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# Does Sectoral Productivity Convergence Promote Per Capita Output Convergence in the Country Level Across Asian Countries?

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ABSTRACT

Per capita output convergence is confirmed across some Asian countries such as the “Asian Tigers”, i.e., Hong Kong, Korea, Singapore, and Taiwan（Matsuki, 2019）. In addition, some other countries such as India, Indonesia, Malaysia, and Thailand show converging tendencies toward long-run convergence in the sense of asymptotically relative convergence. This paper examines whether sectoral productivity convergence across these countries contributes in achieving per capita output convergence at the aggregate（whole country）level. We also discuss which industry’s growth trend is more influential to the aggregate level convergence. Moreover, we try to identify possible growth determinants, such as international trade, macroeconomic stability, government expenditure, human capital accumulation, TFP, and ICT, promoting sectoral productivity convergence and strengthening causality relationships from sectoral productivity convergence to per capita output convergence at the whole country level.

Keywords：Productivity convergence; Output convergence; Unit roots; Stationary covariate; Causality.

JEL Classification Numbers：C12, C22, O47, O53.

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## 1. Introduction

Some growth theorists and empirical researchers claim that income gaps between poor and rich countries have become wider in recent decades. In the late 1800s, the income gap between the richest and the poorest countries was about one-tenth of what it was in 2010, without getting narrowed once through all the decades. This expanding gap is called the Great Divergence. The issue has been briskly argued in recent literature, e.g., Jones（2016）.

However, when focusing on industrial sectors across countries, some researches such as Bernard and Jones（1996）and Rodrik（2013）reported that unconditional convergence at sectoral productivity level holds across some countries. In addition, McMillan and Rodrik（2011）discussed that raising productivity at sector level may become a key driver of economic development of a country. Their view also suggests that narrowing sector productivity gaps between countries seems to contribute in achieving output convergence at the aggregate（whole country）level.

The purpose of this paper is to tackle this theme in Asia, i.e., to unbind whether convergence of productivity level in dominant sectors across Asian countries helps to achieve and maintain long-run per capita output convergence at country level. To this end, we employ more powerful unit root testing methods such as the covariate augmented Dickey-Fuller（CADF）test with/without endogenous structural breaks（Hansen, 1995; Matsuki, 2019）. We also try to identify which sectoral productivity convergence influences output convergence the most at the aggregate level.

The remainder of this paper is organized as follows. Section 2 conducts the preliminary investigation of productivity improvement and industrial structures in

Asian countries. Section 3 explains the definition of the convergence of per capita output and sectoral productivity level. Section 4 begins with an explanation of Hansen's testing method, and then mentions the test with endogenous structural breaks as its extension. The empirical results are discussed in Section 5, and Section 6 concludes the study.

## 2. Preliminary investigation of productivity improvement and industrial structures in Asian countries

### 2.1. Type of productivity improvement

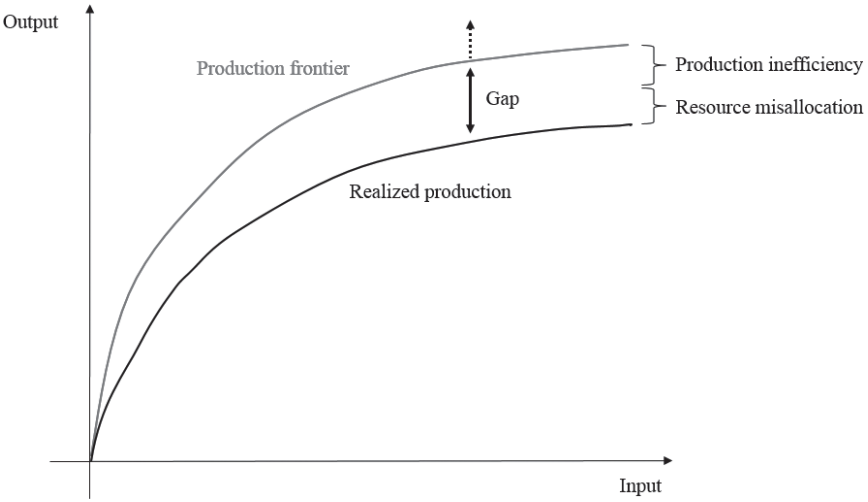
Let us consider what types of productivity improvement Asian countries have experienced. To this end, we use McMillan and Rodrik's（2011）labor productivity decomposition. This approach allows us to decompose per capita output productivity into intra-industry and inter-industry productivity improvements. Figure 1 shows that these two types of productivity improvements in a country push up its realized production closer to the production frontier. The productivity decomposition by McMillan and Rodrik（2011）is defined as follows.

$$\Delta Y_t = \sum_{i=1}^{n} \theta_{i,t-k} \Delta y_{i,t} + \sum_{i=1}^{n} y_{i,t} \Delta \theta_{i,t} \qquad (1)$$

where $Y_t$ and $y_{i,t}$ are the productivity values（production/labor）in the whole economy and each sector. $\theta_{i,t}$ is the labor share in sector $i$. $\Delta Y_t$ is the growth rate of per capita output productivity in a country. In this equation, the first term in the right hand side is the weighted sum of intra-industry growth in each sector, and the second term is the sectoral reallocation of labor resources across different sectors.

Figure 2 shows the decomposition of per labor production growth into the intra-

Figure 1. Type of productivity improvement



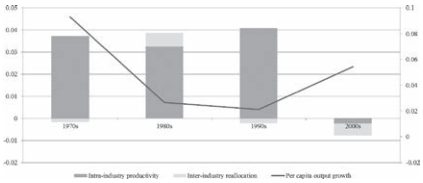

industry productivity and inter-industry（labor input）reallocation. In all the countries except Thailand, during the sample period, the intra-industry productivity improvement more largely contributes to the per labor production growth in the whole country. This means that the intra-industry productivity improvement has played a principal role in the sectoral production increase in Asia. Then, this enhanced sectoral production aggregately leads to the whole country's economic growth. From this fact, to uncover the structure of growth processes of Asian countries, we will mainly focus on the productivity improvement within each industrial sector in the subsequent sections.

### 2.2. Leading industries in Asian countries

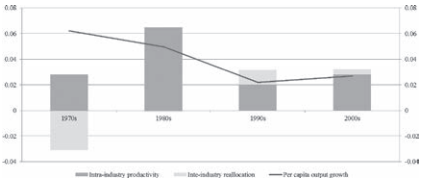
We here confirm trends of industrial structures in Asian countries. Figure 3 shows the structure of the value added in nine sectors, categorized by ISIC Rev.3.1

Figure 2. Intra-industry productivity and inter-industry reallocation

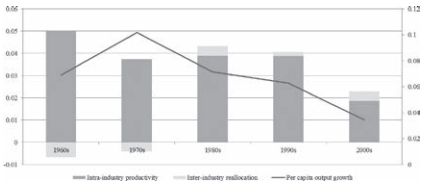
SGP[1)]



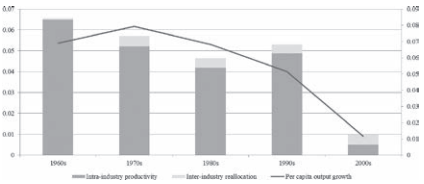

HKG



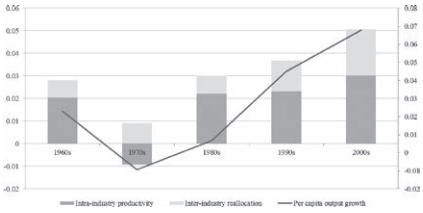

KOR



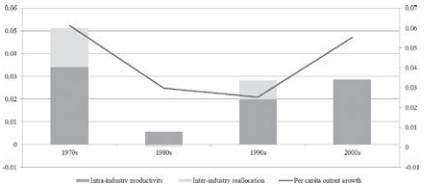

TWN



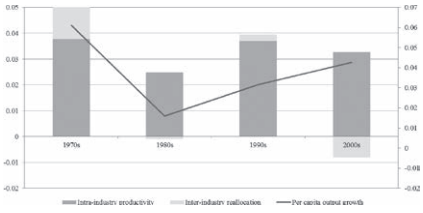

IND



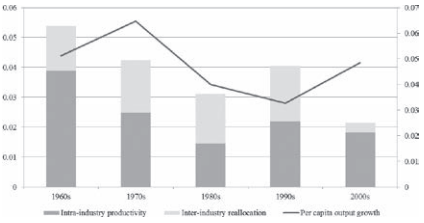

IDN




MYS



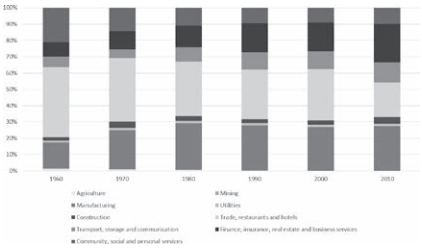

THA




1）SGP, HKG, KOR, TWN, IND, IDN, MYS, and THA stand for Singapore, Hong Kong, Korea, Taiwan, India, Indonesia, Malaysia, and Thailand, respectively.

