Terra Economicus, 2023, 21(4): 106–122
DOI: 10.18522/2073-6606-2023-21-4-106-122

Application of ARDL model to capture the differences in causal relations operating in crop production across geographic regions: A study on Latin America and South Asia

Debasis Neogi
National Institute of Technology, Agartala, India, e-mail: dneogi@nita.ac.in

Citation: Neogi D. (2023). Application of ARDL model to capture the differences in causal relations operating in crop production across geographic regions: A study on Latin America and South Asia. *Terra Economicus* **21**(4), 106–122. DOI: 10.18522/2073-6606-2023-21-4-106-122

The identification of the causal relations between the determinants of crop production and the crop production index has serious policy implications. Given the importance attached to agriculture in Latin America & Caribbean Islands and Southern Asia, understanding the differences in the causal relations operating in crop production in both the regions is necessary, especially to capture the policy differentials, if any required, to combat underdevelopment. With this backdrop, the present study aims to figure out the differences between both the regions in the nature of causal relations existing among select factors associated with the crop production. The study is based on the World Bank data. The model used in the present study consists of a dependent variable in the form of crop production index that has dependence on its lagged values. The dependent variable is also influenced by the lagged values of a set of independent variables – share of permanent crop land in total land available in the region, fertilizer usage, carbon dioxide emission and GDP growth per capita. The study uses auto regressive distributed lag (ARDL) model for data analysis. The study finds that in Latin America & Caribbean Region no long run relations exist between the dependent and the independent variables, while in South Asia significant long run relations exist between them.

Keywords: *causal relations; crop production; carbon dioxide emission; GDP growth rate per capita; fertilizer*

JEL codes: *C01; N50; N56*

Применение модели ARDL для анализа растениеводства в разных географических регионах (на примере Латинской Америки и Южной Азии)

Неоги Дебасис

Национальный технологический институт, Агартала, Индия, e-mail: dneogi@nita.ac.in

Цитирование: Neogi D. (2023). Application of ARDL model to capture the differences in causal relations operating in crop production across geographic regions: A study on Latin America and South Asia. *Terra Economicus* **21**(4), 106–122. DOI: 10.18522/2073-6606-2023-21-4-106-122

Выявление причинно-следственной связи между факторами, влияющими на растениеводство, и индексом производства продукции растениеводства имеет высокую значимость для политики. Учитывая важность, придаваемую сельскому хозяйству в странах Латинской Америки и Карибского бассейна, а также в странах Южной Азии, необходимо понимать различия, характеризующие растениеводство в этих регионах, особенно в контексте специфики политических решений, направленных на преодоление отсталости. Цель исследования состоит в выяснении различий между обозначенными регионами в том, что касается характера причинно-следственных связей между отдельными факторами, воздействующими на растениеводство. В работе использованы данные Всемирного банка. В модели в качестве зависимой переменной выступает индекс производства продукции растениеводства, который определяется его лагированными значениями. На зависимую переменную также влияют лагированные значения ряда независимых переменных, таких как: доля постоянных пахотных земель в общей площади земельных участков, имеющихся в регионе; использование удобрений; выбросы углекислого газа; рост ВВП на душу населения. Для анализа данных используется модель авторегрессии с распределенным лагом (ARDL). Результаты показали, что в странах Латинской Америки и Карибского бассейна между зависимой и независимыми переменными не существует долгосрочных связей. Для стран Южной Азии, в свою очередь, обнаружены значимые долгосрочные связи между переменными.

Ключевые слова: *причинно-следственная связь; растениеводство; выбросы углекислого газа; темпы роста ВВП на душу населения; удобрения*

Introduction

Latin America and Asia are two promising regions of the world playing decisive roles in ensuring growth of the global economy over a few decades now. The decades, that many termed as "Asian Century" and the "Decade of Latin America and the Caribbean". Both the regions maintained stable economic growth, especially in the post financial crisis period of the present millennium, as compared with that of the developed nations[1]. Latin America & Caribbean Region consists of three sub regions. These are South America, Central America and the Caribbean Islands. Based on World Bank's[2] income wise classifications of the countries, both the regions are divided into high income, upper-middle

[1] Dharmawardhane, I. (2015). South Asia and Latin America: A powerful friendship to be nurtured. Presented to the Second Global South International Studies Conference of the International Studies Association (ISA)'s Global South Caucus (GSCIS) and Singapore Management University (SMU), January 8-10, 2015, Singapore. http://web.isanet.org/Web/Conferences/GSCIS%20Singapore%202015/Archive/89fd8a1e-c859-4595-a79e-e1fa7445a565.pdf

[2] The World Bank. https://data.worldbank.org/

income, lower-middle income and low income categories. Latin America & Caribbean Region has forty nine nations in total. Out of that sixteen nations from Caribbean Region, that include Antigua and Barbuda, Aruba, Bahamas, Barbados, British Virgin Islands, Cayman Islands, Curacao, Martinique, Netherlands Antilles, Puerto Rico, Saint Kitts & Nevis, Saint Martin, Trinidad and Tobago, Turks and Caicos Islands and United States Virgin Islands, are demarcated as high income countries. There are four nations from South America – Chile, Falkland Islands, French Guiana and Uruguay that also belong to the high income category. From Caribbean island ten nations – Anguilla, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Jamaica, Montserrat, Saint Lucia and Saint Vincent and Grenadines, are recognized as upper-middle income countries. In the same group from South America there are nine countries – Argentina, Brazil, Colombia, Ecuador, Guyana, Paraguay, Peru, Surinam and Venezuela. Belize, Costa Rica, Mexico and Panama are the four nations from Central America, which are also categorized as upper middle income countries. Bolivia from South America and El Salvador, Guatemala, Honduras and Nicaragua from Central America are included in the lower middle income group category. Only Haiti from Caribbean Region belongs to the low income category. On the other hand, Southern part of Asia consists of nine nations in total. Out of that Iran and Maldives are the only nations that belong to upper-middle income group. India, Bhutan, Bangladesh, Pakistan and Sri Lanka are the five nations that are demarcated as lower-middle income countries. Afghanistan and Nepal are the two nations that fall under low income category. Thus, breadth wise and also in terms of economic affluence, Latin America & the Caribbean Region is way ahead of South Asia.

