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Testing the convergence and the divergence in five Asian countries: from a GMM model to a new Machine Learning algorithm

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Abstract

Purpose – The purpose of this paper is to empirically test the economic convergence that operate between five selected Asian countries (namely Thailand, Singapore, Malaysia, the Philippines and Indonesia). In particular, it seeks to investigate how increased economic integration has impacted the inter-country income levels among the five founding members of ASEAN.

Design/methodology/approach – A new Machine Learning (ML) approach is applied along with a panel data analysis (GMM), and the application of KOF Globalization Index.

Findings – The Generalized Method of Moments (GMM) results highlight that the endogenous growth theory seems to be supported for the selected Asian countries, indicating evidence of diverging forces resulting from unequal growth and polarization dynamics. Overcoming the technical issues raised by the econometric approach, the new ML algorithm brings contrasted but interesting results. Using the KOF Globalization Index, the authors confirm how the last phase of globalization set the conditions for an economic convergence among sample members.

Originality/value – Using the KOF Globalization Index, the authors confirm how the last phase of globalization set the conditions for an economic convergence among sample members. As a matter of fact, the new LSTM algorithm has provided consistent evidence supporting the existence of converging forces. In fact, the results highlighted the effectiveness of the experiments and the algorithm we chose. The high predictability of the authors' model and the absence of self-alignment in the values showed a convergence be-tween the economies.

Keywords Convergence, ASEAN, GMM, Panel data, Machine learning, LSTM

Paper type Research paper

1. Introduction

The concept of divergence and convergence among countries in terms of GDP per capita is currently a controversial issue as well as a recurrent question of economic thinking. According to the early growth theories, economic integration was meant to allow for an equalization of growth rates while reducing the income gap (Solow, 1956; Swan, 1956; Mankiw *et al.*, 1992; Barro and Sala-i-Martin, 2004; Cieślik and Wciślik, 2020). Hence, regardless of the difference in the initial per capita income of economies, richer and poorer countries may converge accordingly. Several critics have been addressed to this pattern. Starting with the endogenous growth theories (Romer, 1986; Lucas, 1988) and followed by the

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new economic geography (Krugman, 1991), several approaches have demonstrated that strong diverging forces might emerge among economies, supporting thus the existence of an opposite dynamic (Cieślik and Wciślik, 2020).

This controversy of income convergence and divergence has drawn the attention of many researchers who tempted to bring theoretical insights on this topic. Far from being outdated, such debate questions whether the development gap between countries standing at different economic stages is practicable through economic liberalization (Urata and Narjoko, 2017). Accordingly, the main idea regarding convergence is viewed as the approximation of qualitative and quantitative attributes of countries based upon the neoclassical growth model developed by Solow (Guerrini, 2006). As relevantly detailed in Ghatak and De (2016), the main mechanism behind the convergence dynamic stands in the assumption of diminishing returns. Indeed, a negative coefficient on initial income refers to poor countries whose growth may be faster than richer ones. Developing countries displaying a low capital to labour ratio experience diminishing returns to capital which in turn, translates into a relatively higher marginal products of capital. Consequently, low income countries tend to grow faster than others, inducing thus a tendency to convergence at the same steady state. Surprisingly, this theory remains consistent when the selected economies present different initial levels of per capita income, although their rate of population growth, the investment ratio or technology development should be closely related to converge to the same growth path. Such statement has been later extended by new growth theories which postulated the possible existence of a multiple steady-state equilibrium (Azariadis and Drazen, 1990; Durlauf and Johnson, 1995; Bernard and Jones, 1996). Finally, endogenous growth models (Romer, 1986; Lucas, 1988) shed light on the innovation and knowledge diffusion determinants as potential convergence-enabler.

Facing this lack of consensus, a range of empirical studies have addressed this research question, but no clear-cut answer has been brought to this debate so far. Mostly because of different approaches, this topic has become a subject of intense controversy. Indeed, a wave of economists have opposed the concept of trade liberalization on the grounds that it continues to increase disparities between richer and poorer countries. Thus, they brought key mechanisms to light. By contrast to the idea of convergence, reducing the barriers to economic flux among countries may reinforce their structural disparities. While the economic activities of richer countries could be strengthened, the less competitive countries may face adverse trade and economic effects, leading thus to unequal and heterogeneous growths, polarization, and extreme divergence. Notwithstanding their limitations, documenting these theories with an empirical approach is believed to enrich the ongoing debate on this subject. This appears even more crucial since a range of advanced and emerging countries are currently engaged into economic integration process. Therefore, examining which driving forces matter is of high interest as it could consistently document these phenomena.

To give further insights, we represent in Figure 1 the historical pattern of economic growth in five Asian countries. Data were compiled from the World Development Indicators (2019) database. A visual inspection of the figure indicates evidence of a significant correlation between the series, especially for the last two decades. One interesting aspect stands in the relatively similar response of the region to the Asian economic crisis of 1997–1998 (Malarvizhi *et al.*, 2019). All economies have recorded an absolute decrease or substantial slowdown in income growth at this point of time. Prior to this, series display a common upward trend that turn to be strengthened after the 2000s. However, respective changes over time reveal heterogeneous magnitudes and might be explained by the individual economic characteristics of the selected countries. Far from being a coincidence, it underlines the possible existence of interdependencies among these economies, and sheds light on potential