Figure 3. Shares of sectoral value added（excluding government services）

SGP

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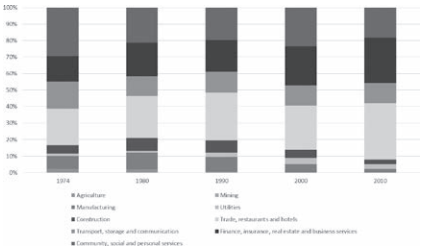


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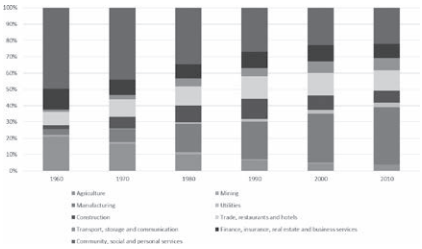


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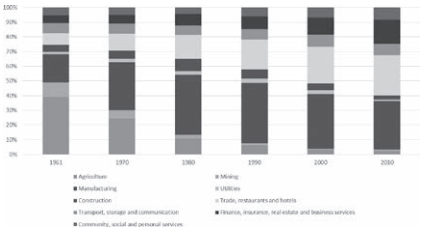
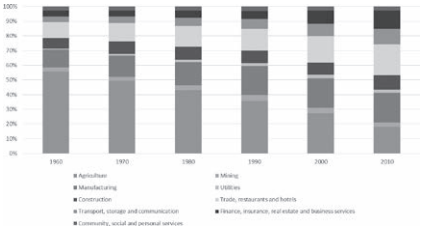



IND

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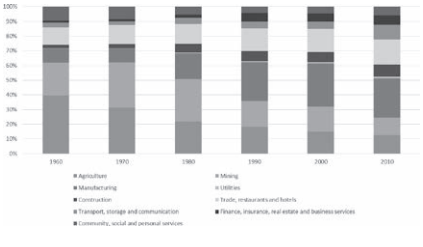


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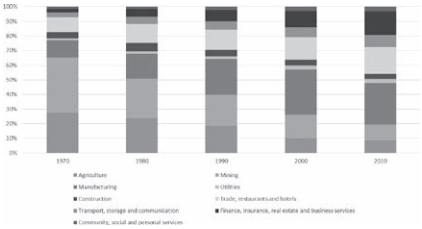
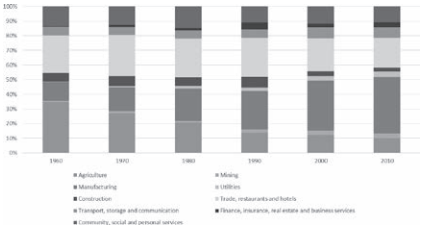



THA



classification（see Table A1 in Appendix for more details）. Among Singapore, Hong Kong, Korea, and Taiwan, apparently, manufacturing, trade, and finance are the dominant industries, though in Hong Kong, the last category（community）has the second largest share. As for other four countries, manufacturing and trade also occupy large shares in all economies. Finance is important in India and Malaysia. In addition, agriculture is not negligible in India, Indonesia, and Thailand. From these tendencies of industrial structures in Asian countries, at least manufacturing, trade, and finance are essential industries in most countries' growth strategies, and agriculture is important for some countries such as India, Indonesia, and Thailand.

As for some of these important industries, we try to find the evidence of sectoral productivity convergence across countries in Section 4. By doing so, we examine whether some key industries contribute to the whole country convergence.

## 3. Concept of convergence of per capita output

We adopt the definition of convergence proposed by Bernard and Durlauf（1995）and Hobijn and Franses（2000）. They noted that the convergence of outputs between two countries holds if the long-run forecasts of output differences approach zero as the forecasting horizon approaches infinity.

$$\lim_{h\to\infty} E\left(y_{i,t+h} - y_{j,t+h} \middle| I_t\right) = 0 \qquad (2)$$

where $y_i$ and $y_j$ are per capita outputs of countries $i$ and $j$, respectively, $h$ is the forecasting horizon, and $I_t$ is an information set at fixed time $t$. This definition will be satisfied in the time series context if $y_{i,t+h} - y_{j,t+h}$ is a mean zero stationary

process. That is, even if a certain shock affects the outputs of two countries and their output difference deviates from zero, this deviation is simply temporal and eventually the difference reverts to zero. As Evans and Karras（1996）and Hobijn and Franses（2000）have discussed, the zero mean stationarity of output difference is considered as asymptotically absolute（or perfect）convergence（hereafter, absolute convergence）.

On the other hand, when the output difference shows the nonzero mean stationarity, it never vanishes even in the long run but does not divert and stably moves around its mean. From an economic perspective, by introducing advanced technologies of the leader country in a certain region, the follower country is gradually catching up with the leader country but the gap of per capita output between the countries is not perfectly removed even in the long-run steady-state. This relation is defined as asymptotically relative convergence（hereafter, relative convergence）.

The current and lagged series of per capita output difference are commonly used in an empirical framework. In multi-country settings, deviations from a reference country are often taken as the convergence measure. Following Matsuki（2019）, Singapore and Hong Kong are used as reference countries in Asia.

Many empirical studies confirm the validity of Eq.(2) using the current and lagged series of $y_i$ and $y_j$ or those of their difference in a unit root or cointegration test framework. However, this approach may use the information pertaining to $I_t$ only to a limited extent. Following Matsuki（2019）, to confirm whether Eq.(2) holds more precisely, we employ additional information as a stationary covariate in the ADF regression model, which will be explained in details in Sections 4 and 5.

## 4. Model and statistical methodology

In this section, we first explain the ideas of the covariate augmented Dickey-Fuller（CADF）test proposed by Hansen（1995）; then, its extension to consider the existence of structural breaks in the model. These are our main methods in the analysis.

### 4.1. The covariate augmented Dickey-Fuller test

In order to estimate the autoregressive（AR）parameter of the ADF model more precisely and then enhance its test power, Hansen（1995）introduced a stationary covariate into the model. This idea stems from the fact that a time series under investigation is believed to be related to another time series. In other words, the additional available information about the kind of correlation structure among these time series can be utilized to estimate the ADF model more efficiently and make the test more powerful.

Hansen's（1995）general model specification is as follows.

$$y_t = d_t + S_t \tag{3}$$

$$a(L)\Delta S_t = \delta S_{t-1} + v_t \tag{4}$$

$$v_t = b(L)'(\Delta x_t - \mu_x) + e_t \tag{5}$$

where $d_t$ is a deterministic term, wherein $d_t = \{\emptyset\}$ and $\{1\}$ in this study. $a(L) = 1 - a_1 L - a_2 L^2 - \cdots - a_p L^p$ is a $p$-th order polynomial in the lag operator. $v_t$ is a white noise process, which covariates with $\Delta x_t$ shown in Eq.(5). $\Delta x_t$ is an $m$-vector, $\mu_x = E(\Delta x_t)$, and $b(L) = b_{q2} L^{-q2} + \cdots + b_{q1} L^{q1}$ is a lag polynomial allowing for both $q2$ leads and $q1$ lags of $\Delta x_t$ in Eq.(5). In addition, the long-run

covariance matrix is defined as

$$\Omega = \sum_{k=-\infty}^{\infty} E\left[\begin{pmatrix} v_t \\ e_t \end{pmatrix}(v_{t-k} \quad e_{t-k})\right] = \begin{pmatrix} \sigma_v^2 & \sigma_{ve} \\ \sigma_{ve} & \sigma_e^2 \end{pmatrix} \tag{6}$$

and the long-run squared correlation between $v_t$ and $e_t$ is defined as

$$\rho^2 = \frac{\sigma_{ve}^2}{\sigma_v^2 \sigma_e^2} \ . \tag{7}$$

$\rho^2$ shows the relative contribution of $\Delta x_t$ to $v_t$ at zero frequency. When $\Delta x_t$ explains nearly all the zero-frequency movement in $v_t$, meaning $\sigma_{ve}^2 = 0$, $\rho^2$ takes zero. When $b(L) = 0$, $v_t = e_t$ and $\rho^2 = 1$.