In spite of differences, Latin America & the Caribbean Islands share some similarities with Asia, though the economic diversity of Asia surpasses that of Latin America. Both the regions are characterized by significant amount of land dedicated to Agriculture[3]. Though South America is located at a far distance from South Asia, there is striking resemblance between the economies of these two regions[4]. In 2019, Latin America & the Caribbean Region as a whole was the home to around 650 million people. During the same time, South Asia was inhabited by almost 2 billion population. The contribution of Agriculture in GDP is 6.54% in Latin America and Caribbean Region, while the same is 18.02% in South Asia.

In the post Second World War scenario, especially during 1960s, developed economies affected by war had started to recover from the devastation faced in the war. Also, the newly independent nations started its journey towards industrialization. This created a world-wide economic environment – conducive in nature. Making effective use of the rapidly growing export opportunities, the Asian economy led by Japan, South Korea and Taiwan started realizing significant economic growth. Latin America, on the other hand, could not reap the full benefit of such economic opportunities. Chile, presently recognized as a high income country, and Argentina, presently an upper-middle income country got stuck to attend only low levels of economic growth. The difference between the two regions on the economic front got widened with the first oil embargo during 1973–1974 followed by wide spread inflation, when the East Asian countries were able to control inflation more efficiently as compared to its Latin American counterparts. The difference between the two regions grew further when the second wave of oil price rise during 1979–1980 further destabilized the Latin American economies with high external deficits and price rise (Lin, 1988).

Since 1980s also the economic growth of Latin America lagged behind that of Asia. Though, one can cite, at the outset, Latin America's over dependence on extraction and processing of natural resources for revival of the economy as one of the factors responsible for this, the sluggishness in technological up gradation was also an important factor. But, besides all these, the role of the differences in politico-development models adopted in these countries could not also be ruled out. While, the nationalist capitalist model was adopted in most of the strong economies of Asia, the dependent capitalist model was in force in Latin America. Such political practices created widespread mistrust among the various stakeholders in the society. This, in turn, weakened the confidence of the businesses both within and across the national territories. Such political model also resulted in poor delivery by the public administrative entities. The whole region was trapped in heavy dependence on natural resources with industrial activities and technological enhancement reaching to bare minimum. The relatively larger autonomy enjoyed by the Asian economies resulted in better

[3] Molano, W. Latin America and Asia: Contrasts and comparisons. *Economonitor*, September 26, 2007. https://www.thestreet.com/economonitor/latin-america/latin-america-and-asia-contrasts-and-comparisons

[4] Southeast Asia risks stumbling toward a South American future. *Nikkei Asia*. https://asia.nikkei.com/

economic growth in the region (Kohli, 2012; Tsunekawa, 2019). By 1980, the average per capita income of Latin America was eight times that of East Asia. The figures were US$ 8000 and US$ 1000 in Latin America and East Asia respectively. But, within a span of thirty years, the difference between them fell to a meagre US$ 2000 only – Latin America recording US$ 9700 and Asia recording US$ 7700[5].

Till 1960s, the entire region of Asia was trapped under severe underdevelopment. In fact, it was the poorest among all the continents of the world. The past of Asia, however, was not the same. As early as in 1820, it was home to over 65% of the world population. The continent generated over 50% of global income. But after that, the down fall of the region in terms of economic prosperity started – mostly due to the beginning of colonial rule in most parts of the region and subsequently causing its economic exploitation. Since 1960s, however, the region started its economic revival. By 2016, the region started contributing about 30% of world income. The region emerged as the world's manufacturing hub and significantly accounted for the global trade. Two of the largest economies of the world – India and China had great influence in the economic revival of the region[6]. The tremendous transformation of the entire Asia and Pacific region from a predominantly agrarian economic structure, characterised by widespread poverty to an industrial economy, characterised by capability to undertake innovation became exemplary. The economy, which found it difficult to feed its expanding population, eventually emerged as the source of skilled labour force. The GDP per capita of the region grew, on an average, from 2.2% during 1960s to 6.2% during 2000s before proceeding finally to 5.5% in between 2010 to 2018[7].

In China, the rigorous economic reform started in early 1980s, while in India the same started in early 1990s. In both the countries, agriculture sector played a key role in its economic development, especially during the early period of reforms. The importance of agriculture as one of the economic sectors increased many folds when the efficacy of the sector to tackle two of the pressing issues of the world – eradication of poverty and hunger were considered[8].

Drawing comparison between the Eastern part of Asia and Latin America, it was noticed that in the aftermath of the Second World War, East Asia's economic growth was quite sustainable. But, this growth started slowing down during 1990s, especially during the Asian economic crisis. This was also the time when the Latin America's economic growth surpassed that of East Asia. The factors responsible for such differences in the growth rates can be classified into three broad categories. The first most important one was the differences in the initial endowments of these two regions. The second one was the differences in economic policies pursued in these regions, and the third one was the differences in the institutional framework existing in both the regions. Latin America with rich base of natural resources was way ahead of East Asia in terms of initial endowments. However, in the other two categories, East Asia was ahead of Latin America (Fukuyama and Marwah, 2000).

The differences in the dynamism of the institutions present in these two regions, however, had differential impacts on the economic growth of these regions. Besides, the administrative models followed in these two regions brought about the socio-political change in the respective regions. Such change, accompanied by the differences in the initial endowments of natural resources and capital, had impacted the economic growth of these two regions differently (Nissanke and Thorbecke, 2010).

Since 1960s, Latin America passed through a series of turmoil – that included economic, political and subsequently social. This had curbed the economic growth of the region. More than inadequate capital formation and investment, it was the low total factor productivity, which could be held responsible for this. It was evident from the growth statistics during 1980s. During this period, capital and labour – both grew at 4% per annum. However, the overall output growth was only 1.5% (Zettelmeyer, 2006). But, after every disorder the Latin American economy revived. This definitely had net positive impact on the economic development of the regions. The countries' improvement on health and education fronts eventually brought in improvement in GDP per capita. As the region had more

[5] Latin America no longer views Asia with envy. https://www.worldbank.org/en/news/feature/2014/04/11/latinoamerica-ya-no-mira-con-envidia-a-asia. April 11, 2014

[6] Nayyar, D. How Asia transformed from the poorest continent in the world into a global economic powerhouse. *The Conversation*, October 17, 2019. https://theconversation.com/how-asia-transformed-from-the-poorest-continent-in-the-world-into-a-global-economic-powerhouse-123729

[7] Asian Development Bank (2020). 50 years of Asian Development. In: *Asia's Journey to Prosperity: Policy, Market, and Technology Over 50 Years*, pp. 1–28. DOI: 10.22617/TCS190290

[8] https://www.fao.org/3/ag087e/ag087e05.htm

intense economic integration with the rest of the world, the various institutions of the region also underwent qualitative upgradation, especially in managing the economy (Blyde and Fernandez, 2004).

