the estimated model is stable during the observation period, this study uses the Chow test of N decreasing steps and N increasing steps (N↓step Chow test: break-point F-test; N↑step Chow test; Forecast F-test) to check the stability of model structural, the test results show that at the 1% level of significance, none of the models can reject the null hypothesis that there is no structural instability phenomenon, that is, there is no significant structural change during the entire study period. It can be confirmed that the VECM model constructed in this study has the appropriateness of its application, that is, the validity of the model estimation is sufficient, and further economic analysis can be carried out.

According to the empirical results, it shows that there is co-integration among the stock markets of Shenzhen, Shanghai, Taiwan, Hong Kong and Singapore, which means that there is a stable linear combination relationship and long-term common trend between the stock price trend of one stock market and the stock price of other stock markets. As far as investors are concerned, if they invest in a portfolio of these co-integrated stock markets, they cannot benefit from the diversification of international investment portfolios; On the other hand, for speculators, since there is co-integration among various stock markets, a country's stock market can use the changes of other stock markets with co-integration to predict the stock market it wants to invest in, thus obtaining arbitrage opportunities.

3.4 Estimated Results and Explanations of Common factors (Components)

In the previous Subsection 3.3, it has been verified that there is co-integration among Shenzhen, Shanghai, Taiwan, Hong Kong and Singapore stock markets, and the co-integration vector has also been estimated. Based on the common factor ($f_t = \alpha'_\perp X_t$) derived in Section 2, this section describes the long-run equilibrium among the stock markets, or which leading factors contribute to the existence of a long-run equilibrium. According to the test of co-integration in the error correction model, it is known that the number of co-integration vectors is 1, so β is a vector of 5×1, M is a matrix of(5-1)×5, and its estimated value ($\hat{\alpha}_\perp$) is the $\hat{\alpha}_\perp$ vector corresponding to the smaller 4 eigenvalues, which shows that there are four common factors f_{t1}, f_{t2}, f_{t3}, f_{t4} among the all stock markets as follows:

$$f_{t1} = 0.3615\ SZ + 0.1741\ SH + 0.8051\ TW + 0.4612\ HK - 0.3542\ SG \qquad (19)$$

$$f_{t2} = -0.1371\ SZ + 0.0912\ SH + 0.5413\ TW - 1.0617\ HK + 0.5467\ SG \qquad (20)$$

$$f_{t3} = 0.4621\ SZ + 0.5012\ SH - 0.3613\ TW - 0.3815\ HK - 0.0247\ SG \qquad (21)$$

$$f_{t4} = -0.3712\ SZ + 0.1520\ SH + 0.2615\ TW + 0.1447\ HK - 1.2009\ SG \qquad (22)$$

Where
SZ: Shenzhen B-Share Index
SH: Shanghai B-Share Index
TW: Taiwan Stock Exchange Weighted Index
HK: Hong Kong Hang-Seng Index
SG: Singapore Straits Times Index

According to the estimation results of the common factor model, the largest interactive force (the largest common factor) that affects the stock markets of Shenzhen, Shanghai, Taiwan, Hong Kong and Singapore from short-run disequilibrium to long-run equilibrium is:

$$f_{t1} = 0.3615\ SZ + 0.1741\ SH + 0.8051\ TW + 0.4612\ HK - 0.3542\ SG$$

The countries with the largest factor loadings are Taiwan and Hong Kong, which are also the countries with the largest correlation with the common factor. We find that co-movement is mainly driven by long-run forces, while temporary fluctuations are fairly insignificant for all stock market.