$$\Delta y_t = \hat{\alpha} d_t + \hat{\delta} y_{t-1} + \hat{b}(L)'(\Delta x_t - \mu_x) + \sum_{p=1}^{\bar{p}} \hat{a}_p \Delta y_{t-p} + error. \tag{8}$$

Eq.(8) is the regression equation, in which to remove the autocorrelation in the error term, the lagged first-differenced terms of $y_t$ are included. Hansen (1995) also derived the limiting distribution of *t*-statistic $t(\hat{\delta}) = \hat{\delta}/s(\hat{\delta})$ under the null hypothesis of the unit root test, namely, $\delta = 0$, which is a weighted sum of a Dickey-Fuller distribution and a standard normal one in the case of $d_t = \{\emptyset\}$.

In practice, one adds a covariate $\Delta x_t$ with its leads and lags to the ADF model, and then, the null of $\delta = 0$ is tested. The critical values corresponding to each $\rho^2$ are tabulated in Table 1 in Hansen's (1995) paper.

### 4.2. Extension of the covariate augmented Dickey-Fuller test to allow for endogenous structural breaks

Matsuki (2019) has extended the conventional CADF test to consider the

presence of structural changes in the model. Following Hansen（1995）, the models under the null hypothesis are Eqs.(3)，(4)，and (5) with $\delta = 0$. In addition, structural breaks up to two are introduced into the alternative model and regression equation. The models for the case of two structural breaks are as follows.

$$a(L)\Delta S_t = \delta S_{t-1} + \gamma DU(\tau_1)_t + \zeta DU(\tau_2)_t + v_t \tag{9}$$

$$\Delta y_t = \hat{\alpha} d_t + \hat{\delta} y_{t-1} + \hat{b}(L)'(\Delta x_t - \mu_x) + \hat{\gamma} DU(\tau_1)_t + \hat{\zeta} DU(\tau_2)_t + \sum_{p=1}^{\bar{p}} \hat{a}_p \Delta y_{t-p} + error \tag{10}$$

where $DU(\tau_i)_t = 1$ for $t \geq \tau_i T$ and zero otherwise $(i = 1, 2)$. $\tau_i$ is the fraction of the $i$-th break in $0 < \tau_i < 1$, and $\tau_i T$ is the $i$-th break date $(i = 1, 2)$. The break dates are assumed to be unknown; therefore, they are endogenously determined to be located where the one-sided $t(\hat{\delta})$ is minimized in sequential estimation over all possible combinations of break dates within $0 < \tau_1 < \tau_2 < 1$. In Eq.(3), when $d_t = \{1\}$, the series is demeaned before estimating the model.

Since this minimum *t*-statistic does not belong to the probability distribution derived by Hansen（1995）, its critical values are not available for the test. Therefore, these values were obtained based on a Monte Carlo simulation, and are tabulated in Table A4 in Matsuki（2019）.

## 5. Empirical analysis

### 5.1. Data

The data herein are mainly sourced from Penn World Table 9.0, World Development Indicators, and GGDC（Groningen Growth and Development Centre）10-sector database. The sample period is 1970-2011 against Singapore and 1974-2011 against Hong Kong. Real per capita GDP is obtained by dividing output-side real GDP（in mil. 2005US$）by population. We use the following variables as stationary covariates for the CADF test: trade/GDP ratio, inflation rate, government expenditure/GDP ratio, human capital index, total factor productivity（TFP）index, and ICT（see Table A2 for more details）. These variables are considered to be possible economic growth determinants that drive Asian countries toward long-run output convergence. The trade/GDP ratio shows the effectiveness of the export-oriented strategy for economic growth. The inflation rate represents the macroeconomic stability needed to provide a strong foundation for active economic activities. The government expenditure/GDP ratio denotes the degree of contribution of the central government's fiscal policies toward economic development. The human capital index confirms the importance of the quality of the potential labor force to the long-term growth path. The TFP index indicates possible improvements to increase the production level in an economy. The ICT shows the level of ICT technology or its penetration level in the economy. All the variables are taken in natural logarithms except the ICT variable. The logs of the human capital index and TFP index are first-differenced.

### 5.2. Empirical results

Table 1 shows the summary of empirical results highlighted in Matsuki（2019）.

The results reveal that the absolute output convergence holds among Singapore, Hong Kong, Korea, and Taiwan, which is detectable with/without a stationary covariate in the regression model（in the second and fourth columns）. In addition, when the trade/GDP ratio is used as a stationary covariate, the relative convergence is found between Singapore and Thailand（in the third column）. Malaysia, India, and Indonesia also display relative convergence tendencies toward Hong Kong, when the CADF test utilizes growth factors such as the trade/GDP ratio, government expenditure/GDP ratio, and human capital index for Malaysia; inflation rate for India; and government expenditure/GDP ratio for Indonesia（in the fourth column）.

In the light of these facts, we then proceed to investigate sectoral productivity convergence toward the reference countries.

### 5.2.1. CADF tests with/without structural breaks

We first apply the CADF test without structural breaks; then with one or two structural breaks to the manufacturing and finance sectors.[1)] The results for the CADF test without any breaks are shown in Tables 2a, 2b, 3a, and 3b; those for one-break are shown in Tables 4a, 4b, 5a, and 5b. The results for tests with two breaks are not displayed here.[2),3)] We find more significant rejections of the null hypothesis（no productivity convergence）when we allow for one possible structural break（Tables 4a, 4b, 5a, and 5b）. Moreover, in the finance industry,

1）The optimum lag length of the regression equation is selected by the modified Akaike information criterion（MAIC）suggested by Ng and Perron（2001）. The maximum lag length is set at $12(\frac{T}{100})^{1/4}$.

2）The results are available on request to the author.

3）We have also applied the ADF test and the unit root test with one endogenous structural break proposed by Matsuki and Usami（2011）. The results are omitted here, but are available on request to the author.

Table 1 Empirical results of output convergence in the whole country level in Asia（Summary）[1)]

| Tests | Reference country: Singapore | | Reference country: Hong Kong | |
|---|---|---|---|---|
| | Absolute convergence | Relative convergence | Absolute convergence | Relative convergence |
| ADF, DF-GLS, KPSS | | | Korea, Taiwan | |
| Zivot and Andrews（1992） | | | | |
| Lumsdaine and Papell（1997） | | | | Malaysia |
| Perron and Vogelsang（1992） | – | | – | |
| Papell and Prodan（2006） | – | | – | |
| CADF | | | Korea（All）,<br>Taiwan（All）,<br>Singapore（Tra, Gov） | |
| CADF with one break | Korea（HC） | Thailand（Tra）,<br>Taiwan（Tra） | Singapore（Gov）,<br>Korea（HC） | |
| CADF with two breaks | Korea（HC） | Taiwan（Tra） | Singapore（Gov） | Malaysia（Tra, Gov, HC）,<br>India（Inf）,<br>Indonesia（Gov）,<br>Singapore（Gov） |

（Source）Matsuki（2019）.

1）Appearance of the country name indicates significant convergence toward the reference country.　The words in the parentheses are covariates corresponding to the displayed results, i.e. All, Tra, Inf, Gov, and HC denote all the covariates, the trade/GDP ratio, inflation rate, government expenditure/GDP ratio, and human capital index, respectively.