Similar socio-politico-economic disorder also affected the economy of South Asia. The issues such as high fiscal deficit, widespread corruption, civil war and political coup destabilized the regional economy. In spite of that, however, the region was able to revive its economic progress. The institutional capabilities of the region also improved over the years. For instance, facing high fiscal deficit, India nevertheless could well keep inflation and interest rates under control. Nepal successfully explored the possibility of enhancing national income by encouraging out migration of population. Sri Lanka's success in containing civil conflicts in some of its provinces saved the economy from collapsing. These efforts had positive impact on the economic prospect of the entire region. All these happened regardless of the fact that agriculture was the largest employment provider in the major economies of the region, like in India. The performance of the agriculture sector was also not so impressive. This had an adverse impact on the rural economies. The metropolitan cities of the region emerged as the epicentres of economic prosperity. Though, poverty in the region came down to less than 10%, income inequality accompanied such growth[9]. All these disruptions notwithstanding, South Asia could manage to maintain notable economic growth during 1990s and was also able to curb poverty. This success could be attributed to the economic reforms carried out in the early 1990s (Devarajan and Nabi, 2006).

In terms of persistent income inequality, Latin America is no different from South Asia. In fact, the inequality in Latin America is one of the highest in the world. With about 70 million population pulled out of poverty, the region, however, experienced manifold increase in the middle class population during the entire decade of 1990s. The share of population below poverty remained at only 5%. This demographic shift helped the region to improve on its inequality count. East Asia, on the other hand, especially during the three decades spanning from 1980 to 2010, was also able to reduce poverty from a very high of 77% to as low as 12%. In some of the Asian countries like China huge economic growth and wide spread income inequality coexisted[10].

There are quite a large number of studies that compare two regions – Latin America & the Caribbean Islands and Southern part of Asia. These comparisons are on various fronts – demographic, socio-economic, politico-development etc. The summary of all points is the existence of poverty and wide-spread income inequality in both the regions. The literature also acknowledges the importance attached to agriculture in both the regions. Thus, from policy perspective, improvement in agriculture has the potential to bring about the differential impact on food security, poverty eradication and reduction in income inequality in both the regions. Recognizing the importance attached to agriculture in both the regions, understanding the differences in the causal relations attached with agricultural production is necessary – especially to capture the policy differentials, if any, to combat poverty. With this backdrop, the present study aims to figure out the differences in the nature of causal relations existing among selected factors associated with the agricultural production between both the regions.

Novelty of the study and its policy implications

The study is, perhaps, the first of its kind to draw comparisons of the causal relations operating in crop production, between the two regions. The findings of the study have serious policy implications. The differences in the causal relations, if any, will help one understand (a) to what extent the sustainable agriculture is practiced in the individual region, (b) if there is need for any change in the existing mode of production to ensure food security, besides ensuring sustainable agricultural production, and (c) whether any change in policy is required in the countries of the individual regions, in the light of the differences in the causal relations existing in the agricultural production between the two regions and also in the light of varying policy outcomes in both the regions in terms of developmental agendas like poverty alleviation and reduction in income inequality, etc.

[9] International Growth Centre, Pakistan Programme, and Development Policy Research Center, School of Humanities, Social Sciences and Law, Lahore University of Management Sciences (2010). *Economic Growth and Structural Change in South Asia: Miracle or Mirage?* Working Paper 10/0859, March 2010. http://eprints.lse.ac.uk/36389/1/Economic_growth_and_structural_change_in_South_Asia.pdf

[10] Latin America no longer views Asia with envy. *World Bank*, April 11, 2004. https://www.worldbank.org/en/news/feature/2014/04/11/latinoamerica-ya-no-mira-con-envidia-a-asia

Theoretical framework

The agriculture sector always has a distinct importance in the socio-economic development of a region. Today, the most pressing problem the world faces is perhaps the sufferings from hunger. The crop production index of a region determines its advancement on agriculture front. Towards this end only, some of the global funding agencies decided to launch "Crops to End Hunger" program during 2017–2018. The objective of the program was modernization of crop cultivation in the lower income countries (Wiebe et al., 2021). To understand the economics of crop cultivation, one has to analyze the various factors that influence crop production. The nature of influence, however, differs across the regions. Among a large number of factors influencing crop production – few important ones are the carbon dioxide emission; use of fertilizer; share of permanent crop land and GDP of the country/region.

Carbon dioxide emission and its impact on climate change is, now, a well studied subject. While, on the one hand, climate change poses a serious concern for agriculture and food security, on the other hand, there is evidence of increase in carbon dioxide emission due to agricultural production. FAO report 2018 stated that in 2018 only, the green house gas emission, exclusively due to agricultural activities, was to the tune of 9.3 billion tonnes of carbon dioxide equivalent. The emission of methane and nitrous oxide due to crop and livestock activities saw an enormous increase in 2018 as compared to the emissions in 2000. The rise was estimated to be as high as 14%. In Africa, over the same period the growth in emissions from farm activities was reported to be 38%[11].

In another study, it was found that in India, the green house gas emission recorded rise of 161% in between 1960 and 2010. The study found that such a huge rise could be attributed to more use of chemical nitrogen fertilizer and rapid mechanization of agriculture (Sah and Devakumar, 2018).

While crop cultivation leading to green house gas emission is only one side of the issue, the other side is definitely the impact of such emission on crop production. A study on Ethiopia showed that carbon dioxide emission had adverse impact on the agricultural productivity. The study was based on simulation of changes in total factor productivity in agriculture due to carbon dioxide emission over a period of twenty years from 2010 to 2030. The study also found that such emission worsened the production of traded and non-traded crops more as compared to the production of others like livestock (Mulatu et al., 2016).

Increase in green house gas emission leads to climate change, which eventually becomes a deterrent to agricultural output. Any obstacle on the way to agricultural production can have consequences in terms of threat to food security. At the same time, however, agricultural production does cause emission of such gas. Studies found that the influence of crop production on green house gas emission was greater in the lower middle-income countries (Ayyildiz and Erdal, 2021).

