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## Are dragons and tigers catching up?

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## **ADB Working Paper Series**

### **ARE DRAGONS AND TIGERS CATCHING UP?**

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**Abstract**

This paper studies the catching-up process in per capita income of the so-called Asian Dragons and Tigers. It contributes to the literature in several ways. First, it tests the catching-up hypothesis using the longest time span ever considered, from 1870 to 2014. Second, it documents the experiences of these two groups of countries and provides potential explanations for them. Third, by using the Kejriwal and Perron (2010) algorithm, we are able to endogenously estimate multiple structural breaks in the level and the trend of the series without prior knowledge of their integration level. This surpasses technical concerns of previous empirical studies. Fourth, it inquires into how the Asian financial crisis affected the catching-up process among the Dragons' and Tigers' economies.

**Keywords:** catching up, structural breaks, Asian Dragons, Asian Tigers

**JEL Classification:** C22, O11, O55

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# 1. INTRODUCTION

The rapid economic growth of East and Southeast Asian countries during the last three decades has been considered a “miracle” (Lucas 1993). In fact, the World Bank (1993) reported that the per capita income in 23 East Asian economies grew on average at a rate of 6–7% over the period 1965–1990. The pace of growth, however, has varied substantially across countries. Such a “miracle” was first performed by the so-called “Dragons” (Hong Kong, China; Singapore; the Republic of Korea; and Taipei, China), and a few decades later was followed by the so-called “Tigers” (Indonesia, Malaysia, Philippines, and Thailand). Particularly successful has been the Dragons’ performance, which has grown at an average rate of 7–8% per annum since the beginning of their miraculous process (The Growth Report, World Bank 2008).

The literature has attributed this remarkable achievement to several factors. Young (1992, 1994, and 1995) argues that the economic growth in these countries has been due to high rates of savings and investment, rapid capital accumulation, and sectoral reallocation of factors of production. In fact, the eight economies have experienced a sizable increase in their capital accumulation that has come along with an increase in their per capita income. On the other hand, Lee and Kiseok (2010) claim that the gains in productivity that have mainly occurred due to technological improvements have been more important, especially in their manufacturing sectors. Another explanation rests on the significant increase in the countries’ trade openness, which has allowed them to receive large inflows of foreign direct investment and substantial advancement in human capital through education. Financial openness has also played an important role (Sachs, Radelet, and Lee 2001; Kawai and Wignaraja 2014; Singh 2010).

Yet the economies of the Dragons and Tigers seem to have changed significantly during the current century. Some authors claim that, after the long period of rapid growth, their growth rates of physical capital and productivity slowed down in the aftermath of the Asian crisis, leading to lower rates of per capita income growth (Riedel 2011; Anand et al. 2014). Taking that into account, some debates have arisen on whether the catching up of the Dragons and Tigers has come to an end (Eichengreen, Park, and Shin 2012 and 2013; Rodrik 2011). Some authors even talk about the Asian tragedy (Agénor and Canuto 2012; Aiyar et al. 2013; Ohno 2009). Although their growth rates are still high compared to other parts of the world, there is a growing concern, both internationally and domestically, about their economic outlook.

Does the economic slowdown mark the end of the Asian miracle or is it only a temporary deviation from its long-run path? Can the Dragons and Tigers preserve their growth trend? Are these countries catching up with the highest per capita income countries, particularly the US? Are there any substantial differences in the convergence experience of the Dragons and Tigers? If this is the end of the miracle, there should be a structural change in their per capita income trend. The catching-up topic is of most interest to growth economists because it constitutes a major challenge faced by emerging and developing countries. The theory states that a lagging country, with initially lower productivity and per capita income, should tend to grow more rapidly than a wealthier country by copying their technology, eventually catching up with their per capita income level (Bernard and Durlauf 1996).

The diversity of average growth rates and income inequality across countries has generated a large number of papers testing whether there has been a convergence in Asian countries. The early work on estimating time trends in relative per capita income assumes linear functional forms without any break in the trend (Carlino and Mills 1993; Bernard and Durlauf 1995; Loewy and Papell 1996; Li and Papell 1999). More recently,

some empirical studies have used single-break unit root tests for convergence (Oxley and Greasley 1995; Li and Papell 1999; Strazicich, Lee, and Day 2004; Maeso-Fernandez 2003; Datta 2003; Tomljanovic and Vogelsang 2002), although it is possible that more than one break may have occurred. The problem with these studies is that, in the same way that one structural break may lead to the conclusion that a stationary series is nonstationary, a single-break test may lead to the same conclusion if two or more breaks are present (Vogelsang 1997). Moreover, given that Asian countries are structurally different from one another (Evans and Kim 2011), they may be subject to country-specific shocks, which, depending on their magnitude, severity, and timing, may cause multiple structural breaks at different points in time.