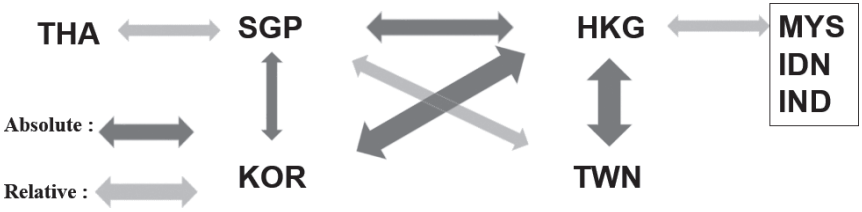


Table 2a CADF test results (Reference country: Singapore) -Manufacturing

| Countries | Covariate: Trade/GDP ratio | | | | Covariate: Inflation rate | | | | Covariate: Government expenditure/GDP ratio | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Raw data | | Demeaned data | | Raw data | | Demeaned data | | Raw data | | Demeaned data | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Hong Kong | -0.282 | 0.88 | -1.615 | 0.99 | -0.334 | 1.00 | -2.222 | 0.98 | -0.423 | 0.78 | -3.000** | 0.73 |
| Indonesia | 0.192 | 0.67 | -1.238 | 0.60 | 0.377 | 0.42 | -0.771 | 0.56 | 0.967 | 0.88 | 0.014 | 0.98 |
| India | 1.032 | 0.90 | -0.583 | 0.99 | 0.605 | 0.42 | 0.617 | 0.53 | 1.179 | 0.83 | 0.078 | 0.90 |
| Korea | -0.361 | 0.75 | -1.376 | 0.78 | 0.053 | 0.85 | -0.649 | 0.87 | -0.258 | 0.83 | -1.183 | 0.91 |
| Malaysia | 1.095 | 0.76 | -0.058 | 0.84 | 0.842 | 1.00 | -0.917 | 1.00 | 0.971 | 0.76 | -1.004 | 0.70 |
| Thailand | 1.873 | 0.91 | 0.619 | 0.84 | 1.636 | 0.98 | 0.146 | 0.99 | 1.808 | 0.91 | 0.564 | 0.91 |
| Taiwan | 0.864 | 0.97 | -1.187 | 0.74 | 0.956 | 0.99 | -0.480 | 0.96 | 0.703 | 0.91 | -1.953 | 0.70 |

| Countries | Covariate: Human capital index | | | | Covariate: Welfare TFP index | | | | Covariate: ICT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Raw data | | Demeaned data | | Raw data | | Demeaned data | | Raw data | | Demeaned data | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Hong Kong | -0.356 | 0.80 | -2.343 | 0.90 | -0.155 | 0.81 | -2.243 | 0.88 | -0.305 | 0.98 | -2.085 | 0.97 |
| Indonesia | 1.320 | 0.89 | 0.351 | 0.96 | 1.825 | 0.46 | 0.674 | 0.54 | 1.044 | 0.92 | 0.104 | 0.98 |
| India | 0.960 | 0.96 | -0.642 | 0.98 | 1.175 | 0.92 | -0.407 | 0.94 | 0.481 | 1.00 | -0.906 | 0.95 |
| Korea | -0.083 | 0.99 | -0.934 | 1.00 | -0.174 | 0.84 | -1.220 | 0.84 | -0.155 | 0.95 | -1.089 | 0.93 |
| Malaysia | 1.478 | 0.66 | -0.122 | 0.85 | 0.949 | 0.86 | -0.772 | 0.87 | 1.171 | 0.82 | -0.028 | 0.85 |
| Thailand | 1.378 | 0.97 | -0.850 | 0.84 | 1.789 | 0.84 | 0.178 | 0.87 | 1.845 | 0.91 | 0.646 | 0.92 |
| Taiwan | 0.818 | 0.96 | -1.618 | 0.58 | 1.029 | 0.99 | -0.167 | 0.99 | 0.847 | 0.97 | -1.570 | 0.53 |

***, **, and * denote statistical significance at the 1, 5, and 10% levels, respectively. The percentage points of the tests are displayed in Table 1 in Hansen's (1995) paper.

Table 2b CADF test results（Reference country: Singapore）–Finance

| Countries | Covariate: Trade/GDP ratio | | | | Covariate: Inflation rate | | | | Covariate: Government expenditure/GDP ratio | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Raw data | | Demeaned data | | Raw data | | Demeaned data | | Raw data | | Demeaned data | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Hong Kong | -2.277** | 1.00 | -0.497 | 0.88 | -2.127** | 0.61 | 0.472 | 0.10 | -3.809*** | 0.66 | -1.168 | 0.92 |
| Indonesia | -1.375 | 0.36 | -1.617 | 0.34 | -1.056 | 0.28 | -1.248 | 0.27 | 0.176 | 1.00 | -0.012 | 1.00 |
| India | 0.196 | 0.91 | -0.986 | 1.00 | 0.632 | 0.67 | -0.421 | 0.77 | 0.317 | 0.88 | -0.925 | 0.98 |
| Korea | 0.642 | 0.98 | 0.456 | 0.98 | 1.588 | 0.72 | 1.362 | 0.74 | 0.435 | 1.00 | 0.250 | 1.00 |
| Malaysia | -0.098 | 0.79 | -0.162 | 0.59 | -0.132 | 0.98 | -1.600 | 0.97 | -0.140 | 1.00 | -1.737 | 0.97 |
| Thailand | -0.314 | 1.00 | -1.216 | 0.96 | -0.355 | 1.00 | -2.113 | 0.93 | -0.360 | 0.98 | -1.843 | 0.93 |
| Taiwan | -0.418 | 0.90 | -0.221 | 0.55 | -0.130 | 0.79 | -1.939 | 0.90 | -0.350 | 1.00 | -2.615* | 0.99 |

| Countries | Covariate: Human capital index | | | | Covariate: TFP index | | | | Covariate: ICT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Raw data | | Demeaned data | | Raw data | | Demeaned data | | Raw data | | Demeaned data | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Hong Kong | -2.511** | 0.90 | -1.077 | 0.98 | -2.683*** | 0.90 | -1.116 | 0.91 | -3.072*** | 0.85 | -0.390 | 0.68 |
| Indonesia | 0.147 | 1.00 | -0.034 | 1.00 | 0.882 | 0.47 | 0.767 | 0.47 | 0.564 | 0.97 | 0.420 | 0.97 |
| India | -0.334 | 1.00 | -1.375 | 1.00 | -0.198 | 0.88 | -1.097 | 0.90 | -0.088 | 0.98 | -1.169 | 1.00 |
| Korea | 0.754 | 0.91 | 0.509 | 0.94 | -0.126 | 0.82 | -0.294 | 0.82 | 1.164 | 0.77 | 0.972 | 0.79 |
| Malaysia | -0.178 | 0.87 | -1.396 | 0.58 | -0.074 | 0.73 | -1.144 | 0.79 | -0.224 | 0.83 | -2.875** | 0.24 |
| Thailand | -0.336 | 0.87 | -1.874 | 0.83 | -0.076 | 0.93 | -1.138 | 0.94 | -0.165 | 0.98 | -0.241 | 0.97 |
| Taiwan | -0.338 | 1.00 | -2.576* | 1.00 | -0.362 | 0.98 | -2.722* | 0.98 | -0.321 | 0.92 | -0.340 | 0.70 |

***, **, and * denote statistical significance at the 1, 5, and 10% levels, respectively.　The percentage points of the tests are displayed in Table 1 in Hansen's（1995）paper.