Thus, two-way causal relations are expected between crop production and the green house gas emission. In case of crop production generating the green house gas, the recommended policy should insist on changes in the technology used in production. In case the green house gas emission affecting crop production, the recommended policy should focus on searching the sources of such emission and take remedial action to reduce such emission to the minimum.

The basics of Agricultural Economics claim that fertilizer, as an input, contributes significantly in crop production and also in maintaining food supply in a region. In a study, it was estimated that the yields of corn in the USA could drop by as much as 40% if the cultivation was carried out without using nitrogen fertilizer. The study also pointed to the fact that the drop could be even larger if the use of other ingredients like phosphorous and potassium were inadequate. In some other long term studies carried out in Oklahoma and Missouri, similar results were obtained. In Oklahoma, the yield of wheat dropped by 40% in the absence of regular use of nitrogen and phosphorus, while the study in Missouri confirmed that 57% of the grain yield was due to proper use of fertilizer and lime[12].

The relations between growth in GDP per capita and crop production may be explained with the help of Engel's law. Ernst Engel, in 1857, observed that with the rise in the household income, the share of income spent on food dropped. This also indicated that the income elasticity of demand for food was less than one. This was due to the fact that every household had a maximum capacity of food intake.

[11] Emissions due to agriculture. Global, regional and country trends 2000–2018. https://www.fao.org/3/cb3808en/cb3808en.pdf

[12] Understanding fertilizer and its essential role in high yielding crops (2022) https://www.cropnutrition.com/resource-library/understanding-fertilizer-and-its-essential-role-in-high-yielding-crops

When income increased, the demand for food did not rise in the same proportion. As a result, the share of income spent on food declined. Increase in income simultaneously raised demand for the luxury goods. Collectively, at the national level also, growth in GDP per capita signifies increased income for the households, other things remaining the same. Thus, it is obvious that at higher growth rates of GDP per capita, the relative demand for food does not rise proportionately. Besides this, the increased income can also potentially accommodate more imports – including the imports of food, which also has a negative impact on demand for domestically produced crop. This, in turn, can cause the crop production to fall.

Finally, the quantum of permanent crop land also impacts the crop production. As the share of land dedicated to the crop production increases, the volume of crop production is also expected to rise, provided demand for crop is sufficient. Generally, in low income countries as the idle land is converted into permanent crop land, more people get engaged in cultivation of various crops on the converted piece of land. As a result, the crop production increases. In one of the FAO reports[13], it was mentioned that the expansion of arable land might prove decisive in increasing the crop production, especially in several parts of the least developed and developing regions of the world, that include the sub-Saharan Africa, Latin America, East Asia etc.

Data and Methodology

The study is based on the World Bank data. Since the study is a comparative analysis of the causal relations existing for a select factors affecting crop production in Latin America & Caribbean Islands and South Asia, data on these selected parameters were collected for Latin America & Caribbean Islands and South Asia. To understand the nature of data, we need to have the descriptive statistics of the individual regions (Tables 1 and 2).

Table 1

Descriptive statistics: Latin America

Variable	Unit	Observations	Mean	Std. dev.	Minimum	Maximum
CO_2 (carbon-dioxide emission)	Tons per capita	58	2.248537	0.4158724	1.370715	2.917722
Fertilizer (fertilizer usage)	Kilograms per hectare of arable land	58	76.53807	45.25398	11.03967	171.2072
GDP (GDP per capita growth)	Annual %	58	1.710561	2.260359	-4.169583	5.502377
Land (share of permanent crop land in total land available)	% of land area	58	1.003609	0.1348514	0.7857562	1.207889
Production (crop production index) (2014–2016 = 100)	–	58	0.0994727	0.0461184	0.0398207	0.184689

Source: author's computations

[13] Crop production and natural resource use. *World Agriculture: Towards 2015/2030- An FAO Perspective*. https://www.fao.org/3/y4252e/y4252e06.htm

Table 2

Descriptive statistics: South Asia

Variable	Unit	Observations	Mean	Std. dev.	Minimum	Maximum
CO_2 (carbon-dioxide emission)	Tons per capita	58	0.6686491	0.3571558	0.2780266	1.526651
Fertilizer (fertilizer usage)	Kilograms per hectare of arable land	58	73.60536	55.54486	2.379015	170.1385
GDP (GDP per capita growth)	Annual %	58	3.039599	2.494588	-4.922136	6.3465
Land (share of permanent crop land in total land available)	% of land area	58	2.069317	0.7436645	1.188744	3.366344
Production (crop production index) (2014-2016 = 100)	–	58	0 .1051038	0.0453011	0.0479005	0.1885136

Source: author's computations

To move ahead further with the investigation of causal relations in each of the regions, we have the basic equation of the model, applicable separately for each of the regions:

$$y_t = \beta_0 + \beta_1 y_{t-1} + ... + \beta p y_{t-p} + \alpha_0 x_t + \alpha_1 x_{t-1} + ... + \alpha_q x_{t-q} + \mu_0 w_t + \mu_1 w_{t-1} + ... \mu_r w_{t-r} + \sigma_o u_t + \sigma_1 u_{t-1} + ... + \sigma_s u_{t-s} + \varepsilon_t.$$

Here y – crop production index; x – gdp growth rate per capita; w – usage of fertilizer per hectare of land; and u – percentage of rural population in the total population of the country. ε_t is the error term.

The model implies that the dependent variable (here y) is influenced by its lagged values. This makes the model Auto Regressive. The model shows that the dependent variable y also has dependence on the lagged values of the other independent variables. This generates the Distributed Lag component of the model. The combination of both of these components makes the model an Auto Regressive Distributed Lag (ARDL) Model. Like any time series model, ARDL also requires the variables to be stationary – either at the levels [I(0)] or at its first order integration [I(1)] (Shrestha and Bhatta, 2018). Since most of the non-stationary variables become stationary at [I(1)], before applying the model, we need to ascertain that the variables do not require second order or higher integration [I(2)] to reach the stationary state. Since the study intends to undertake a comparative analysis of the time series data in respect of the individual regions, we apply the same model for both the regions considered in the present study.

We begin with the test of stationarity of the variables. All of the four variables in respect of each of the six countries need to be stationary either at I(0) or at I(1). The special feature of ARDL model is that unlike Vector Auto Regression, it can accommodate variables across levels. For testing the stationarity of the variables, we use two very popular techniques – Dickey Fuller test and Phillips Perron test. If the variable(s) are not found stationary, we take first order difference to bring it to its stationary state.