This paper examines the catching-up performance of the Dragons and Tigers. To this end, it uses the Kejriwal and Perron (2010) (KP) algorithm to endogenously detect the number and time period of structural breaks in the level and trend for each of the countries in the sample. The KP algorithm has the advantage over previously developed algorithms that first, it can detect multiple structural breaks, and second, it does it without previous knowledge of the integration order of the series (Noguera 2013). To measure the catching-up process, we use the per capita income ratio between each Asian country and the United States, which is our proxy for the wealthiest economy. We are particularly interested in inquiring into how the Asian crisis affected convergence.

The rest of the paper is structured as follows. Section II presents the theoretical framework. Section III describes data sources and methodology. Section IV shows estimation results. Section V uses development accounting to discuss the findings and Section VI concludes.

## 2. THE THEORETICAL FRAMEWORK

Let us assume that there is a representative individual whose lifetime utility function is

$$U = \sum_{t=0}^{\infty} \beta^t u(c_t), \quad 0 < \beta < 1, \quad (1)$$

where  $c_t$  denotes consumption. Let  $f(k_t)$  be the production function, where  $k$  denotes physical capital. All variables are measured in per capita terms. Let  $w$  denote the individual wealth and  $\delta$  be the depreciation rate of the physical capital. The individual's budget constraint is

$$w_t = f(k_t, A) + (1 - \delta)k_{t-1} = c_t + k_t. \quad (2)$$

The individual's problem is to choose the paths for  $c_t$  and  $k_t$  that maximize (1) subject to the restriction (2). Solving this problem we obtain the classical expression

$$\frac{u_c(c_t)}{u_c(c_{t+1})} = \beta [f_k(k_t) + 1 - \delta]. \quad (3)$$

In a steady state,  $c_t = c_{t+1} = \tilde{c}$ ,  $k_t = k_{t+1} = \tilde{k}$ , and this equation turns into  $1 = \beta[f_k(\tilde{k}) + 1 - \delta]$ . To provide some intuition, let us assume that there is a Cobb-Douglas technology,  $f(k_t) = Ak_t^\alpha$ , where  $A$  denotes productivity, then  $\tilde{k} = \left[ \alpha A / \left( \frac{1}{\beta} - 1 + \delta \right) \right]^{1/(1-\alpha)}$  and the steady-state per capita output becomes

$$\tilde{y} = bA^{1/(1-\alpha)}, \quad (4)$$

where  $b = \left[ \alpha / \left( \frac{1}{\beta} - 1 + \delta \right) \right]^{\alpha/(1-\alpha)}$  is a constant parameter. From (4), it is apparent that steady-state per capita income depends on labor productivity, along with physical capital. Labor productivity, on the other hand, is determined by a number of factors such as human capital (Lucas 2015), technological advances (Mankiw 1995; Romer 1990), and institutions (North 1990), among others. Hence, physical capital and per capita income converge to a steady-state level conditional on the productivity level ( $A$ ). The question becomes, therefore, whether poor countries are increasing their productivity in such a way that they can converge to rich countries' per capital income level. Let  $y_{rt}$  and  $y_{pt}$  be the per capita income of a rich and a poor country, respectively, in period  $t$ . There will be convergence if the long-run trend of the ratio  $y_p/y_r$  increases toward one as time goes by. Thus, we define  $y_t = y_{pt}/y_{rt}$  as the per capital income ratio between a poor and a rich country in period  $t$ , and estimate the regression

$$[1 - A(L)]y_t = a + bt + \varepsilon_t \quad (5)$$

where  $\varepsilon_t$  is white noise and  $A(L)$  is a polynomial on the lag operator. Then, the estimated long-run trend of the poor country would be  $\hat{y}_t = \hat{a} + \hat{b}t$ , where the “hat” denotes that it is the estimated variable, and it would be converging on the rich country level if  $\hat{b} > 0$ .

### 3. METHODOLOGY

To undertake this exercise, we estimate (5) for each of the Dragons and Tigers, using the United States' per capital income as a proxy variable for the rich country. Data are obtained from the Maddison Historical Database and the World Bank beginning 1870 for Indonesia; 1900 for Taipei, China and the Philippines; 1911 for Malaysia and the Republic of Korea; and 1950 for Thailand; Hong Kong, China; and Singapore. The data span of data is up to 2014. All variables are measured in logs.