Based on the largest common factor in this formula, it can be found that the absolute value of the coefficient affecting the common factor is the largest in Taiwan stock price index, followed by Hong Kong. This confirms that the Taiwan and Hong Kong stock market return indexes are the dominant components of the common factor. Taiwan and Hong Kong stock markets are the most sensitive to changes in the common component stock returns. Our empirical findings are similar and supported by research results from related studies such as Yeh and Lee (2000), Cheng and Glascock (2005), Johansson and Ljungwall (2009), Huang and Kuo (2015) and more recently Mitra and Iyer (2017).The two stock markets jointly affect the trend of the whole system. This phenomenon can also be explained as individual stock markets may have different fluctuations in the short term, but the long-term stock price trend will still show a co-movement phenomenon driven by the stock price indexes of Taiwan and Hong Kong to drive other stock markets. This fact can also be proved by removing the Taiwan or Hong Kong stock market indexes from the entire analysis system during the empirical period in this study, so that there is no co-integration among other stock markets. There is indeed an intraregional linkage or correlation between stock price movements in Asian-Pacific Chinese Region, and price movements or co-movements are mainly dominated by Taiwan and Hong Kong stock markets. Investors should consider price movements or linkages in the region's stock markets in their investment strategies. These empirical results can be considered as contributions of our study to existing research findings. Therefore, when investing in the five stock markets in the Asian-Pacific Chinese Region, investors may pay attention to the information of the Taiwan and Hong Kong stock markets and conduct in-depth analysis when assessing risk aversion and arbitrage in order to make appropriate investment decisions.

4 Concluding Remarks

In this study, we propose a co-integration-based permanent-transitory decomposition for non-stationary time series models. This approach takes advantage of the co-integration relationship between observable variables and assumes that they are driven by a common and specific components. The common components are further divided into long-run non-stationary components and short-run stationary components. The aim of this study is to understand which common factors in the co-integration model lead the short-run disequilibrium to the long-run equilibrium. Johansen's maximum likelihood method is used to estimate the error correction model, and the common components are obtained through the decomposition of P-T. This study takes the 5 stock market indexes (Hong Kong, Singapore, Taiwan and China including Shanghai and Shenzhen stock markets) of the Asian-Pacific Chinese region as the object of empirical research. By allowing for a P-T decomposition, we are able to analyze not only the long-run dynamics of the series but also the co-movement of different stock markets. The conclusions and implications obtained from the empirical analysis are as follows:

The stock market indexes in the Asia Pacific Chinese region (Taiwan Stock Exchange Weighted Index, Hong Kong Hang-Seng Index, Singapore Straits Times Index, Shanghai B-share Index and Shenzhen B-share Index) are subject to individual unit root test. The 5 stock market indexes in the Asia Pacific Chinese region are subject to individual unit root test. It is found that although the indexes of all countries are not from the same type of unit root test models, all stock markets have a unit root I(1), indicating that all stock markets are non-stationary processes, and the trend or movement of each stock market presents a random walk process. All of our variables are integrals of order 1, which means that any shock to the variables is only temporary. Again, if this random trend is common in the variable, the shock described above will dissipate, returning to the long-term mean.

After the co-integration analysis of the five stock indexes (weekly data) and the verification of Johansen's maximum eigenvalue and trace tests, it is found that the fact of co-integration exists among these stock markets. As far as investors or portfolio managers are concerned, if they invest in one of these co-integrated stock markets, they need to care for that they will not be able to diversify their risk from international portfolio. On the other hand, for speculators, since there is co-integration among various stock markets, the stock market of one country can use the movements of other stock markets with co-integration to predict the stock market they want to invest in or provides insight into some aspect of investment timing or other portfolio decisions and gain arbitrage opportunities.

According to the fact of the existence of co-integration among stock markets, the common factor can be further estimated and the largest common factor existing in long-term equilibrium can be obtained. The largest coefficient leading the common factor is from Taiwan and Hong Kong stock market indexes, indicating that the formation of co-integration is mainly due to Taiwan and Hong Kong stock market return indexes, i.e., Taiwan and Hong Kong stock markets are the most sensitive to changes in the common component stock returns. Therefore, when investors or portfolio managers make investing decision in the five stock markets in the Asia-Pacific Chinese region, investors or portfolio managers may pay attention to the information of the Taiwan and Hong Kong stock markets and conduct in-depth analysis when assessing risk aversion and arbitrage in order to make appropriate investment decisions.

Finally, it must be understood that the conclusions and recommendations presented in this study are based on the specific data and estimation methods used in the model. Therefore, when quoting the results of this study, we should consider the changes of the environment and the economic situation at that time, so that they can be flexibly applied.

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