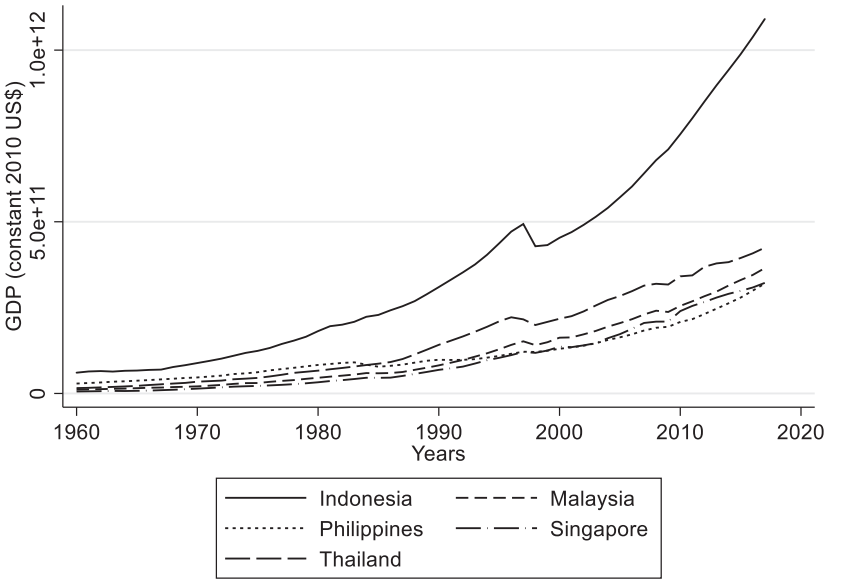


Figure 1.
Historical economic growth pattern in Indonesia, Malaysia, Thailand, Singapore, and the Philippines, 1960–2017 (level scale)

Source(s): Our elaborations based on WDI data

converging economic forces in operation in this region (Magazzino, 2014). While significant income differences among member countries persist, there is a point in asking whether the existence of a "catching up" phenomenon from the richer economies by the relatively less developed is feasible in South Asia (Kanbur *et al.*, 2014; Piketty, 2014).

Accordingly, this paper seeks to contribute to the literature in several ways (both empirically and methodologically). To the best of our knowledge, this is the first empirical examination of the convergence hypothesis among these selected countries. Second, the use of ML experiments to complement a panel data analysis remains incipient for such type of study, although it has demonstrated a powerful capacity to depict causalities among multiple variables on neighbouring topics (Mele and Magazzino, 2020; Magazzino *et al.*, 2020a, b, c, d, 2021a, b, c, d, e; Magazzino and Mele, 2021; Mele *et al.*, 2021a, b). Thus, this paper finds its second contribution in employing an innovative methodology able to confirm the econometric results obtained, but also extend them in the most robust manner. Indeed, we wrote a new ML algorithm to test the hypothesis. Third and finally, most of the existing studies relied on historical data prior to the 2012 sovereign debt crisis (Button and Pentecost, 1995; Estrin *et al.*, 2001; Azomahou *et al.*, 2011; Magazzino, 2017, 2020). Here, we consider that such timely information cannot be neglected because the last two decades have been accompanied by key trade agreements and ongoing integration processes that will impact the economic performance of the whole region. Often omitted in previous works, including time-series data covering the most recent period would bring more reliable information on whether the five Asian countries converge or not. This is where stands the third contribution of this study.

The aim of this paper is to assess the existence of economic convergence among five selected Asian countries (Thailand, Singapore, Malaysia, Philippine, and Indonesia). More precisely, it seeks to investigate how increased economic integration has impacted the inter-country income levels among the 5 founding members of ASEAN. To do so, we collected per

capita income data covering the largest and most recent period: from 1960 to 2017. A consistent convergence testing framework is elaborated and comprises 3 distinct methodologies: (1) The System Generalized Method of Moments (GMM) is first conducted to provide econometric evidence. (2) The KOF Gloablization Index is then analysed for our sample of selected countries. (3) In line with Magazzino *et al.* (2021a, b), a ML approach is then adopted. A Long Short-Term Memory network (LSTM) is applied and thought to overcome the statistical limits of econometric tools. Obtained results are finally compared. Based on that, methodological and economic conclusions are drawn, along with policy recommendations for the Asian region. The present paper is thought to represent a fruitful research direction and bring robust inferences on this topic. Indeed, to the best of our knowledge, this is the first paper that applies a ML to inspect income convergence. The reason should be attributed to the mathematical and computational difficulties involved in such a particular analysis. Therefore, this paper, overcoming theoretical and computational difficulties, might open a new fruitful line of research.

The rest of the paper is organized as follows. Section 2 presents the relevant literature. Section 3 describes the data, the GMM framework, and the panel data results. Section 4 provides the LSTM model outcomes and a discussion. In Section 5, concluding remarks and policy implications are given, as well as suggestions for future research [1].

2. Literature survey

In this Section, a brief literature survey is presented. Starting by a state-of-the-art on the convergence hypothesis, attention is paid on the impact of globalization on growth and inequality in developing countries *(2.1.)*. Then, the most relevant and recent assessing the existence of an income convergence among non-Asian countries are outlined *(2.2.),* followed by a specific focus on the Asian literature *(2.3.)*. Finally, major research gaps are highlighted, and our contribution is formulated *(2.4.)*

2.1 Background: the convergence hypothesis in a context of globalization

The convergence hypothesis has currently become a dominant topic because many people question the living standards of those in underdeveloped countries, whether it has improved due to trade liberalization, has increased extensively compared to that of the richer nations, or whether their live standards keep deteriorating while their rich counterparts continue to get richer. The neoclassical growth model extensively supports the main idea of convergence among nations. According to Egger and Pfaffermayr (2006), although the poor countries often start at a disadvantaged position, both their economies and their rich counterparts will one day converge to one growth path or a steady state. The authors conducted empirical research studies using different data, methodology, and countries based on the 1956 Solow growth model. Their findings indicate that as nations continue to trade with one another with lenient tariff barriers between them, they tend to consolidate the economic activities between them which in turn promotes the economic growth in the poorer countries. Since then, many empirical studies have been conducted with different variables which have all predicted economic growth among nations. For instance, as Madsen (2007) states, openness promotes the movement of capital between countries, which in turn stimulates the growth of the countries involved. In this case, convergence is ensured by certain factors such as technology, factor mobility, and goods.