Since the economy converges to its steady state, in estimating (5) we are particularly interested in the estimated coefficient  $\hat{b}$ , which measures the growth rate of the ratio  $\hat{y}_t$ . Yet, if the long-run trend of the growth rate ratio  $\hat{y}_t$  has experienced a change in its convergence speed, that should be reflected as a change in the trend, that is, in  $\hat{b}$ . By applying the Kejriwal and Perron (2010) procedure to each of the series, we inquire as to whether  $y_t$  shows any structural break in the intercept and the slope. The advantage of this algorithm over all previous procedures developed is that it endogenously detects any number of structural breaks in the series, which, if they occurred, would mean that the country's relative income would show a change in its level or in its trend, and hence in its convergence rate. Table 1 presents the results. It shows the number of breaks, the break years and the  $F((i+1|i))$  statistics. Significance levels are given at 5% and are dependent on the number of breaks. Critical values are given at the bottom

of the table. The algorithm suggests the existence of four structural breaks for the Philippines and Indonesia; two for the Republic of Korea; Singapore; Taipei, China; and Thailand; and one for Hong Kong, China and Malaysia. Table 2 reports estimations of the regression

$$y_t = a + \sum_{i=1}^n a_i + bt + \sum_{i=1}^n b_i t_i + u_t. \quad (6)$$

for each country in the sample, where  $t_i = t$  and  $a_i = 1$  for  $t_i \geq \tau_i$  and zero otherwise, and where  $\{\tau_1, \tau_2, \dots, \tau_n\}$  are the breakpoints detected by the Kejriwal and Perron algorithm. That allows us to take into account the structural breaks shown in Table 1. This shows the initial intercept and trend, and then the subsequent changes in the level ( $a_i$ ) and in the trend ( $b_i$ ). Standard errors are shown in parenthesis below each coefficient. The results summarized in Table 2 for the intercept and trend in each subperiod allow us to analyze the catching-up process in the next section. Notice that  $\hat{\gamma} = \hat{b}$  is the estimation of the initial growth rate, but  $\hat{\gamma}_k = \hat{b} + \sum_{i=1}^k \hat{b}_k$  is the growth rate estimation during the period represented by the interval  $[j, j+1)$  for  $0 < j < n-1$ . The coefficients  $\hat{\gamma}_i$  are the estimated growth rate changes at which a given country is converging to or diverging from the US per capita income level during the time period  $[j, j+1)$ .

**Table 1: Trend Break Tests**

Per Capita Real GDP							
Country	Break	Year	F(i+1 i)	Country	Break	Year	F(i+1 i)
Hong Kong, China	1	1999	5.09	Republic of Korea	1	1939	101.2
	2		1.45		2	1944	8.48
Indonesia	1	1933	21.7		3		1.11
	2	1944	7.66	Singapore	1	1971	6.78
	3	1975	6.25		2	1999	5.65
	4	1999	34.6		3		2.28
	5		1.75	Taipei, China	1	1933	95.5
Malaysia	1	1942	12.82		2	1943	5.80
	2		2.78				0.00
Philippines	1	1942	7.68	Thailand	1	1991	13.4
	2	1948	26.0		2	1999	17.5
	3	1986	19.3		3		2.71
	4	2005	23.1				
	5		2.47				
Critical Values							
Breaks under the Null		Breaks under the Alternative		5%			
0		1		3.66			
1		2		4.06			
2		3		4.34			
3		4		4.59			
4		5		4.79			