Once the stationarity of the variables is established, we run ARDL model with dependent variable being crop production index and independent variables being share of permanent crop land, fertilizer usage, carbon-dioxide emission and GDP growth rate per capita. We observe the p value of the F statistic. If $p<0.05$, we infer that the model is well fitted.

In the next stage, we estimate the optimal lag length of the variables. There are different criteria used to determine the optimal lag length – LR (Likelyhood Ratio), FPE (Final Prediction Error), AIC (Akaike Information Criterion), HQIC (Hannan Quinn Information Criteria and SBIC (Schwartz Information Criteria). For individual variables we consider the majority of the decisions obtained from these criteria.

Once the optimal lag length is determined, we run ARDL model once again with the specification of lags as derived from the various criteria. Here we also include the necessary error correction. The outcome of the model shows the influence of independent variables on the dependent variables both in the short run and in the long run. The respective p values corresponding to each decide whether the short run impact or/and the long run impact of the independent variables on the dependent variables are statistically significant.

However, before we can jump to an inference, the validity of the long run impact needs to be ascertained. Here we conduct Pesaran, Shin and Smith (2001) bounds test. The null hypothesis indicates no level relationship against the alternative hypothesis of relationship existing. The test gives Kripfganz and Schneider (2018) critical values and the approximate p-values. Based on this, the criteria for accepting or rejecting null hypothesis are:

(i) do not reject H_0 if both F and t are closer to zero than critical values for I(0) variables (if p-values > desired level for I(0) variables),

and (ii) reject H_0 if both F and t are more extreme than critical values for I(1) variables (if p-values < desired level for I(1) variables).

Thus, rejection of null hypothesis will indicate existence of long run relations between the independent variable(s) and the dependent variable.

Results and discussion

We begin the discussion with region specific analysis.

Latin America and Caribbean Islands

For Latin America and Caribbean Islands, both the tests ensured that the variable GDP growth rate (gdp) is stationary at level. But, in case of the rest of the variables – crop production index (production), fertilizer usage (fertilizer), share of crop land (land) and CO_2 emission (CO_2), the stationarity is reached at first difference. Since the stationarity of the variables is attained with the combination of I(0) and I(1) levels, ARDL model can be well applied (Tables 3 and 4).

Table 3

Latin America & Caribbean Region: Stationarity of the variables at different orders of integration

Variable	Latin America & Caribbean Region
GDP growth	I(0)
Crop	I(1)
Fertilizer	I(1)
CO_2	I(1)
Crop land	I(1)

Source: author

The p value of F statistic justifies that the model is statistically significant. The R square indicates that 70% of the variations in the dependent variable are explained by the independent variables. The different criteria used to decide optimal lag length show that for crop production, the optimal lag length is 4 in its first difference. The same for land in its first difference is 0. For first-differenced fertilizer it is 2; for first-differenced CO_2 it is 0, and for GDP growth at level it is 1. Table 5 summarizes optimal lag lengths for each parameter.

Table 4

Output of ARDL model for Latin America & Caribbean Region

```
. ardl dproduction dland dfertilizer dco2 gdp

ARDL(3,2,4,0,0) regression

Sample: 1966 - 2018                          Number of obs   =        53
                                             F(  13,     39) =      7.26
                                             Prob > F        =    0.0000
                                             R-squared       =    0.7077
                                             Adj R-squared   =    0.6103
Log likelihood =  251.56355                  Root MSE        =    0.0024
```

dproduction	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
dproduction						
L1.	-.6111438	.146374	-4.18	0.000	-.9072131	-.3150745
L2.	.189026	.1235598	1.53	0.134	-.0608973	.4389492
L3.	.4505628	.1225537	3.68	0.001	.2026746	.6984511
dland						
--.	-.1018993	.0216462	-4.71	0.000	-.1456828	-.0581157
L1.	.0152824	.0224985	0.68	0.501	-.0302251	.0607899
L2.	.1024034	.0291926	3.51	0.001	.0433557	.161451
dfertilizer						
--.	.0001443	.000049	2.95	0.005	.0000453	.0002434
L1.	.0002664	.0000592	4.50	0.000	.0001467	.0003862
L2.	-4.25e-06	.0000559	-0.08	0.940	-.0001174	.0001089
L3.	.0000723	.0000491	1.47	0.149	-.000027	.0001716
L4.	.0001514	.0000499	3.04	0.004	.0000505	.0002523
dco2	.0107339	.0059026	1.82	0.077	-.0012052	.0226731
gdp	-.0002954	.0002472	-1.19	0.239	-.0007955	.0002047
_cons	.0010144	.0008479	1.20	0.239	-.0007006	.0027295

Source: author's computations

Table 5

Latin America & Caribbean Region: Optimal lag lengths for each parameter

Variable	Latin America & Caribbean Region
Crop production	4
Crop land	0
Fertilizer	2
CO_2	0
GDP	1

Source: author

Now we run ARDL with lags of 4, 0, 2, 0 and 1. The following results were obtained (Table 6).

The p value for F statistic indicates that $p<0.05$. So, the model is statistically significant. Crop production, at its first integration, is influenced by its past two values in the short run at 5% level of significance. Permanent crop land also has influence on crop production at 5% level of significance. Fertilizer usage positively impacts crop production at 5% level of significance. CO_2 emission and GDP per capita growth rate, however, do not have any statistically significant impact on crop production.

Let us now undertake the Pesaran, Shin and Smith (2001) bounds test to check whether the relationships between the independent and dependent variables exist in the long run also (Table 7).