Since different methodologies often produce different results, the impact of globalization on growth and inequality in poor countries has become a crucial focus of the debate. Much of this idea is inspired by Baddeley (2006), who examined the impacts of globalization on cross-country comparative patterns of growth and development. Emphasizing on key factors such

as capital flows, computerization, and trade, the author conducted her analysis using club convergence model. The results show that globalization, as in the past, promoted financial flows and trade towards poor and underdeveloped countries. Additionally, findings indicate that globalization has improved information flow, which is critical when it comes to economic and financial linkages. This is in line with Madsen's claim that since the beginning of the 21st century, some developing countries have converged towards the European per-capita income. However, Baddeley (2006) study also reveals that presently, globalization is associated with inequalities rather than the convergence in the economic outcome.

2.2 Economic convergence in the OECD, EU, and SAARC area

A first strand of literature brought evidence supporting the economic convergence among various case studies. For instance, Gaulier *et al.* (1999) found evidence supporting the existence of an absolute and common convergence process for per capita GDP in Europe only. However, for OECD countries, structural disparities remain while no convergence is supported for the World. Badinger *et al.* (2004) inspected the converging forces among 196 economic regions in Europe using data spanning the 1985–1999 period. They concluded to a rate of convergence estimated at 7% using the GMM approach. Ralhan and Dayanandan (2005) explored the conditional income convergence among 10 provinces in Canada. The authors applied the first-differenced GMM estimation technique using data between 1981 and 2001, concluding that the rate of convergence is about 6%. Gadea Rivas and Sanz Villarroya (2017) employed the Panel Quantile Regression over 10 periods of 5 years (from 1950 to 2000) and validated the convergence hypothesis for 21 OECD countries. This is in line with Angeloni and Dedola (1999) who presented evidence supporting that cross-country correlations have significant risen among European Monetary Union (EMU) member countries. Similarly, this corroborates Arnold *et al.* (2011) for 21 OECD countries, although their estimated speed of convergence appears non-compatible with the augmented Solow model. This is in line with Khan and Daly (2018), Safdar and Nawaz (2020), Simionescu (2017), and Lafuente *et al.* (2020) for five SAARC countries, six SAARC economies, 28 EU countries, and 26 EU countries, respectively. However, such a conclusion differs from Azomahou *et al.* (2011) as their parametric and semi-parametric estimations conducted on 157 regions of EU countries led to contrasting results. While low-income regions are found to converge, medium income regions are found to substantially diverge.

Inversely, some economists have supported the divergence hypothesis. Hence, they consider that the persistence of huge disparities between the poor and the rich nations can be attributed to trade liberalization. In Nahar and Inder (2002), the authors revealed results of strong convergence for the vast majority of 22 OECD countries. Monfort *et al.* (2013) conducted a Cluster Analysis and supported the existence of a strong economic divergence for a sample comprising 14 EU countries. This corroborates Zia and Mahmood (2019) whose panel results exhibited evidence of no-convergence for SAARC economies and Cieślik and Wciślik (2020) for 15 EU countries. As defended in Wahiba (2015), trade liberalization often leads to divergence. While the majority of the countries participating in a trade exchanges remain the same, countries characterized as an intermediate divide to might potentially diverge with the richer economy and converge to the poorer countries. This is in line with Hallett and Piscitelli (2002) who claimed that underdeveloped countries which are poorly integrated into the global market may actually converge. Nonetheless, most nations that are integrated effectively in the global market and are more stable often diverge.

Using a slightly different approach, Camarero *et al.* (2013) inspected whether OECD countries converge in eco-efficiency using Data Envelopment Analysis (DEA). Findings showed that only the most eco-efficient countries and the worst ones tend to form clubs of convergence. Recently, Parker and Liddle (2017) employed a Clustering Algorithm and

showed the existence of a manufacturing energy productivity club convergence based on data on 33 countries including 23 low to middle income non-OECD countries (see Appendix).

2.3 Economic convergence in Asia

Looking at the Asian region, the related literature provides interesting insights. Above all, Park (2000) investigated the issue of convergence among Southeast Asian economies during the 1960–1997 period, but no related evidence was found. Subsequently, Michelis and Neaime (2004) evaluated empirically the hypothesis of income convergence in the Asia–Pacific region during the 1960–1999 period. Thus, econometric output provided weak evidence of conditional β-convergence in a group of 16 Asia–Pacific Economic Cooperation (APEC) countries and an even much weaker evidence of income convergence in East Asia countries. Ghatak and De (2016) who analysed whether 32 Asian countries have witnessed income convergence using β- and σ-convergence, and a non-parametric distribution estimation developed in Quah (1993, 1997). Empirical findings confirmed that the income gap among the countries appears to decline over time while a possible unconditional convergence is underlined in the long run. Furuoka *et al.* (2018) tested the income convergence hypothesis for 5 ASEAN countries during the Fourier Augmented Dickey-Fuller (FADF) method. However, the results showed a positive causal relationship with 10% of the two-country pairings. These findings suggested that other fundamental variables, such as technology and innovation may be more important than trade liberalization efforts to reduce inter-country income gaps. Zulfiqar (2018) conducted an assessment on the income convergence process for a set of 40 Asian countries over the 1980–2016 period. To do so, a pooled least square methodology is applied with time dummies and cross section weights standard errors. Findings concluded to the presence of conditional convergence in Asian region which is further established by including population growth, inflation rate, unemployment rate, exports growth and openness as control variables. More recently, Yaya *et al.* (2020) employed the Fourier unit root test with break to examine the income convergence in 9 major economies from three Asian regions. As a result, a relatively greater income convergence is revealed in the South Asia. By contrast, a mixed trend of income convergence and income divergence is supported among Northeast and Southeast Asian regions. Lastly, Ghatak (2021) investigated whether there exists income convergence across SARRC and ASEAN countries using data spanning the 1970–2017 period. The 2SLS results validated the convergence of income across ASEAN member countries only (see Appendix).