**Table 2: Trend Break Coefficients – Diagnostic Check**

Country	Break Dates	Intercept (a)	Trend (b)	Changes in the Intercept				Changes in the Trend			
				a <sub>1</sub>	a <sub>2</sub>	a <sub>3</sub>	a <sub>4</sub>	b <sub>1</sub>	b <sub>2</sub>	b <sub>3</sub>	b <sub>4</sub>
Hong Kong, China	1999	−4.509 (0.106)	0.032 (0.001)	0.149 (0.220)				−0.003 (0.002)			
Indonesia	1933 1944 1975 1999	−3.102 (0.164)	0.004 (0.003)	4.200 (0.835)	−4.168 (0.928)	−3.187 (0.320)	−1.179 (0.365)	−0.063 (0.013)	0.054 (0.008)	0.032 (0.003)	0.007 (0.003)
Malaysia	1942	−2.695 (0.274)	0.011 (0.006)	−1.004 (0.265)				0.003 (0.003)			
Philippines	1942 1948 1986 2005	−2.732 (0.206)	0.006 (0.004)	3.921 (3.824)	−4.133 (3.841)	0.798 (0.267)	−4.961 (0.142)	−0.067 (0.051)	0.060 (0.052)	−0.009 (0.003)	0.037 (0.001)
Republic of Korea	1939 1946	−2.740 (0.219)	0.010 (0.004)	14.705 (2.164)	−18.333 (2.167)			−0.211 (0.025)	0.241 (0.030)		
Singapore	1971 1999	−1.984 (0.513)	0.005 (0.006)	−2.568 (0.486)	0.811 (0.343)			0.029 (0.006)	−0.008 (0.002)		
Taipei, China	1933 1943	−3.356 (0.145)	0.017 (0.003)	6.066 (0.864)	−8.734 (0.903)			−0.092 (0.013)	0.112 (0.014)		
Thailand	1991 1999	−5.445 (0.146)	0.022 (0.001)	1.239 (1.546)	−1.696 (1.592)			−0.008 (0.012)	0.012 (0.013)		

Standard errors are in parenthesis below the estimated coefficient.

**Table 3: Unit Root Tests**

		MSB	Mza	MZt
Hong Kong, China	In Levels	0.20	−11.80	−2.38
	First Diff.	0.13*	−30.49**	−3.90**
Indonesia	In Levels	0.13**	−31.36**	−3.96**
	First Diff	0.09***	−50.9***	−5.04***
Malaysia	In Levels	0.13	−28.1	−3.71
	First Diff	0.07***	−99.9***	−7.06***
Philippines	In Levels	0.11***	−38.8***	−4.39***
	First Diff	0.10***	−48.3***	−4.91***
Singapore	In Levels	0.17**	−16.4**	−2.82**
	First Diff	0.12***	−31.4***	−3.96***
Republic of Korea	In Levels	0.15*	−23.2*	−3.39*
	First Diff.	0.10**	−45.8***	−4.78***
Taipei, China <sup>†</sup>	In Levels	0.12	−31.7	−3.93
	First Diff	0.10**	−5.0**	−50.5**
Thailand	In Levels	0.20*	−10.7**	−2.22**
	First Diff	0.12**	−31.4**	−3.95**

1% significant level \*\*\* 5% significant level \*\* 10% significant level \*.

† For Taipei, China, we consider an outlier in 1945, when per capita income was more than 50%.

Table 3 shows the test inquiring about the presence of unit roots in the series. This is important because it determines whether the series tends to return to its long-run trend. For this purpose, we use the tests proposed by Ng and Perron (2001). However, following Perron and Rodriguez (2003), Carrion-i-Silvestre, Kim, and Perron (2009) show that in the presence of structural breaks, these statistics do not follow the distribution shown by Ng and Perron (2001), but another one that they developed in

their work. The test results suggest that the per capita income ratios are  $I(0)$  and therefore stationary for Indonesia, the Philippines, and Singapore, and so their trajectories converge to the long-run trend. On the other hand, Hong Kong, China; Malaysia; the Republic of Korea; and Taipei, China show one unit root; that is, they are  $I(1)$ , and hence their trajectories follow random walks. Fortunately, their log differences are stationary and converge to zero. Therefore, although the series in levels may be a random walk, it will eventually return to its long-run trend as its growth rate converges to zero. The test for the series in levels for Thailand shows mixed results in the sense that two tests reject the null hypothesis of a unit root and the other one does not, but the tests for the first difference clearly suggest that, in the worst case, its growth rate is stationary.