Table 3a CADF test results（Reference country: Hong Kong）-Manufacturing

| Countries | Covariate: Trade/GDP ratio | | | | Covariate: Inflation rate | | | | Covariate: Government expenditure/GDP ratio | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Raw data | | Demeaned data | | Raw data | | Demeaned data | | Raw data | | Demeaned data | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Indonesia | -3.194*** | 0.48 | -1.799 | 0.58 | -2.550** | 0.56 | -1.212 | 0.58 | -1.128 | 0.91 | 0.021 | 0.98 |
| India | 0.149 | 0.58 | 0.122 | 0.80 | 0.291 | 0.60 | -0.101 | 0.67 | 0.735 | 0.57 | 0.185 | 0.78 |
| Korea | -1.120 | 0.97 | -1.696 | 0.98 | -0.949 | 0.63 | -1.100 | 0.73 | -1.110 | 1.00 | -1.689 | 1.00 |
| Malaysia | -1.548 | 0.77 | -0.704 | 1.00 | -1.770* | 1.00 | -1.019 | 1.00 | -1.811* | 0.81 | -1.055 | 0.82 |
| Singapore | -0.334 | 1.00 | -2.215 | 0.97 | -0.344 | 0.99 | -2.274 | 0.99 | -0.354 | 0.98 | -2.458 | 0.94 |
| Thailand | 0.706 | 0.70 | 0.442 | 0.76 | -0.346 | 0.95 | -0.589 | 0.96 | 0.260 | 0.85 | 0.022 | 0.88 |
| Taiwan | -1.439 | 0.98 | -0.701 | 0.95 | -0.772 | 0.93 | 0.257 | 0.81 | -1.105 | 1.00 | 0.260 | 0.97 |

| Countries | Covariate: Human capital index | | | | Covariate: TFP index | | | | Covariate: ICT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Raw data | | Demeaned data | | Raw data | | Demeaned data | | Raw data | | Demeaned data | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Indonesia | -0.317 | 0.98 | 0.179 | 0.95 | -1.064 | 0.03 | -0.722 | 0.04 | -0.397 | 0.98 | 0.568 | 0.90 |
| India | 0.731 | 0.72 | -0.648 | 0.79 | 0.639 | 0.55 | -0.397 | 0.56 | 0.215 | 0.06 | 0.538 | 0.06 |
| Korea | -1.071 | 0.98 | -1.008 | 0.97 | -1.351 | 0.73 | -1.841 | 0.75 | -1.094 | 0.90 | -1.038 | 0.87 |
| Malaysia | -1.165 | 0.96 | 0.016 | 0.88 | -1.012 | 0.73 | -0.224 | 0.71 | -0.572 | 0.84 | 0.183 | 0.71 |
| Singapore | -0.395 | 0.73 | -2.503 | 0.87 | -0.314 | 0.88 | -2.022 | 0.94 | -0.321 | 1.00 | -2.241 | 0.94 |
| Thailand | -0.790 | 0.97 | -1.109 | 0.95 | -0.041 | 0.45 | -0.313 | 0.47 | 0.545 | 0.72 | 0.314 | 0.76 |
| Taiwan | -1.466 | 0.92 | -1.465 | 0.78 | -1.435 | 0.93 | -0.517 | 0.95 | -1.308 | 0.96 | -1.379 | 0.61 |

***, **, and * denote statistical significance at the 1, 5, and 10% levels, respectively. The percentage points of the tests are displayed in Table 1 in Hansen's (1995) paper.

Table 3b CADF test results（Reference country: Singapore）–Finance

| Countries | Covariate: Trade/GDP ratio | | | | Covariate: Inflation rate | | | | Covariate: Government expenditure/GDP ratio | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Raw data | | Demeaned data | | Raw data | | Demeaned data | | Raw data | | Demeaned data | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Indonesia | -0.887 | 0.29 | -2.186 | 0.25 | 0.578 | 0.32 | -0.534 | 0.35 | -0.276 | 0.95 | -2.055 | 0.34 |
| India | -0.214 | 0.14 | 0.654 | 0.02 | -0.462 | 0.39 | -0.024 | 0.21 | -0.807 | 0.45 | -0.050 | 0.12 |
| Korea | 0.923 | 1.00 | -0.298 | 0.92 | 0.469 | 0.68 | 1.177 | 0.37 | 0.972 | 1.00 | 0.150 | 1.00 |
| Malaysia | -1.241 | 0.94 | 0.158 | 0.90 | -1.419 | 0.99 | -0.540 | 0.99 | -1.437 | 0.86 | -0.586 | 0.89 |
| Singapore | -3.229*** | 0.88 | -0.518 | 0.77 | -2.287** | 1.00 | -1.044 | 1.00 | -2.144** | 0.99 | -0.636 | 0.92 |
| Thailand | -0.611 | 1.00 | -2.015 | 0.94 | -0.699 | 0.98 | -1.940 | 0.87 | -0.590 | 0.99 | -1.831 | 1.00 |
| Taiwan | -2.389** | 1.00 | -1.186 | 1.00 | -2.410** | 0.99 | -1.213 | 0.99 | -2.261** | 0.97 | -0.900 | 0.98 |

| Countries | Covariate: Human capital index | | | | Covariate: TFP index | | | | Covariate: ICT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Raw data | | Demeaned data | | Raw data | | Demeaned data | | Raw data | | Demeaned data | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Indonesia | -0.011 | 1.00 | -0.918 | 0.93 | 1.144 | 0.15 | 0.467 | 0.16 | 0.694 | 0.94 | 0.081 | 0.98 |
| India | -0.683 | 0.91 | -0.862 | 0.76 | -0.690 | 1.00 | -1.132 | 1.00 | -0.147 | 0.04 | 0.902 | 0.03 |
| Korea | 1.073 | 0.81 | -1.139 | 0.55 | 1.137 | 0.84 | 0.649 | 0.83 | 0.911 | 1.00 | -0.120 | 0.92 |
| Malaysia | -1.232 | 0.92 | 0.215 | 0.88 | -1.051 | 0.80 | -0.311 | 0.93 | -1.298 | 0.97 | -0.155 | 0.97 |
| Singapore | -2.453** | 0.87 | -0.987 | 0.91 | -2.228** | 0.99 | -1.029 | 0.96 | -2.985*** | 0.84 | -0.317 | 0.63 |
| Thailand | -0.472 | 0.76 | -1.207 | 0.83 | -0.442 | 0.88 | -1.258 | 0.91 | -0.523 | 0.99 | -1.875 | 0.96 |
| Taiwan | -2.020** | 0.70 | -0.117 | 0.63 | -2.322** | 1.00 | -1.001 | 1.00 | -2.289** | 0.91 | -0.925 | 0.93 |

***, **, and * denote statistical significance at the 1, 5, and 10% levels, respectively.　The percentage points of the tests are displayed in Table 1 in Hansen's（1995）paper.

Table 4a CADF test results with one structural break（Reference country: Singapore）-Manufacturing

| Countries | Covariate: Trade/GDP ratio | | | | Covariate: Inflation rate | | | | Covariate: Government expenditure/GDP ratio | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Hong Kong | -0.607 | 1.00 | -2.350 | 0.21 | -1.017 | 0.99 | -2.801 | 0.54 | -1.227 | 0.70 | -3.413 | 0.66 |
| Indonesia | -4.235***+++ | 0.09 | -5.099***+++ | 0.03 | -4.248***+++ | 0.11 | -3.796*+ | 0.04 | -3.444*+ | 0.35 | -3.260 | 0.35 |
| India | -0.331 | 0.86 | -2.443 | 0.76 | -0.520 | 0.47 | -1.514 | 0.64 | -0.923 | 0.34 | -2.177 | 0.97 |
| Korea | -1.376 | 0.97 | -1.633 | 0.81 | -1.032 | 0.82 | -1.718 | 0.83 | -1.420 | 0.95 | -1.904 | 0.95 |
| Malaysia | -0.482 | 0.74 | -2.226 | 0.39 | -0.379 | 1.00 | -2.234 | 1.00 | -0.124 | 0.78 | -2.428 | 0.36 |
| Thailand | -0.438 | 0.73 | -1.991 | 0.95 | -0.627 | 0.99 | -2.586 | 1.00 | -1.216 | 0.13 | -2.282 | 0.72 |
| Taiwan | -2.418 | 0.81 | -3.483 | 0.28 | -2.077 | 0.99 | -1.606 | 0.99 | -1.806 | 0.99 | -2.474 | 0.77 |

| Countries | Covariate: Human capital index | | | | Covariate: TFP index | | | | Covariate: ICT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Hong Kong | -0.920 | 0.87 | -2.790 | 0.88 | -1.124 | 0.98 | -2.537 | 0.98 | -0.932 | 1.00 | -2.414 | 0.75 |
| Indonesia | -1.572 | 0.96 | -2.829 | 0.73 | -1.481 | 0.46 | -1.261 | 0.29 | -2.039 | 1.00 | -1.010 | 1.00 |
| India | -0.153 | 0.61 | -2.372 | 0.52 | -0.945 | 0.97 | -2.788 | 0.98 | -0.684 | 0.98 | -3.081 | 0.99 |
| Korea | -1.607 | 0.88 | -2.807 | 0.57 | -1.597 | 0.75 | -2.124 | 0.85 | -1.609 | 0.86 | -3.120 | 0.56 |
| Malaysia | -1.095 | 0.47 | -1.325 | 0.65 | -1.883 | 0.76 | -2.257 | 0.84 | -0.134 | 0.55 | -2.405 | 0.77 |
| Thailand | -0.322 | 0.98 | -2.598 | 0.33 | -0.476 | 0.86 | -2.005 | 0.90 | -0.715 | 0.89 | -0.860 | 0.98 |
| Taiwan | -2.223 | 0.92 | -2.358 | 0.65 | -2.033 | 1.00 | -1.633 | 0.99 | -2.078 | 0.99 | -2.005 | 0.56 |

***, **, and * denote statistical significance at the 1, 5, and 10% levels of the asymptotic distribution of the test, respectively, and +++, ++, and + denote statistical significance at the 1, 5, and 10% levels of the finite-sample distribution of the test, respectively. These percentage points of the tests are displayed in Table A4 in Matsuki（2019）.