2.4 Synthesis, gaps in the literature and contribution proposal

A synthesis of the above-mentioned findings brings fruitful insights. One striking observation is that almost all studies, whether they are Asian-related or not, relied on econometric tools to address the economic convergence question. However, previous examinations sharply differ in terms of econometric estimator employed. Besides, an important strand of the literature recursively tested the convergence hypothesis for a group of 20 OECD countries but did not end up to the same outcome. Specifically, the economic convergence is not always confirmed and its empirical validation seems highly sensitive to the income groups of the countries considered. Studies based on widely heterogeneous groups often supported more contrasted results than those based on relatively homogeneous samples. Moreover, case studies, sample size and data periods substantially differ and might explain the conflicting findings reported in the Asian literature. In the light of these above-mentioned reasons, no clear consensus is reached on the empirical validation of the economic convergence hypothesis in Asia. This is backed by both statistical, methodological, and conceptual evidence that we cannot neglect anymore.

Also, an in-depth review of the literature highlights major gaps. To the best of our knowledge, no previous single assessment has been reported on whether an economic convergence exists among Thailand, Singapore, Malaysia, Philippine, and Indonesia. Except for Parker and Liddle (2017) who applied a Clustering Algorithm on 33 OECD and non-OECD countries, one must admit that the use of ML algorithms remains seminal and lacks on this question. As a matter of fact, converging forces have been rarely inspected through models derived from AI, although it has already provided powerful evidence on neighbouring topics (Mele and Magazzino, 2020; Magazzino *et al.*, 2020a, b, c, d). Therefore, further inquiries are necessary into this topic. Here, we propose to expand the scope of possible methodologies to outreach the contrasted findings reported above by econometric papers. ML procedures can overcome standard statistical issues and might extend the previous econometric results. In addition, applying two distinct econometric and ML techniques might help reconciling the conflicting literature, open a fruitful research direction.

3. Data and econometric methodology

3.1 Data collection and econometric framework

The methodology applied to verify the existence of convergence or divergence is divided into two studies proposals. Regarding the first study approach, this study covers the 1960–2017 period for 5 selected Asian countries, namely Thailand, Singapore, Malaysia, Philippine, and Indonesia. The chosen sample period is based on the data availability constraint of economic indicators for these countries. Data are compiled from the World Development Indicators database.

Additionally, to measure the divergence or convergence forces among several economies, a neo-classical approach to convergence is utilized. Indeed, the validation of the economic convergence implies that poor nations have a faster growth rate compared to richer countries in terms of the per capita income. The empirical analysis is based on a panel data set chosen from the five selected countries. The System GMM estimator is applied to the following equation:

$$y_{it} = (1 + \beta)\ y_{it-1} + ax_{it} + \mu_i + \varphi_t + \varepsilon_{it} \tag{1}$$

where y_{it} is the log of real gross domestic product per capita (constant 2010 US$) about country i in a time t, $x_{i,t}$ represents the share of investment in GDP (in % GDP) and the openness ((export + import)/GDP) as well as the level of literacy relative to primary school (% of total), μ_i represents all those economic characteristics of the countries under study that affect other determinants of economic growth and that we have not taken into consideration in $x_{i,t}$. Finally, φ_t refers to the specific effect at the study period, and ε_{it} is the error term. Now, if we assume that n the number of criteria that our countries respect at time t, in relation to GDP logarithmic and delayed per capita, we have:

$$y_{it} = (1 + \beta)\ y_{it-1} + \Omega n_{it} + \zeta n_{it} y_{it-1} + \alpha x_{it} + \mu_i + \varphi_t + \varepsilon_{it} \tag{2}$$

4. Empirical results

4.1 GMM results

In Table 1 are provided the estimated results from the System GMM represented by the previous two equations and with data spanning the period 1960–2017.

As we can see from the results obtained in Table 1 the convergence coefficient is negative and statistically significant in the within estimator $(1 + \beta) = 0.726$. So, our convergence coefficient is 0.726–1 = −0.274: it increased when we entered the control variables for a value of about −0.3. The "3 Within" shows reversed the sign of the coefficient number of criteria

Variables	1 within	2 within	3 within	GMM	GMM	GMM
y_{it-1}	0.726	0.723	0.605	0.923	0.950	0.950
	(0.059)	(0.070)	(0.110)	(0.014)	(0.001)	(0.005)
n_{it}		0.0163	−0.0129		0.0375	0.0186
		(0.021)	(0.0268)		(0.0206)	(0.0112)
$n_{it}\, y_{it-1}$		−0.0021	0.0032		−0.0062	−0.0010
		(0.0020)	(0.0051)		(0.0020)	(0.0013)
Investment			0.0687			0.102
			(0.00701)			(0.0412)
Openness			0.115			0.015
			(0.0542)			(0.0196)
Literacy			0.025			0.010
			(0.020)			(0.010)
Constant	0.756	0.748	0.144	0.204		
	(0.359)	(0.375)	(0.675)	(0.153)		
R^2	0.801	0.812	0.840			
F test	4.52	5.02	5.05			
	(0.0000)	(0.0000)	(0.0000)			
AR(2)				0.41	0.39	0.43
				(0.007)	(0.005)	(0.008)
Hansen J test				(0.009)	(0.007)	(0.001)
C test				(0.005)	(0.004)	(0.006)
Sargan test				0.43	0.81	0.95
				(0.000)	(0.000)	(0.001)

Note(s): Robust Standard Errors in parenthesis

Table 1. System GMM estimates

met by interaction with the logarithm of the lagged GDP, but it is not no significant in "2 Within". On the contrary, for us, it is exciting how the convergence elements are all significant in the System GMM and with a low robust standard error. The analysis of the control variables chosen in our model delineates exciting aspects. In particular, openness to international trade has a positive influence on the economic growth of the panel of countries. This result confirms the economic theory relative to the characteristic of the countries chosen in our study to be export-leg. In fact, since 1960, they have used international trade as a link between economic growth and the structural change of their economies. Certainly, some of them have grown faster than others (also in relation to the political and social characteristics within the country). The literacy variable also played an essential role in the countries studied in the economic convergence process. In fact, this variable hides (over time) that of human capital, which represents an essential variable of the theory of economic growth. Finally, the investment variable also shows positive and convergence effects on economic growth.