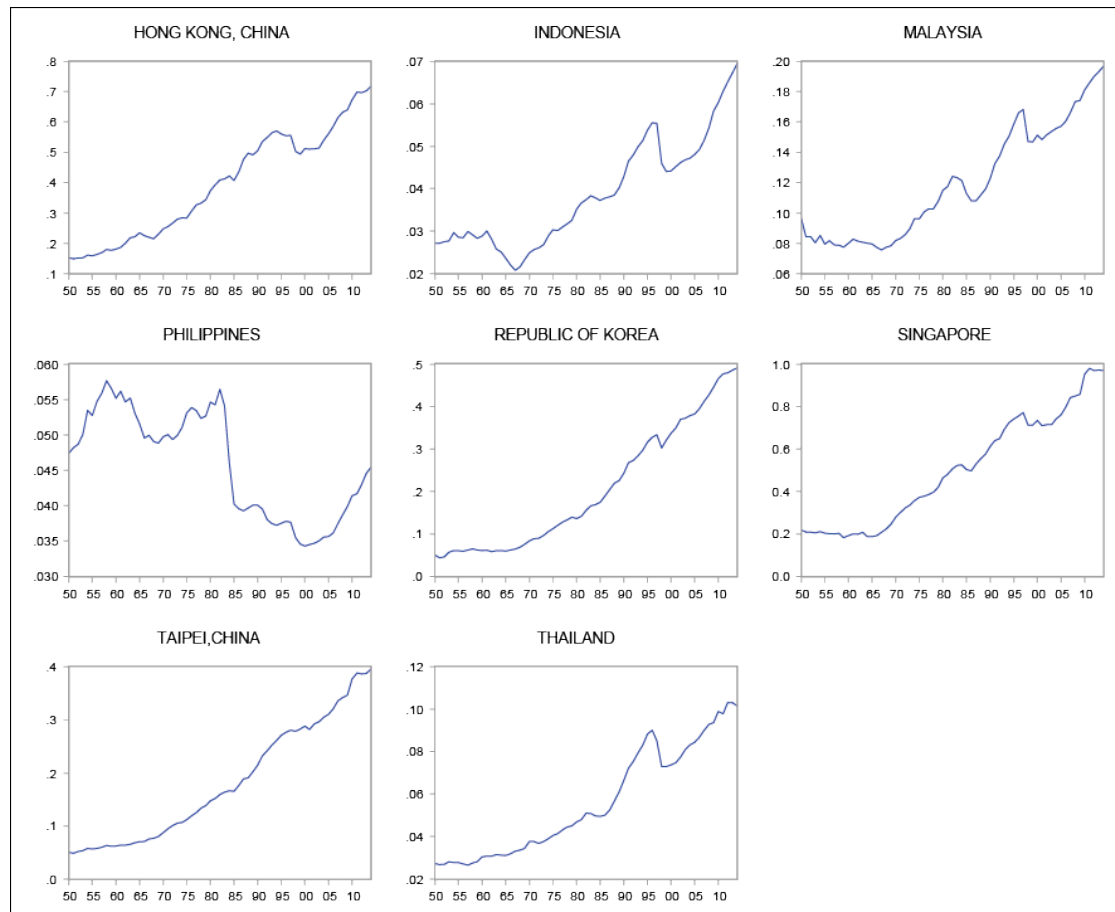
#### **4. DRAGONS AND TIGERS AND THEIR DIFFERENT STORIES**

For each of the eight countries in the sample, Table 4 shows the associated relative per capita real income growth rates within each of the periods defined by the structural breaks shown in Tables 1 and 2. From these tables, together with Figure 1, it is apparent that all countries have exhibited upward trends in recent years, suggesting that all eight countries are currently converging, although at different speeds, to the level of the US. Figure 1 illustrates this. Results also suggest that they are catching up at different rates and over different time periods. All Dragons have experienced catching-up rates since the end of World War II, and at least from 1950 on. In fact, Hong Kong, China was converging at a 3.2% rate from 1950, but it has slowed down to 2.8% since 1999. Singapore started with an anemic rate of 0.5% that accelerated to 3.4% in 1971, before slowing down to 2.6% in 1999. The Republic of Korea and Taipei, China have had the most impressive performances. After performing poorly for an extended period, both countries have experienced sustained catching-up rates of 4.0% and 3.7%, respectively, since the mid-1940s. Such extraordinary performances imply that, using the data source mentioned in Section III, Hong Kong, China has been able to increase its low 0.15 relative income in 1950 to 0.72 in 2014, and Singapore increased it from 0.22 to 0.97, nearly closing the per capita income gap with the US. The Republic of Korea's relative income increased from 0.05 to 0.49 and Taipei, China's from 0.05 to 0.40. This evidence suggests that the Dragons have exhibited a strong and robust catching-up process.

The Tigers' performance has been much more diverse than that of the Dragons. First, some of them started their catching up much more recently than others. Indonesia's startup was in 1975 with a 2.6% long-run growth rate, speeding up to 3.3% from 1999, and the Philippines' was as recent as 2005. On the other hand, Malaysia and Thailand have been catching up since the beginning of the sample. Malaysia has done so at a relatively slow long-run rate of 1.4%, while Thailand started with an initially good 2.2%, slowing down to 1.4% in 1991, and sped up again to 2.5% in 1999. However, in all cases, their relative incomes are still far from reaching that of the US. By 2014, Thailand's relative per capita income was 0.10, Malaysia's was 0.20, Indonesia's was 0.07, and the Philippines' was 0.05.