Table 6

Latin America & Caribbean Region: Output of ARDL with optimal lags

```
. ardl dproduction dland dfertilizer dco2 gdp, lags(4 0 2 0 1)

ARDL(4,0,2,0,1) regression

Sample: 1966 - 2018                              Number of obs   =        53
                                                 F(  11,     41) =      4.38
                                                 Prob > F        =    0.0002
                                                 R-squared       =    0.5405
                                                 Adj R-squared   =    0.4172
Log likelihood =  239.57458                      Root MSE        =    0.0030

------------------------------------------------------------------------------
 dproduction |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 dproduction |
         L1. |  -.4144843   .1495577    -2.77   0.008    -.7165223   -.1124463
         L2. |   .1316474   .1456514     0.90   0.371    -.1625015    .4257963
         L3. |   .4682962   .1334543     3.51   0.001     .1987797    .7378127
         L4. |   .2068861   .1425039     1.45   0.154    -.0809064    .4946786
             |
       dland |  -.0592473   .0245872    -2.41   0.021    -.1089021   -.0095924
             |
 dfertilizer |
         --. |   .0001294    .000065     1.99   0.053    -1.86e-06    .0002607
         L1. |   .0001203   .0000582     2.07   0.045     2.74e-06    .0002379
         L2. |  -.0000444   .0000591    -0.75   0.457    -.0001637     .000075
             |
        dco2 |   .0112463   .0070591     1.59   0.119    -.0030099    .0255024
             |
         gdp |
         --. |  -.0002074   .0003469    -0.60   0.553    -.0009079    .0004932
         L1. |    .000179    .000278     0.64   0.523    -.0003824    .0007405
             |
       _cons |   .0011428   .0010693     1.07   0.291    -.0010166    .0033022
------------------------------------------------------------------------------
```

Source: author's computations

Table 7

Latin America & Caribbean Region: Bounds test

```
. estat ectest

Pesaran, Shin, and Smith (2001) bounds test

H0: no level relationship                                        F =     3.951
Case 3                                                           t =    -2.044

Finite sample (4 variables, 53 observations, 6 short-run coefficients)

Kripfganz and Schneider (2018) critical values and approximate p-values

   | 10%               | 5%                | 1%                | p-value
   |     I(0)     I(1) |     I(0)     I(1) |     I(0)     I(1) |     I(0)     I(1)
---+-------------------+-------------------+-------------------+-----------------
 F |    2.551    3.783 |    3.064    4.442 |    4.254    5.948 |    0.015    0.084
 t |   -2.517   -3.620 |   -2.858   -4.012 |   -3.542   -4.786 |    0.226    0.597

do not reject H0 if
    both F and t are closer to zero than critical values for I(0) variables
      (if p-values > desired level for I(0) variables)
reject H0 if
    both F and t are more extreme than critical values for I(1) variables
      (if p-values < desired level for I(1) variables)
```

Source: author's computations

The result shows that at 1% level of significance, F=3.951 and t=-2.044 are closer to zero than F=4.254 and t=-3.542 at I(0). So, we do not reject null hypothesis at 1% level of significance and infer that the variables – permanent crop land, fertilizer usage, CO_2 emission and GDP per capita growth rate do not have any long run impact on crop production. At 5% level of significance, both F and t statistics lie within the lower and upper bounds of the respective statistic. Hence, the outcome is inconclusive to judge the existence of long run relations between dependent variable and the independent variables.

South Asia

Let us now consider South Asia.

The tests for stationarity of the variables confirm that like what we found in case of Latin America, in South Asia also except for GDP per capita growth rate, all other variables become stationary at their first differences [I(1)]. GDP per capita growth rate is stationary at level. Since in case of South Asia also, the stationarity of the variables are attained in the combination of I(0) and I(1), here also ARDL model is very much applicable. So, we run ARDL with the first-differenced crop production as the dependent variable and first differenced variables like permanent crop land, fertilizer usage and CO_2 emission, besides GDP per capita growth rate at level as the independent variables (Tables 8 and 9).

Table 8

South Asia: Stationarity of the variables at different orders of integration

Variables	South Asia
GDP growth	I(0)
Crop	I(1)
Fertilizer	I(1)
CO_2	I(1)
Crop land	I(1)

Source: author

Table 9

Output of ARDL model for South Asia

```
. ardl dproduction dland dfertilizer dco2 gdp

ARDL(1,0,0,0,0) regression

Sample: 1966 - 2018                             Number of obs   =         53
                                                F(   5,     47) =       4.37
                                                Prob > F        =     0.0024
                                                R-squared       =     0.3174
                                                Adj R-squared   =     0.2448
Log likelihood =  223.31188                     Root MSE        =     0.0038

 dproduction |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]

 dproduction |
         L1. |  -.2021521   .1285139    -1.57   0.122    -.4606887    .0563846

       dland |   .0229733   .0137489     1.67   0.101     -.004686    .0506326
 dfertilizer |   .0000738     .00011     0.67   0.506    -.0001475     .000295
        dco2 |  -.0009344   .0265603    -0.04   0.972    -.0543668     .052498
         gdp |   .0006929   .0002614     2.65   0.011     .0001669    .0012188
       _cons |  -.0001713   .0010058    -0.17   0.865    -.0021948    .0018521
```

Source: author's computations

The p value of F statistic indicates that the model is statistically significant. However, the R square is weaker in this model as compared to that of Latin America. The R square value indicates that 31.74% of the variations in crop production are explained by the variations in the independent variables.

In order to run the model with optimal lag length of the variables, we need ascertain the optimal lag length in respect of each of the variables. The optimal lag lengths are 1, 3, 0 and 3 respectively for crop production, permanent crop land, fertilizer use and CO_2 emission in its first order integration. The same for GDP per capita growth rate at level is 1.

Now, we run the same ARDL model with the variables at its optimal lag lengths (Tables 10 and 11). In this model also, the p value of F statistic indicates that the model is statistically significant at 5% level of significance. The R square value, however, is better in the present model. This value indicates that 40.61% of the variations in crop production are influenced by the variations in the independent variables.

Table 10

South Asia: Optimal lag lengths for each parameter

Variable	Latin America & Caribbean Region
Crop production	1
Crop land	3
Fertilizer	0
CO_2	3
GDP	1