4.2 LSTM results

The first step about our experiment was to test the forward feed of NNs belonging to the LSTM family. We used an LSTM experiment because it generates better performance than standard statistical models. It can outperform both statistical/econometric and generic ML methods such as the classic NN.

In Table 2, we represent the results evaluated on the data for every single contrast in the set through the Area Under the Receiver Operating Characteristic (AUROC) algorithm.

The results shown in Table 2 confirmed the high predictability about the model used. In particular, our experiment falls under a ROC curve with predictive values above 80%. This result guarantees the absence of false positives or negatives.

In the second experiment, we use the algorithm to train a model capable of predicting the transfer of each variable among the countries covered by the study. The results are reported, respectively, in Tables 3 and 4.

The results show that our model was able to obtain mutual relations between countries. Our experiment was able to generalize different variables on the dependent variable. In particular, the model we trained on a country's economy was able to predict the effects on other countries at the same time. Since the predictive value for each country is between 55 and 95%, we can say that the economies have realized a process of economic convergence in the "ages". This statement is confirmed by the fact that the algorithm evaluated the model in a set of k-th data. In other words, we did not use any alignment of values. In addition, the convergence between countries, in a Machine Learning approach, is evidenced in a "historical" process by the Quasi-Newton method algorithm errors history. It is based on Newton's method, but it does not require calculation of second derivatives. As we can observe from Figure 2, only in the fourth epoch (the value is 0 since the link is slow convergence) the training and selection errors (the blue line represents the training error, while the orange one is the selection error) turn out to be convergent.

Looking at the Asian-related literature, our ML results contrast with Park (2000) who found no evidence of convergence among Southeast Asian economies during the 1960–1997 period. Similarly, our findings are not in line with those of Michelis and Neaime (2004) who

Table 2.
AUROC results for each country

LSTM	Thailand	Singapore	Malaysia	Philippine	Indonesia
Training set	0.95475	0.89654	0.92159	0.88456	0.90159
Test set	0.86145	0.78165	0.87156	0.77156	0.82168

Source(s): Our elaborations in Oryx 2.0

Table 3.
AUROC training set

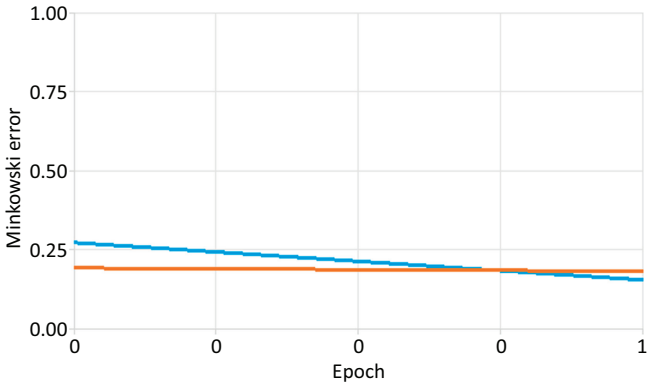
Countries	Thailand	Singapore	Malaysia	Philippine	Indonesia
Thailand	0.836478	0.84152	0.79495	0.79786	0.73571
Singapore	0.95146	0.77365	0.98231	0.76524	0.66519
Malaysia	0.65689	0.73221	0.60753	0.69234	0.68473
Philippine	0.72231	0.73421	0.61481	0.75198	0.64297
Indonesia	0.75884	0.77464	0.76777	0.72458	0.61725

Source(s): Our elaborations in Oryx 2.0

Table 4.
AUROC test set

Countries	Thailand	Singapore	Malaysia	Philippine	Indonesia
Thailand	0.80494	0.78945	0.72619	0.75491	0.69851
Singapore	0.81119	0.76581	0.82944	0.70949	0.66059
Malaysia	0.60949	0.70918	0.58911	0.61984	0.62941
Philippine	0.70949	0.76749	0.56127	0.73978	0.60119
Indonesia	0.71940	0.70149	0.71742	0.67431	0.55297

Source(s): Our elaborations in Oryx 2.0



Source(s): Our elaborations in Oryx 2.0

Figure 2.
Quasi-Newton method algorithm errors history

brought only weak evidence of conditional β-convergence in a group of 16 APEC countries over the 1960–1999 period. Furthermore, our results partly validate Furuoka *et al.* (2018) since their results showed a positive causal relationship with only 10% of the two-country pairings, suggesting thus that other fundamental variables, such as technology and innovation may matter in the process of income convergence among 5 Asian countries. However, our study confirms the insights displayed in Ghatak and De (2016) as they confirmed that the income gap among 32 Asian countries appears to decline over time while a possible unconditional convergence is underlined in the long run. Finally, the evidence of the present study corroborates Zulfiqar (2018) and Yaya *et al.* (2020) who revealed the existence of a relatively greater income convergence for 40 and 9 Asian economies, respectively. While the former insisted on a convergence phenomenon conditional to the inclusion of further variables (i.e. population growth, inflation rate, unemployment rate, exports growth, and openness), the latter emphasised the emergence of a mixed trend of income convergence and income divergence among Northeast and Southeast Asian regions.

5. Concluding remarks and policy recommendations

The aim of this paper is to assess the existence of economic convergence among five selected Asian countries (Thailand, Singapore, Malaysia, Philippine, and Indonesia). We collected data from 1960 to 2017.