**Table 4: Steady-State Growth Rates (%)**

	Since the beginning of the Sample	After T1	After T2	After T3	After T4
Hong Kong, China	3.2 (1950)	2.8 (1999)			
Indonesia	0.4 (1870)	-6.0 (1933)	-0.6 (1944)	2.6 (1975)	3.3 (1999)
Malaysia	1.1 (1911)	1.4 (1942)			
Philippines	0.6 (1900)	-6.1 (1942)	0.0 (1948)	-0.9 (1986)	2.8 (2005)
Singapore	0.5 (1950)	3.4 (1971)	2.6 (1999)		
Republic of Korea	1.0 (1911)	-20 (1939)	4.0 (1946)		
Taipei, China	1.7 (1900)	-7.5 (1933)	3.7 (1943)		
Thailand	2.2 (1950)	1.4 (1991)	2.5 (1999)		

**Figure 1: Relative per capita GDP for Dragons and Tigers**


The figure gives the regions' per capita real GDP relative to the US's per capita real GDP (US's real per capita income equals 1).

In order to better understand the reasons behind such different performances, we conduct a simple development accounting exercise. Table 5 shows the per capita human and physical capital, total factor productivity (TFP), and per capita income levels for each country relative to those of the US. Data for human and physical capital are obtained from the Penn World Tables, and the TFP is computed assuming a Cobb-Douglas function with an output elasticity of capital of 1/3. Results are interpreted as the contributions of factors of production and the TFP to the relative per capita income.

**Table 5: Basic Development Accounting**  
(relative to the United States, US=1)

Country	Year	Output Per Worker, y	Productivity	Human Capital Per Worker, h	Physical Capital Per Worker, k	Factors of Production, $k^{1/3}h^{2/3}$
Hong Kong, China	1960	0.18	0.42	0.68	0.17	0.43
	1999	0.49	0.59	0.79	0.91	0.83
	2011	0.70	0.76	0.83	1.11	0.92
Indonesia	1960	0.03	0.14	0.44	0.04	0.20
	1975	0.03	0.16	0.47	0.03	0.19
	1999	0.04	0.17	0.53	0.06	0.26
	2011	0.06	0.19	0.57	0.10	0.33
Malaysia	1960	0.08	0.22	0.53	0.16	0.36
	2011	0.19	0.30	0.82	0.36	0.62
Philippines	1950	0.05	0.16	0.55	0.08	0.30
	1986	0.04	0.13	0.69	0.06	0.31
	2005	0.04	0.10	0.75	0.08	0.36
	2011	0.04	0.11	0.75	0.10	0.38
Republic of Korea	1960	0.06	0.20	0.64	0.07	0.30
	2011	0.48	0.53	0.92	0.88	0.91
Singapore	1960	0.19	0.45	0.59	0.14	0.36
	1971	0.30	0.96	0.61	0.16	0.40
	1999	0.71	0.99	0.72	0.77	0.74
	2011	0.98	1.07	0.76	1.40	0.94
Taipei, China	1960	0.06	0.23	0.68	0.04	0.27
	2011	0.39	0.49	0.89	0.63	0.79
Thailand	1950	0.03	0.10	0.60	0.05	0.26
	1991	0.07	0.20	0.58	0.13	0.36
	1999	0.07	0.16	0.60	0.28	0.47
	2011	0.10	0.21	0.67	0.25	0.48

The data show that both the Dragons and the Tigers had small and similar physical and human capital levels by 1960, ranging from 0.04 to 0.17 and from 0.44 to 0.68, respectively. On the other hand, the original total factor productivity levels were much higher in Singapore and Hong Kong, China (0.45 and 0.42, respectively) than in the other six countries (between 0.10 and 0.23). It should be noted that there have been some important disparities between the Dragons and the Tigers. Among the Dragons, although human capital substantially improved and productivity increased by about twice as much in each of these countries, what stands out and seems to be the main contributor to their improvement is the impressive increase in physical capital in each of them. Between 1960 and 2011, the increase in the relative physical capital was

6.5 times in Hong Kong, China; 12.6 times in the Republic of Korea; 10 times in Singapore; and 15.8 times in Taipei, China. This matches the results found by Young (1992; 1995).