Table 4b CADF test results with one structural break（Reference country: Singapore）–Finance

| Countries | Covariate: Trade/GDP ratio | | | | Covariate: Inflation rate | | | | Covariate: Government expenditure/GDP ratio | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Hong Kong | -3.281 | 0.92 | -3.697 | 0.75 | -2.039 | 0.36 | -2.919 | 0.31 | -3.357 | 0.78 | -3.551 | 0.74 |
| Indonesia | -6.284***+++ | 0.10 | -5.369***+++ | 0.01 | -4.443***+++ | 0.29 | -1.781 | 0.30 | -6.630***+++ | 0.56 | -7.614***+++ | 0.49 |
| India | -3.228 | 0.65 | -4.675**++ | 0.56 | -1.838 | 0.75 | -2.866 | 0.85 | -3.715*+ | 0.96 | -4.807**++ | 0.90 |
| Korea | -3.908**++ | 0.86 | -4.018 | 0.76 | -2.809 | 0.85 | -2.901 | 0.87 | -3.388 | 1.00 | -3.957 | 0.75 |
| Malaysia | -0.405 | 0.68 | -4.618**++ | 0.54 | -0.108 | 0.98 | -3.816 | 1.00 | -0.436 | 0.19 | -4.040 | 0.94 |
| Thailand | -4.758***+++ | 0.12 | -5.059***+++ | 0.03 | -2.023 | 1.00 | -4.177*+ | 0.92 | -1.660 | 1.00 | -3.578 | 0.88 |
| Taiwan | -0.911 | 0.71 | -4.708**++ | 0.44 | -1.213 | 0.71 | -2.759 | 0.78 | -0.821 | 0.96 | -3.531 | 0.41 |

| Countries | Covariate: Human capital index | | | | Covariate: TFP index | | | | Covariate: ICT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Hong Kong | -3.222 | 0.96 | -3.455 | 0.94 | -2.455 | 0.95 | -3.491 | 0.96 | -4.547***+++ | 0.66 | -3.951 | 0.63 |
| Indonesia | -2.975 | 0.58 | -1.959 | 0.56 | -2.598 | 0.51 | -1.050 | 0.23 | -4.249**++ | 0.98 | -6.419***+++ | 0.32 |
| India | -3.488+ | 1.00 | -4.082 | 0.95 | -3.246 | 0.99 | -4.140*+ | 0.99 | -3.879**++ | 0.58 | -3.754 | 0.78 |
| Korea | -3.721 | 0.95 | -3.616 | 0.91 | -3.995**++ | 0.79 | -4.218 | 0.73 | -4.188**++ | 0.79 | -4.752**++ | 0.75 |
| Malaysia | -0.073 | 0.73 | -3.271 | 0.89 | -0.172 | 0.73 | -3.568 | 0.88 | -0.059 | 1.00 | -4.739**++ | 0.65 |
| Thailand | -1.715 | 0.90 | -2.636 | 0.93 | -1.610 | 0.79 | -2.540 | 0.82 | -2.887 | 0.59 | -5.508***+++ | 0.15 |
| Taiwan | -1.200 | 0.94 | -2.916 | 0.96 | -1.256 | 0.97 | -2.898 | 0.95 | -0.911 | 0.86 | -3.796 | 0.73 |

***, **, and * denote statistical significance at the 1, 5, and 10% levels of the asymptotic distribution of the test, respectively, and +++, ++, and + denote statistical significance at the 1, 5, and 10% levels of the finite-sample distribution of the test, respectively. These percentage points of the tests are displayed in Table A4 in Matsuki（2019）.

Table 5a CADF test results with one structural break（Reference country: Hong Kong）–Manufacturing

| Countries | Covariate: Trade/GDP ratio | | | | Covariate: Inflation rate | | | | Covariate: Government expenditure/GDP ratio | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Indonesia | -8.001***+++ | 0.20 | -7.057***+++ | 0.07 | -9.028***+++ | 0.00 | -5.233***+++ | 0.00 | -3.216 | 0.94 | -4.609**++ | 0.39 |
| India | -1.181 | 0.24 | -3.838 | 0.68 | -0.936 | 0.71 | -3.578 | 0.98 | -3.118 | 0.24 | -3.641 | 0.52 |
| Korea | -3.639*++ | 0.45 | -2.549 | 1.00 | -1.609 | 0.98 | -2.397 | 0.69 | -2.976 | 0.63 | -2.769 | 0.97 |
| Malaysia | -4.449***+++ | 0.15 | -4.667**++ | 0.14 | -2.940 | 0.98 | -2.640 | 0.99 | -3.599*+ | 0.60 | -3.635 | 0.55 |
| Singapore | -1.057 | 1.00 | -2.453 | 1.00 | -1.159 | 1.00 | -2.692 | 1.00 | -1.308 | 0.92 | -2.746 | 0.98 |
| Thailand | -3.474+ | 0.92 | -3.251 | 1.00 | -4.543***+++ | 0.94 | -4.426**++ | 0.91 | -3.830 | 0.99 | -3.744 | 0.99 |
| Taiwan | -2.043 | 0.71 | -2.771 | 0.75 | -0.836 | 0.94 | -0.850 | 0.88 | -1.318 | 0.98 | -1.195 | 1.00 |

| Countries | Covariate: Human capital index | | | | Covariate: TFP index | | | | Covariate: ICT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Indonesia | -3.115 | 0.96 | -3.636 | 0.95 | -4.248***+++ | 0.00 | -2.054 | 0.01 | -2.916 | 1.00 | -1.877 | 0.54 |
| India | -1.762 | 0.69 | -4.125*+ | 0.79 | -2.349 | 0.31 | -3.169 | 0.70 | -0.358 | 0.00 | -0.276 | 0.00 |
| Korea | -3.146 | 0.44 | -3.031 | 0.47 | -3.075 | 0.74 | -3.022 | 0.71 | -2.850 | 0.38 | -1.923 | 0.54 |
| Malaysia | -2.223 | 0.75 | -2.395 | 0.76 | -2.288 | 0.70 | -2.434 | 0.52 | -0.883 | 0.68 | -0.447 | 0.79 |
| Singapore | -1.201 | 0.75 | -2.786 | 0.90 | -1.056 | 0.89 | -2.442 | 0.94 | -1.044 | 1.00 | -2.751 | 0.63 |
| Thailand | -5.978***+++ | 0.44 | -5.521***+++ | 0.46 | -2.832 | 0.38 | -2.364 | 0.51 | -0.946 | 0.12 | -1.139 | 0.17 |
| Taiwan | -2.075 | 0.67 | -2.595 | 0.74 | -1.423 | 0.96 | -2.334 | 0.90 | -1.888 | 0.66 | -2.021 | 0.75 |

***, **, and * denote statistical significance at the 1, 5, and 10% levels of the asymptotic distribution of the test, respectively, and +++, ++, and + denote statistical significance at the 1, 5, and 10% levels of the finite-sample distribution of the test, respectively. These percentage points of the tests are displayed in Table A4 in Matsuki（2019）.