Above all, the GMM results contrast with previous studies and showed that, in general, most countries experienced divergence in the long-run. Due to the phenomena of unequal growth and polarization, the living standards of poor countries such as Philippine and Malaysia continued to deteriorate while that of Singapore keeps improving. However, a scattered plot of GDP per capita shows that many nations particularly the less developed nations exhibited convergence between the early 1960–1983 period. Based on the graphical observation, the GDP gap between the rich and the poor nations appears to have reduced significantly. This indicates that poor countries in the Asian region did catch up with the rich one only during the first wave of globalization. All in all, no evidence of absolute convergence in the five selected countries can be provided by the econometric analysis.

Overcoming the technical issues raised by the econometric approach, our new ML algorithm bring contrasted but interesting results. Using the KOF Globalization Index, we confirm how the last phase of globalization set the conditions for an economic convergence among sample members. Then, the LSTM algorithm has provided consistent evidence

supporting the existence of converging forces, which is congruent with the econometric literature. In fact, the results highlighted the effectiveness of the experiments and the algorithm we chose. The high predictability of our model and the absence of self-alignment in the values present evidence supporting a convergence between the economies. Based on these empirical results, key policy and methodological insights can be formulated.

Above all, the ML analysis confirm that the income gap among Thailand, Singapore, Malaysia, Philippine, and Indonesia might decline with economic development. This supports the view that promoting trade liberalization and economic integration would draw important development benefits for the area. Unsurprisingly, human capital stocks emerge as the central leverage to lower the income disparity between the five selected ASEAN countries. We suggest policy makers to consider these convergence mechanisms when designing development measures targeting the poorest member countries (Yaya *et al.*, 2020). Hence, we recommend strengthening the integration measures, with a specific focus on barriers to Foreign Direct Investments (FDI) and trade flows within the region. This would connect ASEAN members among them and with the world. While it is yet admitted that trade liberalization in the ASEAN-5 has already undergone major improvements, some remaining goods continue to be traded at high tariff rates and with quotas (Furuoka *et al.*, 2018). Also, the trade channel significantly reduces the income gap as it diffuses innovation outputs and productivity gains across members, which in turn, might enable the deployment of an inclusive economic performance in the region. Nonetheless, a particular attention should be paid to the deployment of a strong domestic financial system. As shown in Malarvizhi *et al.* (2019), the Asian crisis of 1997–1998 translated into adverse economic consequences because of the weak financial mechanisms in operation at the time. With the exception of Singapore, the development of financial markets is lagging behind when compared with financial institutions in the region (Haini, 2020). Therefore, in Indonesia, Malaysia, the Philippines, and Thailand, it is crucial to encourage capital flows through the establishment of supervisory institutions able to monitor national organisations across the ASEAN economic community. Moreover, specific measures should be conducted to reduce the sensitivity of ASEAN economies to external shocks, and notably the exchange rate volatility in a context of financial liberalization. Hence, the integration of financial markets should follow a careful, progressive, and timely managed path that does not hinder the economic convergence objective. This is essential to achieve the major pillar of the ASEAN Economic Community Blueprint: ensuring an "Equitable Economic Development" among members (Furuoka *et al.*, 2018). However, the existence of persistent economic divergences cannot be completely excluded, as shown by our econometric output. It implies that policymakers should set-up the trade agreements conditions under which these diverging forces will be minimized. In line with Santosa (2018), the import substitution policy implemented in the five ASEAN countries might induce temporary agroindustry benefits, but should not hide, in our opinion, the need for a long-run trade cooperation in the area. This is, again, unavoidable to pull the poorest economies out of the inequality trap and build a regional identity.

While incipient in the convergence literature (Parker and Liddle, 2017), the use of ML experiments has provided powerful evidence on neighboring topics. Facing the conflicting conclusions recursively drawn in past contributions, we proposed to enlarge the range of possible methodologies on this topic. As a matter of fact, the LSTM algorithm demonstrated a relevant ability to check the robustness and extend the scope of the GMM outputs. It sheds light on the potential of AI tools in assessing the convergence hypothesis and opens a fruitful research direction. Notwithstanding their limitations, we claim here that ML procedures present promising features and may act as appropriate complements to econometric methodologies. Undoubtedly, they may reconcile the literature that suffers from lack of empirical consensus. Therefore, there are number of directions for future works. One of them if to conduct further investigations on this topic using our stepwise methodology comprising

panel econometric regressions first, and non-parametric ML techniques then. If data availability allows that, past contributions may be replicated following this empirical strategy and obtained results may be compared. In addition, we encourage future research to perform similar analysis on larger samples of Asian economies. This would not only fill the gap in Asian investigations reported in our literature Section, but also expand geographically the policy applications of such studies. Overall, this may bring a final answer on whether the validation of the convergence hypothesis is sensitive to the stage of development of the countries and identify which economic characteristics are more likely to drive divergence forces and *vice versa*.

Note

1. We provided, upon request, an Appendix with summary tables on previous applied studies, a discussion of the analysis of the KOF Globalization Index, the theoretical and mathematical formulations of our new LSTM algorithm, and the core line programming codes.

References

Angeloni, I. and Dedola, L. (1999), *From the ERM to the Euro: New Evidence on Economic and Policy Convergence Among EU Countries*, SSRN, 355142.

Arnold, J., Bassanini, A. and Scarpetta, S. (2011), "Solow or Lucas? Testing speed of convergence on a panel of OECD countries", *Research in Economics*, Vol. 65 No. 2, pp. 110-123.

Azariadis, C. and Drazen, A. (1990), "Threshold externalities in economic development", *The Quarterly Journal of Economics*, Vol. 105 No. 2, pp. 501-526.

Azomahou, T.T., Nguyen-Van, P. and Pham, T.K.C. (2011), "Testing convergence of European regions: a semiparametric approach", *Economic Modelling*, Vol. 28 No. 3, pp. 1202-1210.

Baddeley, M. (2006), "Convergence or divergence? The impacts of globalization on growth and inequality in less developed countries", *International Review of Applied Economics*, Vol. 20 No. 3, pp. 391-410.