For the Tigers, this process was quite dissimilar. On the one hand, Thailand increased their relative income 2.5 times, and Indonesia and Malaysia did so by slightly more than 1.8 times. Its condition as a latecomer caused the Philippines' indicators to be barely reflected. Human capital has shown important improvements in Indonesia, Malaysia, and the Philippines, and somewhat less important ones in Thailand. Although there have been important gains in the relative productivity in Malaysia and Thailand, this has not occurred in Indonesia and there has been a slight decline in the Philippines. What all of them have in common, as in the case of the Dragons, is important improvements in their relative physical capital, again matching with the findings of Young (1994).

Table 4 also shows information about the impact of the 1998 Asian financial crisis on the convergence process of the Dragons and Tigers. For the Philippines; the Republic of Korea; Taipei, China; and Malaysia, we find no evidence of an effect of the crisis on their relative per capita income long-run trend. This means that the crisis was a temporary shock to their economies. On the other hand, we did find evidence that the crisis affected the long-run relative per capita income trends in Hong Kong, China; Singapore; Indonesia; and Thailand, although not all countries were affected in the same way. For instance, interestingly, while the affected Dragons (Hong Kong, China and Singapore) showed a slowdown, the affected Tigers (Indonesia and Thailand) experienced a speeding up in their long-run catching-up rates.

## 5. CONCLUSION

This paper studies the catching-up process between two clubs of countries, the so-called "Dragons" and "Tigers." It contributes to the literature by studying the changes in the convergence rates of these countries using sophisticated econometric methods, namely, the Kejriwal and Perron (2010) algorithm and the Carrion-i-Silvestre, Kim, and Perron (2009) tests, which can determine the number of structural breaks in the level and in the trend, without the need to know in advance the integration level of the series. The empirical results suggest that the Dragons have been able to grow at a fast enough rate to approach the level of the United States, while the Asian Tiger economies have exhibited a weaker process.

For the Dragons, the evidence suggests that the process has started at least since 1950, and has not stopped. We found, however, that the 1998 Asian financial crisis slowed down the convergence rate in Hong Kong, China and Singapore. The experience of the Tigers has been much more diverse. While some of them, like Malaysia and Thailand, started to catch up after WWII, the Philippines did so as recently as 2005. We did not find a common pattern in the effect of the Asian crisis on all of the countries that make up either group, the Dragons or the Tigers, which suggests that the effect of the 1998 crisis was country-specific. We did find, however, that the effect on the affected Dragons was negative, in contrast to that on the affected Tigers. Inquiring into the causes of these dissimilar behaviors, using a simple development accounting exercise, we find that the major engine behind their successes has been rapid capital accumulation. That seems to be in accordance with other literature on the topic (Braude and Menashe 2011).

## REFERENCES

- Agénor, P.-R.; Canuto, O. (2012) "Middle-income growth traps," *World Bank Policy Research Working Paper* 6210.
- Aiyar, S.; Duval, R.; Puy, D.; Wu, Y.; Zhang, L. (2013) "Growth Slowdowns and the Middle-Income Trap." *IMF Working Paper* No. 13/71. International Monetary Fund (IMF), Washington D.C.
- Anand, R.; Cheng, K.; Rehman, S.; Zhang, L. (2014) "Potential growth in emerging Asia," *IMF Working Paper* 28.
- Bernard A.; Durlauf S. (1995) "Convergence in international output," *Journal of Applied Econometrics* 10: 97–108.
- Bernard A.; Durlauf S. (1996) "Interpreting tests of the convergence hypothesis," *Journal of Econometrics* 71(1–2): 161–173.
- Braude, J.; Menashe, Y. (2011) "The Asian miracle: Was it a capital-intensive structural change?" *Journal of International Trade & Economic Development* 20(1): 31–51.
- Carlino, G.; Mills, L. (1993) "Are U.S. regional incomes converging? A time series analysis," *Journal of Monetary Economics* 32: 335–346.
- Carrion-i-Silvestre, J.; Kim, D.; Perron, P. (2009) "GLS-based unit root tests with multiple structural breaks under the null and the alternative hypotheses," *Econometric Theory* 25: 1754–1792.
- Datta, A. (2003) "Time-series tests of convergence and transitional dynamics," *Economics Letters* 81: 233–240.
- Eichengreen, B.; Park, D.; Shin, K. (2012) "When fast growing economies slow down: International evidence and implications for China," *Asian Economic Papers*, 11: 42–87.
- Eichengreen, B.; Park, D.; Shin, K. (2013) "Growth slowdowns redux: New evidence on the middle-income trap," *NBER Working Paper* 18673.
- Evans, P.I.; Kim, J. (2011) "Stochastic convergence of the catch-up rate and multiple structural breaks in Asian countries," *Economics Letters* 111: 260–263.
- Kawai, M.; Wignaraja, G. (2014) "Trade policy and growth in Asia," *ADBI Working Papers* 495.
- Kejriwal, M.; Perron, P. (2010) "Testing for multiple structural changes in cointegrated regression models," *Journal of Business and Economic Statistics* 28: 503–522.
- Lee, J.-W.; Kiseok, H. (2010) "Economic growth in Asia: determinants and prospects," *Japan and the World Economy* 24(2): 101–113.
- Li, Q.; Papell, D. (1999) "Convergence of international output: Time series evidence for 16 OECD countries," *International Review of Economics and Finance* 8: 267–280.
- Loewy, M.; Papell, D. (1996) "Are U.S. regional incomes converging? Some further evidence," *Journal of Monetary Economics* 38: 587–598.
- Lucas, R. (1993) "Making a miracle" *Econometrica* 61(2): 251–72.
- Lucas, R. (2015) "Human capital and growth," *American Economic Review* 105(5): 85–88.