Source: author

Table 11

South Asia: Output of ARDL with optimal lags

```
. ardl dproduction dland dfertilizer dco2 gdp, lags(1 3 0 3 1)

ARDL(1,3,0,3,1) regression

Sample: 1965 - 2018                         Number of obs   =         54
                                            F(  12,     41) =       2.34
                                            Prob > F        =     0.0217
                                            R-squared       =     0.4061
                                            Adj R-squared   =     0.2323
Log likelihood =  231.21306                 Root MSE        =     0.0038

------------------------------------------------------------------------------
 dproduction |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 dproduction |
         L1. |   -.275021   .1578718    -1.74   0.089    -.5938495    .0438075
             |
       dland |
         --. |   .0243897   .0154981     1.57   0.123    -.0069093    .0556888
         L1. |   .0085836   .0144665     0.59   0.556     -.020632    .0377993
         L2. |   .0116827   .0121286     0.96   0.341    -.0128116    .0361769
         L3. |  -.0169471   .0124134    -1.37   0.180    -.0420166    .0081223
             |
 dfertilizer |   .0000575   .0001151     0.50   0.620     -.000175    .0002899
             |
        dco2 |
         --. |  -.0040512   .0305182    -0.13   0.895     -.065684    .0575815
         L1. |   .0166895   .0288949     0.58   0.567    -.0416649    .0750438
         L2. |   .0093484   .0278037     0.34   0.738    -.0468023    .0654991
         L3. |  -.0082124   .0294101    -0.28   0.781    -.0676073    .0511824
             |
         gdp |
         --. |    .000497   .0002792     1.78   0.082    -.0000668    .0010608
         L1. |     .00022   .0002835     0.78   0.442    -.0003525    .0007925
             |
       _cons |  -.0004605   .0010717    -0.43   0.670    -.0026249    .0017038
------------------------------------------------------------------------------
```

Source: author's computations

Table 12

South Asia: Bounds test

```
. estat ectest

Pesaran, Shin, and Smith (2001) bounds test

H0: no level relationship                                  F =    14.521
Case 3                                                     t =    -8.076

Finite sample (4 variables, 54 observations, 7 short-run coefficients)

Kripfganz and Schneider (2018) critical values and approximate p-values
```

	10%		5%		1%		p-value	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F	2.539	3.782	3.049	4.441	4.233	5.947	0.000	0.000
t	-2.509	-3.611	-2.851	-4.003	-3.536	-4.779	0.000	0.000

```
do not reject H0 if
    both F and t are closer to zero than critical values for I(0) variables
      (if p-values > desired level for I(0) variables)
reject H0 if
    both F and t are more extreme than critical values for I(1) variables
      (if p-values < desired level for I(1) variables)
```

Source: author's computations

Table 13

South Asia: Long run causal relations in crop production

```
. ardl dproduction dland dfertilizer dco2 gdp, lags(1 3 0 3 1) ec

ARDL(1,3,0,3,1) regression

Sample: 1965 - 2018                              Number of obs    =        54
                                                 R-squared        =    0.7567
                                                 Adj R-squared    =    0.6854
Log likelihood =  231.21306                      Root MSE         =    0.0038
```

D. dproduction	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ADJ						
dproduction						
L1.	-1.275021	.1578718	-8.08	0.000	-1.59385	-.9561925
LR						
dland	.0217321	.0155282	1.40	0.169	-.0096277	.0530919
dfertilizer	.0000451	.0000914	0.49	0.625	-.0001396	.0002297
dco2	.0108032	.0340847	0.32	0.753	-.0580323	.0796386
gdp	.0005623	.0003049	1.84	0.072	-.0000533	.001178
SR						
dland						
D1.	-.0033192	.0216599	-0.15	0.879	-.0470621	.0404238
LD.	.0052645	.0184469	0.29	0.777	-.0319899	.0425188
L2D.	.0169471	.0124134	1.37	0.180	-.0081223	.0420166
dco2						
D1.	-.0178255	.0436175	-0.41	0.685	-.1059127	.0702617
LD.	-.001136	.0413607	-0.03	0.978	-.0846656	.0823935
L2D.	.0082124	.0294101	0.28	0.781	-.0511824	.0676073
gdp						
D1.	-.00022	.0002835	-0.78	0.442	-.0007925	.0003525
_cons	-.0004605	.0010717	-0.43	0.670	-.0026249	.0017038

Source: author's computations

The p value of F statistic is less than 0.05. Hence, the model is statistically significant at 5% level of significance. The p values of the respective variables indicate that in the short run, only the past level of crop production and GDP per capita growth have statistically significant influence on crop production at 10% level of significance. GDP per capita growth has positive impact on crop production.

Next, we need to ascertain the long run relations between the variables. We undertake Pesaran, Shin and Smith (2001) bounds test, as Table 12 presents.

The outcome of the bounds test reveal that F=14.521 and t=-8.076 are more extreme than the critical values for I(1) with F=5.947 and t=-4.779 at 1% level of significance. Hence, we do not reject the null hypothesis. This also means that long run relations do exist among the variables.

To see the impact of the independent variables in the long run, we now run the ARDL model with the optimal lag lengths in respect of each variable (Table 13). In this model we also incorporate the necessary error correction.

The salient feature of the outcome is that the value of R square has improved a lot with error correction. Now, 75.67% of the variations in the crop production are explained by the variations in the exogenous variables. It is now established that in the long run, besides past levels of crop production, GDP per capita growth rate also influences the crop production in South Asia. In both the cases, the impacts are statistically significant at 10% level of significance. The influences of other exogenous variables are not found to be statistically significant.

Discussions

The Auto Regressive Distributed Lag (ARDL) model used for analysing the causal relations is found to be statistically significant for both the regions. However, the nature of such relations is not uniform across the regions. All the factors considered in the present study do not have (statistically) significant influence on crop production. In Latin America & Caribbean Islands, in the short run, the past levels of crop production, the share of permanent crop land and fertilizer usage have significant impact on crop production. However, the directions of the influences are found to be negative in crop production in the immediate preceding period. The direction of influence is, however, positive in second, third and fourth lag. The implications of such negative influence of crop production in the first lag need special mention. The fact indicates that there had been decline in the average volume of crop production. This is possible if the past productions did not fetch expected return to the cultivators or the crop markets faced decline in demand. Given the growth trajectory of the population found in the region, the second alternative can be ruled out. Besides, the World Bank data also reveals that, on an average, the food imports of the region is found to be 9.56% of the total merchandise imports of the region. A curious investigation of the degree of association between the crop production index and the share of food imports results in existence of a high and negative correlation coefficient between the two: r = - 0.73. The declining trend of food imports, as a share of merchandise imports in the region over a period of nearly sixty years from 1962 to 2020 may also be cited as a justification for the negative impact of crop production index in the first lag, preceded by, though, positive impact of the indices in the other lags. So, it is possible that the crop production in the region may get influenced by its food imports. However, its confirmation requires some rigorous econometric testing, which is beyond the scope of the present paper.