Badinger, H., Müller, W. and Tondl, G. (2004), "Regional convergence in the European Union, 1985–1999: a spatial dynamic panel analysis", *Regional Studies*, Vol. 38 No. 3, pp. 241-253.

Barro, R. and Sala-i-Martin, X. (2004), *Economic Growth*, 2nd ed., The MIT Press, Cambridge, MA.

Bernard, A.B. and Jones, C.I. (1996), "Productivity across industries and countries: time series theory and evidence", *The Review of Economics and Statistics*, pp. 135-146.

Button, K.J. and Pentecost, E.J. (1995), "Testing for convergence of the EU regional economies", *Economic Inquiry*, Vol. 33 No. 4, pp. 664-671.

Camarero, M., Castillo, J., Picazo-Tadeo, A.J. and Tamarit, C. (2013), "Eco-efficiency and convergence in OECD countries", *Environmental and Resource Economics*, Vol. 55 No. 1, pp. 87-106.

Cieślik, A. and Wciślik, D.R. (2020), "Convergence among the CEE-8 economies and their catch-up towards the EU-15", *Structural Change and Economic Dynamics*, Vol. 55, pp. 39-48.

Durlauf, S.N. and Johnson, P.A. (1995), "Multiple regimes and cross-country growth behaviour", *Journal of Applied Econometrics*, Vol. 10 No. 4, pp. 365-384.

Egger, P. and Pfaffermayr, M. (2006), "Spatial convergence", *Papers in Regional Science*, Vol. 85 No. 2, pp. 199-215.

Estrin, S., Urga, G. and Lazarova, S. (2001), "Testing for ongoing convergence in transition economies, 1970–1998", *Journal of Comparative Economics*, Vol. 29 No. 4, pp. 677-691.

Furuoka, F., Rasiah, R., Idris, R., Patrick, S., Jacob, R.I. and Munir, Q. (2018), "Income convergence in the ASEAN-5 countries", *International Journal of Business and Society*, Vol. 19 No. 3, pp. 554-569.

Gadea Rivas, M.D. and Sanz Villarroya, I. (2017), "Testing the convergence hypothesis for OECD countries: a reappraisal", *Economics: The Open-Access*, Vol. 11 No. 4, pp. 1-22.

Gaulier, G., Hurlin, C. and Jean-Pierre, P. (1999), "Testing convergence: a panel data approach", *Annales d'Économie et de Statistique*, pp. 411-427.

Ghatak, S. (2021), "Convergence potentials in SAARC and ASEAN economies", *The Journal of Indian and Asian Studies*, Vol. 2 No. 1, 2150004.

Ghatak, S. and De, P. (2016), *Income Convergence Across Asian Economies: An Empirical Exploration*.

Guerrini, L. (2006), "The Solow–Swan model with a bounded population growth rate", *Journal of Mathematical Economics*, Vol. 42 No. 1, pp. 14-21.

Haini, H. (2020), "Examining the relationship between finance, institutions and economic growth: evidence from the ASEAN economies", *Economic Change and Restructuring*, Vol. 53, pp. 519-542.

Hallett, A.H. and Piscitelli, L. (2002), "Does trade integration cause convergence?", *Economics Letters*, Vol. 75 No. 2, pp. 165-170.

Kanbur, R., Rhee, C. and Zhuang, J. (2014), *Inequality in Asia and the Pacific: Trends, Drivers, and Policy Implications*, Routledge.

Khan, G. and Daly, V. (2018), "Growth convergence and divergence in SAARC", *Research in Economics and Management*, Vol. 3 No. 4, p. 315.

Krugman, P.R. (1991), *Geography and Trade*, The MIT Press, Cambridge, MA.

Lafuente, J.Á., Marco, A., Monfort, M. and Ordóñez, J. (2020), "Social exclusion and convergence in the EU: an assessment of the Europe 2020 strategy", *Sustainability*, Vol. 12 No. 5, p. 1843.

Lucas, R.E. Jr (1988), "On the mechanics of economic development", *Journal of Monetary Economics*, Vol. 22 No. 1, pp. 3-42.

Madsen, J.B. (2007), "Technology spillover through trade and TFP convergence: 135 years of evidence for the OECD countries", *Journal of International Economics*, Vol. 72 No. 2, pp. 464-480.

Magazzino, C. (2014), "The relationship between revenue and expenditure in the ASEAN countries", *East Asia*, Vol. 31 No. 3, pp. 203-221.

Magazzino, C. (2017), "Twin deficits or Ricardian equivalence? Empirical evidence in the APEC countries", *Asian Economic and Financial Review*, Vol. 7 No. 10, pp. 959-971.

Magazzino, C. (2020), "The twin deficits in the ASEAN countries", *Evolutionary and Institutional Economics Review*.

Magazzino, C. and Mele, M. (2021), "A dynamic factor and neural networks analysis of the co-movement of public revenues in the EMU", *Italian Economic Journal*.

Magazzino, C., Mele, M. and Schneider, N. (2020a), "The relationship between air pollution and COVID-19-related deaths: an application to three French cities", *Applied Energy*, Vol. 279, 115835.

Magazzino, C., Mele, M. and Schneider, N. (2020b), "The relationship between municipal solid waste and greenhouse gas emissions: evidence from Switzerland", *Waste Management*, Vol. 113, pp. 508-520.

Magazzino, C., Mele, M., Schneider, N. and Sarkodie, S.A. (2020c), "Waste generation, Wealth and GHG emissions from the waste sector: is Denmark on the path towards circular economy?", *Science of The Total Environment*, 142510.

Magazzino, C., Mele, M., Schneider, N. and Vallet, G. (2020d), "The relationship between nuclear energy consumption and economic growth: evidence from Switzerland", *Environmental Research Letters*, Vol. 15, p. 9.

Magazzino, C., Mele, M. and Morelli, G. (2021a), "The relationship between renewable energy and economic growth in a time of Covid-19: a Machine Learning experiment on the Brazilian economy", *Sustainability*, Vol. 13 No. 3, p. 1285.