- Maeso-Fernandez, F. (2003) "A time series approach to  $\beta$  convergence," *Applied Economics* 35: 1133–1146.
- Mankiw, G. (1995) "The growth of nations," *Brookings Papers on Economic Activity* (1): 275–326.
- Ng, S.; Perron, P. (2001) "Lag length selection and the construction of unit root tests with good size and power," *Econometrica* 69: 1519–1554.
- Noguera, J. (2013) "Oil prices: Breaks and trends," *Energy Economics* 37: 60–67.
- North, D. (1990) "Institutions, Institutional Change, and Economic Development," *Cambridge University Press*.
- Ohno, K. (2009) "Avoiding the middle income trap: Renovating industrial policy formulation, Vietnam," *ASEAN Economic Bulletin* 26(1): 25–43.
- Oxley, L.; Greasley, D. (1995) "A time-series perspectives on convergence: Australia, UL and USA since 1870," *Economic Record* 71: 259–270.
- Perron, P.; Rodriguez, G. (2003) "GLS detrending, efficient unit root tests and structural change," *Journal of Econometrics* 115: 1–27.
- Riedel, J. (2011) "The slowing down of long-term growth in Asia: Natural causes, the middle income trap and politics," *School of Advanced International Studies*, Johns Hopkins University.
- Rodrik, D. (2011) "The future of economic convergence," *NBER Working Paper* 17400.
- Romer, P. (1990) "Human capital and growth: Theory and evidence," *Carnegie-Rochester Conference Series on Public Policy* 32(1): 251–286.
- Sachs, J.; Radelet, S.; Lee, J-W. (2001) "Determinants and prospects of economic growth in Asia," *International Economic Journal* 15(3):1–29.
- Shekhar, A.; Duval, R.; Puy, D.; Wu, Y.; Zhang, L. (2013) "Growth slowdowns and the middle-income trap," *IMF Working Paper* 13/71.
- Singh, T. (2010) "Does international trade cause economic growth? A survey," *World Economy* 33(11): 1517–1564.
- Strazicich, M.C.; Lee, J.; Day, E. (2004) "Are incomes converging among OECD countries? Time series evidence with two structural breaks," *Journal of Macroeconomics* 26: 131–145.
- Tomljanovic, M.; Vogelsang, T. J. (2002) "Are U.S. regions converging? Using new econometric methods to examine old issues," *Empirical Economics* 27: 49–62.
- Vogelsang, T. (1997) "Wald-Type test for detecting shifts in the trend function of a dynamic time series," *Econometric Theory* 13: 818–849.
- World Bank (1993) "The East Asian miracle: economic growth and public policy," *Oxford University Press*, New York.
- World Bank (2008) "The growth report: Strategies for sustained growth and inclusive development," Washington, D.C.
- Young, A. (1992) "A tale of two cities: Productivity growth in Hong Kong and Singapore," *NBER Macroeconomics Annual* 1992.
- Young, A. (1994) "Lessons from the East Asian NICs: A contrarian view," *European Economic Review*, 38 (3–4): 964–973.
- Young, A. (1995) "The tyranny of numbers: Confronting the statistical reality of the East Asian growth experience," *Quarterly Journal of Economics* 110(3): 641–680.