Table 5b CADF test results with one structural break（Reference country: Hong Kong）–Finance

| Countries | Covariate: Trade/GDP ratio | | | | Covariate: Inflation rate | | | | Covariate: Government expenditure/GDP ratio | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Indonesia | -6.548***+++ | 0.43 | -6.530***+++ | 0.98 | -4.202**++ | 0.20 | -3.804 | 0.38 | -11.486***+++ | 0.07 | -10.896***+++ | 0.21 |
| India | -3.248 | 0.56 | -5.815***+++ | 0.72 | -2.004 | 0.66 | -4.961***++ | 0.99 | -4.465***+++ | 0.30 | -5.463***+++ | 0.95 |
| Korea | -2.777 | 0.72 | -2.113 | 0.42 | -1.555 | 0.95 | -0.613 | 0.53 | -3.050 | 0.54 | -2.413 | 0.52 |
| Malaysia | -1.777 | 0.98 | -3.327 | 0.83 | -2.028 | 0.92 | -3.866 | 0.96 | -1.887 | 0.86 | -4.055 | 0.72 |
| Singapore | -3.378 | 0.82 | -3.873 | 0.68 | -2.325 | 1.00 | -3.256 | 1.00 | -2.215 | 0.97 | -2.772 | 0.95 |
| Thailand | -4.245***+++ | 0.00 | -4.343**++ | 0.00 | -2.557 | 0.96 | -3.815 | 0.63 | -3.840**++ | 0.38 | -5.699***+++ | 0.04 |
| Taiwan | -3.875**++ | 0.68 | -4.270**+ | 0.54 | -4.399***+++ | 0.45 | -3.776 | 1.00 | -3.306 | 0.96 | -3.532 | 0.98 |

| Countries | Covariate: Human capital index | | | | Covariate: TFP index | | | | Covariate: ICT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | | w/o constant & trend | | w/ constant | |
| | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ | t | $\rho^2$ |
| Indonesia | -10.949***+++ | 0.73 | -12.074***+++ | 0.75 | -4.312***+++ | 0.48 | -5.706***+++ | 0.80 | -9.799*** | 0.76 | -11.216*** | 0.85 |
| India | -1.988 | 1.00 | -6.180***+++ | 1.00 | -1.929 | 0.95 | -5.954***+++ | 0.98 | -2.092 | 0.03 | -0.282 | 0.05 |
| Korea | -1.537 | 0.81 | -2.242 | 0.33 | -1.355 | 0.81 | -0.803 | 0.88 | -2.193 | 0.94 | -1.794 | 0.55 |
| Malaysia | -1.912 | 0.83 | -3.290 | 1.00 | -1.728 | 0.75 | -3.450 | 0.95 | -2.357 | 0.54 | -3.797 | 0.97 |
| Singapore | -3.144 | 0.78 | -3.054 | 0.75 | -2.269 | 0.99 | -3.148 | 1.00 | -3.098 | 0.70 | -5.275*** | 0.35 |
| Thailand | -1.697 | 0.98 | -2.676 | 0.97 | -2.146 | 0.86 | -2.494 | 0.95 | -4.045** | 0.32 | -2.024 | 0.69 |
| Taiwan | -1.906 | 0.99 | -2.030 | 0.83 | 3.199 | 1.00 | -3.599 | 1.00 | 3.365* | 0.64 | -3.464 | 0.33 |

***, **, and * denote statistical significance at the 1, 5, and 10% levels of the asymptotic distribution of the test, respectively, and +++, ++, and + denote statistical significance at the 1, 5, and 10% levels of the finite-sample distribution of the test, respectively. These percentage points of the tests are displayed in Table A4 in Matsuki（2019）.

more converging tendencies of productivity toward the reference countries are observed（Tables 4b and 5b）.

The obtained test results are summarized in Tables 6a and 6b. In the manufacturing industry（Table 6a）, Indonesia and Thailand turn out to have relatively strong absolute convergence trends toward Singapore and/or Hong Kong. In addition, Korea and Malaysia have weak but significant absolute convergence. The relative convergence holds between Singapore and Hong Kong, Singapore and Taiwan, and Hong Kong and India. Thus, in the manufacturing industry, India, Indonesia, Korea, Malaysia, and Thailand seem to have already caught up with Hong Kong in terms of either concepts of productivity convergence.

In the finance industry（Table 6b）, more evidence of converging trends in the productivity level can be observed. In all the countries except Malaysia, the productivity convergence toward the reference countries holds in the sense of absolute convergence. In particular, India, Indonesia, Korea, and Thailand show tendencies toward both the reference countries. Taiwan also has a relative sense of convergence toward Singapore, while Malaysia shows the tendency toward both the reference countries.

Compared to the results of the manufacturing industry（Table 6a）, more countries connected to Singapore and Hong Kong in either convergence concepts in the finance industry. This fact shows that in the finance industry, more countries have effectively caught up with the leader countries by implementing their own economic growth policies, some of which are implied by some stationary covariates used in the regression model. For example, against Singapore, the trade/GDP ratio is effective for India, Indonesia, Korea, and Thailand; government expenditure/GDP ratio for Hong Kong, India, Indonesia, Korea, and Thailand; and ICT for India and Indonesia. Against Hong Kong, the trade/GDP ratio is valid for

Table 6a Summary of the test results（Manufacturing）

| Model | Reference country: Singapore | | Reference country: Hong Kong | |
|---|---|---|---|---|
| | Absolute convergence | Relative convergence | Absolute convergence | Relative convergence |
| ADF | | | | |
| Endogenous one break | | | IDN, THA | IDN, IND |
| CADF | | HKG（Gov） | IDN（Tra, Inf） | |
| CADF with one break | IDN（Tra, Inf） | IND（Tra） | IDN（Tra, Inf, TFP）, KOR（Tra）, MYS（Tra）, THA（Inf, HC） | IDN（Gov）, MYS（Tra）, THA（Inf, HC） |
| CADF with two breaks | IDN（Tra, Inf） | IDN（Tra）, TWN（Tra） | IDN（Tra, Inf）, MYS（Tra）, THA（Inf, HC） | IDN（Tra, Inf, Gov, HC）, KOR（ICT）, MYS（Tra）, THA（HC） |

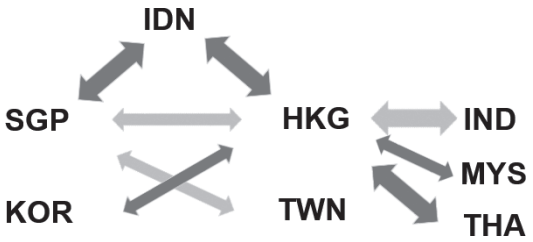
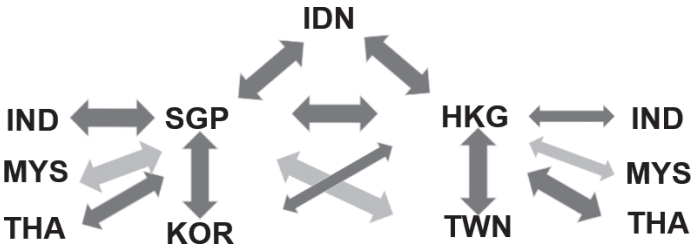


Table 6b Summary of the test results（Finance）

| Model | Reference country: Singapore | | Reference country: Hong Kong | |
|---|---|---|---|---|
| | Absolute convergence | Relative convergence | Absolute convergence | Relative convergence |
| ADF | HKG | | SGP, TWN | TWN |
| Endogenous one break | IDN, KOR | IDN, IND | IDN | IDN, IND |
| CADF | **HKG（All）** | MYS（ICT） | **SGP（All）, TWN（All）** | |
| CADF with one break | HKG（Gov）,<br>IDN（Tra, Inf, Gov, HC）,<br>IND（Gov）,<br>KOR（Tra, Gov）,<br>THA（Tra） | HKG（ICT）,<br>IDN（Tra, Gov, HC）,<br>IND（Tra, HC, ICT）,<br>KOR（Gov）,<br>MYS（Tra, Gov, ICT）,<br>THA（Tra, Gov）,<br>TWN（Tra） | **IDN（All）**, IND（Gov）,<br>THA（Tra, Gov, ICT）,<br>TWN（Tra, Inf） | IDN（Tra, Gov, HC, TFP, ICT）,<br>IND（Tra, Inf, Gov, HC, TFP）,<br>SGP（ICT）,<br>THA（Trade, Gov）,<br>TWN（Tra） |
| CADF with two breaks | HKG（Gov, TFP）,<br>IDN（Tra, HC, ICT）,<br>IND（Tra, Gov, HC, ICT）,<br>KOR（Tra, Gov）,<br>THA（Tra, Gov） | HKG（Tra, Gov, ICT）,<br>IDN（Tra, Gov, HC）,<br>IND（Tra, Gov, HC, ICT）,<br>KOR（Tra, Gov, HC）,<br>MYS（Tra, HC, ICT）,<br>THA（Tra, Inf, Gov, ICT）,<br>TWN（Tra, Gov, HC, TFP, ICT） | **IDN（All）**,<br>THA（Tra, Gov）,<br>TWN（Tra） | **IDN（All）**, MYS（Gov）,<br>SGP（ICT）,<br>THA（Tra, Inf, Gov） |



Thailand and Taiwan; government expenditure/GDP ratio for Indonesia and Thailand. For these countries, the export-oriented economic strategy, government budget policy, and/or the development of ICT technology work as effective driving forces for stepping on the long-run convergence process of productivity level.