Magazzino, C., Mele, M. and Santeramo, F.G. (2021b), "Using an Artificial Neural Networks experiment to assess the links among financial development and growth in agriculture", *Sustainability*, Vol. 13 No. 5, p. 2828.

Magazzino, C., Mele, M. and Schneider, N. (2021c), "A D2C algorithm on the natural gas consumption and economic growth: challenges faced by Germany and Japan", *Energy*, Vol. 219, p. 19586.

Magazzino, C., Mele, M. and Schneider, N. (2021d), "A Machine Learning approach on the relationship among solar and wind energy production, coal consumption, GDP, and CO_2 emissions", *Renewable Energy*, Vol. 167, pp. 99-115.

Magazzino, C., Mele, M., Schneider, N. and Shahbaz, M. (2021e), "Can biomass energy curtail environmental pollution? A quantum model approach to Germany", *Journal of Environmental Management*, Vol. 287, 112293.

Malarvizhi, C.A.N., Zeynali, Y., Mamun, A.A. and Ahmad, G.B. (2019), "Financial development and economic growth in ASEAN-5 countries", *Global Business Review*, Vol. 20 No. 1, pp. 57-71.

Mankiw, N.G., Romer, D. and Weil, D.N. (1992), "A contribution to the empirics of economic growth", *The Quarterly Journal of Economics*, Vol. 107 No. 2, pp. 407-437.

Mele, M. and Magazzino, C. (2020), "A machine learning analysis of the relationship among iron and steel industries, air pollution, and economic growth in China", *Journal of Cleaner Production*, Vol. 277, 123293.

Mele, M., Gurrieri, A.R., Morelli, G. and Magazzino, C. (2021a), "Nature and climate change effects on economic growth: an LSTM experiment on renewable energy resources", *Environmental Science and Pollution Research*.

Mele, M., Magazzino, C., Schneider, N. and Nicolai, F. (2021b), "Revisiting the dynamic interactions between economic growth and environmental pollution in Italy: evidence from a gradient descent algorithm", *Environmental Science and Pollution Research*.

Michelis, L. and Neaime, S. (2004), "Income convergence in the Asia-Pacific region", *Journal of Economic Integration*, September, Vol. 19 No. 3, pp. 470-498.

Monfort, M., Cuestas, J.C. and Ordonez, J. (2013), "Real convergence in Europe: a cluster analysis", *Economic Modelling*, Vol. 33, pp. 689-694.

Nahar, S. and Inder, B. (2002), "Testing convergence in economic growth for OECD countries", *Applied Economics*, Vol. 34 No. 16, pp. 2011-2022.

Park, D. (2000), "Intra-southeast Asian income convergence", *ASEAN Economic Bulletin*, Vol. 17 No. 3, pp. 285-292.

Parker, S. and Liddle, B. (2017), "Economy-wide and manufacturing energy productivity transition paths and club convergence for OECD and non-OECD countries", *Energy Economics*, Vol. 62, pp. 338-346.

Piketty, T. (2014), *Capital in the Twenty-First Century*, Harvard University Press, Harvard.

Quah, D.T. (1993), "Galtons fallacy and the convergence hypothesis", *Scandinavian Journal of Economics*, Vol. 95 No. 4, pp. 427-443.

Quah, D.T. (1997), "Empirics for growth and distribution: stratification, polarization and convergence clubs", *Journal of Economic Growth*, Vol. 2 No. 1, pp. 27-59.

Ralhan, M. and Dayanandan, A. (2005), "Convergence of income among provinces in Canada–an application of GMM estimation", *University of Victoria-Econometrics Working Paper*.

Romer, P.M. (1986), "Increasing returns and long-run growth", *Journal of Political Economy*, Vol. 94 No. 5, pp. 1002-1037.

Safdar, M. and Nawaz, A. (2020), "Testing the convergence hypothesis in Solow growth model: a statistical evidence from SAARC economies", *Bulletin of Business and Economics*, Vol. 9 No. 2, pp. 60-73.

Santosa, D.B. (2018), "Does export promotion policy benefit for ASEAN economic development?", *International Journal of Trade and Global Markets*, Vol. 11 Nos 1-2, pp. 3-11.

Simionescu, M. (2017), "The GDP per capita convergence in the European Union", *Academic Journal of Economic Studies*, Vol. 3 No. 1, pp. 81-87.

Solow, R.M. (1956), "A contribution to the theory of economic growth", *The Quarterly Journal of Economics*, Vol. 70 No. 1, pp. 65-94.

Swan, T.W. (1956), "Economic growth and capital accumulation", *Economic Record*, Vol. 32 No. 2, pp. 334-361.

Urata, S. and Narjoko, D.A. (2017), "International trade and inequality", ADBI Working Paper, p. 675.

Wahiba, N.F. (2015), "Convergence and divergence among countries", *Asian Economic and Financial Review*, Vol. 5 No. 3, pp. 510-520.

Yaya, O.S., Furuoka, F., Pui, K.L., Jacob, R.I. and Ezeoke, C.M. (2020), "Investigating Asian regional income convergence using Fourier Unit Root test with break", *International Economics*, Vol. 161, pp. 120-129.

Zia, U. and Mahmood, Z. (2019), "Tests of income convergence in ASEAN and SAARC trading blocs", *South Asia Economic Journal*, Vol. 20 No. 2, pp. 167-183.

Zulfiqar, K. (2018), "An analysis of income convergence across Asian countries", *Forman Journal of Economic Studies*, January–December, Vol. 14, pp. 125-141.

Further reading

Furuoka, F. (2019), "Do CLMV countries catch up with the older ASEAN members in terms of income level?", *Applied Economics Letters*, Vol. 26 No. 8, pp. 690-697.

Simionescu, M. (2014), "Testing sigma convergence across EU-28", *Economics and Sociology*, Vol. 7 No. 1, pp. 48-60.

Appendix

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