In Figure 4, we superimpose only some strong signs of productivity convergence on the aggregate level per capita output convergence. Thus, we can say that the productivity convergence in the manufacturing and/or finance industries can possibly contribute to the per capita output convergence. Among the Asian Tigers and Thailand, the productivity convergence in the finance sector is more prevalent; while against Hong Kong, Malaysia, India, and Indonesia show that both industries are influential. In the next subsection, we will try to confirm the existence of causality from sectoral productivity convergence to per capita output convergence at the whole country level.

### 5.2.2. Causality analysis

We apply the Granger causality test to the difference series of per capita outputs and those of sectoral productivity levels between two countries. In the test, 4 or 5 lags are used in a VAR model. Table 7 shows the selected test results. When the reference country is Singapore, the productivity convergence in the manufacturing industry significantly contributes to the per capita output convergence in India, Hong Kong, and Taiwan; while in the finance industry, Korea and Thailand show more convergence. When the reference country is Hong Kong, more countries display the causality relationships in both industries. The productivity convergence in the manufacturing industry promotes the per capita output convergence in India, Indonesia, Korea, and Taiwan; while in the finance industry, Korea, Malaysia, Singapore, Thailand, and Taiwan show more convergence.

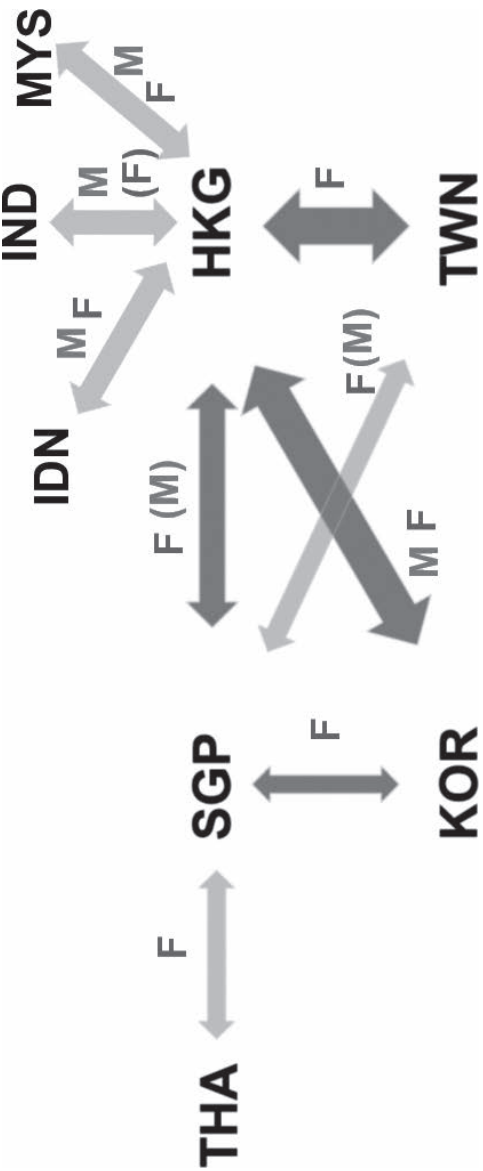


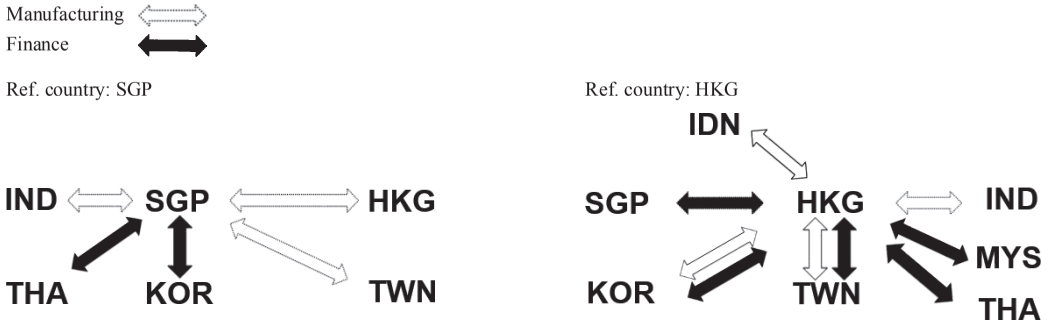

Figure 4. Per capita output convergence and productivity convergence

M and F stand for manufacturing and finance industries. When the letter is in the bracket, the productivity convergence in the industry is relatively weakly detected in the test.

Table 7. Selected results of the Granger causality test

| Regression model | Covariate | Reference country: Singapore | | Reference country: Hong Kong | |
|---|---|---|---|---|---|
| | | Manufacturing | Finance | Manufacturing | Finance |
| w/o covariate | | TWN*** | | IDN***, KOR*** | TWN*** |
| w/ covariate | Trade/GDP | IND**, HKG*, TWN* | KOR*, THA** | KOR* | THA*, TWN*** |
| | Gov. ex/GDP | TWN*** | | KOR* | KOR**, TWN*** |
| | Human cap. | IND*, TWN** | | IND*, KOR*, TWN*** | |
| | ICT | IND**, TWN*** | THA* | IND**, KOR* | KOR*, MYS*, SGP*, THA***, TWN*** |

***, **, and * denote statistical significance at the 1, 5, and 10% levels of the asymptotic distribution of the test, respectively.



Therefore, it can be certainly confirmed that in some Asian countries, sectoral productivity convergence in the manufacturing and finance industries help to achieve per capita output convergence at the whole country level. In addition, both Singapore and Hong Kong, with their advanced and efficient economies, play role models for other Asian countries. By raising the productivity level in dominant sectors, other Asian countries have successfully caught up with Singapore and Hong Kong.

## 6. Conclusion

We have investigated whether sectoral productivity convergence across Asian countries contributes in achieving per capita output convergence at the aggregate（whole country）level. The productivity convergence in several dominant sectors, such as manufacturing and finance sectors, in most countries under investigation turns out to be significantly influential in promoting convergence at the aggregate level. Moreover, we have confirmed that some selected possible growth determinants, such as international trade, government expenditure, human capital accumulation, and ICT, can raise the contribution of sectoral productivity convergence to facilitate per capita output convergence at the country level.

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**Table A1. Value added, ISIC Rev.3.1 classification**

1. Agriculture, hunting, forestry and fishing
2. Mining and quarrying
3. Manufacturing
4. Electricity, gas and water supply
5. Construction
6. Wholesale and retail trade, hotels and restaurants
7. Transport, storage, and communication
8. Finance, insurance, real estate and business services
9. Government services
10. Community, social and personal services

Table A2. The data descriptions

| Variable | Description | Source |
|---|---|---|
| Real per capita GDP | Output-side real GDP at chained PPPs（in mil.2005US$）/population（in millions） | Penn World Table 9.0 |
| Trade/GDP ratio | Trade（export+import）/GDP | World Development Indicators, National Statistics website（the government of the Republic of China） |
| Inflation rate | GDP deflator（annual %） | World Development Indicators, National Statistics website（the government of the Republic of China） |
| Government expenditure/GDP ratio | Share of government consumption at current PPPs | Penn World Table 9.0 |
| Human capital index | Index of human capital per person, based on years of schooling（Barro/Lee, 2013） and returns to education（Psacharopoulos, 1994） | Penn World Table 9.0 |
| TFP index | TFP at constant national prices（2011= 1）, growth of productivity over time | Penn World Table 9.0 |
| ICT | Internet users（%） | World Telecommunication/ICT Indicators Database |