The share of permanent crop land also has negative impact on crop production index. This may happen if the volume of crop production carried out in the newly inducted permanent crop land fails to match the average volume of production of the entire region prior to its induction or if the volume of production in the older pieces of lands falls due to beginning of cultivation in the newly inducted crop land. The World Bank Data suggests that over a period of thirty years from 1991 to 2019, the average employment in agriculture as a share of total employment generated in the region stands at over 17%. With a declining trend in employment in agriculture, and also given that the average share of permanent crop land in the total land area available is around 1%, the data justifies, arguably, the inclusion of new land in crop cultivation. However, the possibility of significant imports of food grains offsetting the motivation for enhanced crop production can also be not ruled out.

In case of fertilizer usage, the positive sign of the coefficients supports the usual propositions that increase in fertilizer usage leads to an increase in crop production. The influence of fertilizer usage is also statistically significant.

The positive sign of the coefficient of carbon-dioxide emission indicates mechanization of agriculture in the region. Burning of fossil fuel for crop production is a usual phenomenon of cultivation, especially in the developing world. However, in the present case, the influence of carbon-dioxide emission on crop production index is not found to be statistically significant.

Finally, the influence of GDP per capita growth on crop production is found to be negative. The fact can be well explained with the help of Engel's law that claims that with rise in income of the households, the demand for food grains falls. In the present case, rise in GDP per capita growth indicates rise in income of the households. Hence, its negative influence of crop production index is well justified. But the coefficient is found to be statistically insignificant. In its first lag, the GDP per capita growth, though, has positive influence on crop production index. But, in this instance also, the influence of GDP per capita growth on crop production index is found to be statistically insignificant.

Finally, one of the important characteristics of crop production in Latin America and the Caribbean Region is that all the determinants of crop production do impact only in the short run. In the long run, none of the four factors have statistically significant impact on crop production indices.

In case of South Asia, in the short run, the crop production index is found to be significantly influenced, at 10% level, by the crop production indices in its first lag. The direction of the relations is negative. This is similar to the relations existing in case of Latin America and the Caribbean Islands. In South Asia, the average imports over a span of almost sixty years from 1962 to 2020, as a share of total merchandise imports of the region stands at 11%. Moreover, here also, the food imports' share faces decline over time. This can justify the negative influence of crop production only in its first lag. Thus, similar to Latin America, in this region also, the possibility of domestic crop producers' returns getting affected by the imports of food grains cannot be ruled out. However, here also its confirmation requires rigorous econometric exercise.

Share of permanent cropland in the total land area of the region, till its second lag, has positive influence on crop production index. This follows the usual theoretical propositions. However, the influence is statistically insignificant.

Fertilizer usage positively impacts crop production. However, in this case also the impact is statistically insignificant.

Green house gas emission negatively influences crop production. But, the emissions in its first and second lags exert positive impact on crop production. This points to the mechanization of agriculture in this region also. However, the impact of such emission on crop production index is statistically insignificant.

Finally, GDP growth per capita positively impacts the crop production index. The impact is statistically significant at 10% significance level. The existence of considerable subsistence economy in the region has possibly resulted in such an outcome.

Finally, in a significant departure from the characteristics observed in Latin America and the Caribbean Regions, in South Asia, out of all the independent variables considered, crop production in the first lag and GDP growth per capita have long run impact on crop production. Though the influence of crop production in the first lag is statistically significant at 10% level of significance, the impact of per capita GDP growth on crop production is statistically significant at 5% level of significance.

Conclusion

The identification of the causal relations between the determinants of crop production and the crop production index has serious policy implications. The present study has considered four of such determinants. There are resemblances, in some aspects, between Latin America and South Asia, as is also evident from the existing literature. While exploring the causal relations, such similarity is also noticed in terms of the short run relations between the determinants and the crop production indices. However, the major difference lies in the long run relations between the variables. While, in Latin America & Caribbean Region no long run relations exist between the variables, in South Asia significant long run relations exist between them. In the absence of any long run relations, it is not possible to frame any specific policy intervention to ensure long run growth in crop production. However, in South Asia, the scope of specific policy intervention is there. The determinants having long run impact on crop production must be given special attention while formulating policy to improve crop production index of the region. The combined efforts, in this regard, of the constituent nations can bring in the desired outcome. Suitable policy framework can also be identified to take care of the negative impact of the previous period's crop production. If further studies indicate that the imports of food grain do offset the demand for domestically produced crops, necessary incentives in the form of subsidy to the crop producers may be called for. Besides, the past levels of crop production, the GDP growth rate per capita are found to have significant long run relations with crop production. In that case, all the initiatives taken by the countries to increase GDP become immensely important. Since per capita GDP also depends on population of the country, adequate policy intervention to restrict demographic explosion may also bring in the desired result.

References

Ayyildiz, M., Erdal, G. (2021). The relationship between carbon dioxide emission and crop and livestock production indexes: A dynamic common correlated effects approach. *Environmental Science and Pollution Research* **28**, 597–610. DOI: 10.1007/s11356-020-10409-8

Blyde, J., Fernandez, A. (2004). *Why does Latin America grow more slowly?* Inter-American Development Bank, Economic and Social Study Series, October. https://publications.iadb.org/publications/english/document/Why-does-Latin-America-Grow-More-Slowly.pdf

Devarajan, S., Nabi, I. (2006). Economic growth in South Asia: Promising, unequalizing, sustainable? *Economic and Political Weekly* **41**(33), 3573–3580. https://www.jstor.org/stable/4418586

Fukuyama, F., Marwah, S. (2000). Dimensions of development. *Journal of Democracy* **11**(4), 80–94. *Project MUSE*, doi:10.1353/jod.2000.0076.

Kohli, A. (2012). Coping with globalization: Asian versus Latin American strategies of development, 1980–2010. *Brazilian Journal of Political Economy* **32**(4). DOI: 10.1590/S0101-31572012000400001

Kripfganz, S., Schneider, D. (2018). *ARDL: Estimating autoregressive distributed lag and equilibrium correction models*. London Stata Conference 2018, Stata Users Group. http://repec.org/usug2018/uk18_Kripfganz.pdf

Lin, C.Y (1988). East Asia and Latin America as contrasting models. *Economic Development and Cultural Change* **36**(3), Supplement: Why does overcrowded, resource-poor East Asia succeed: Lessons for the LDCs? (Apr., 1988), S153–S197. https://www.jstor.org/stable/1566542?seq=1#metadata_info_tab_contents

Mulatu, D., Eshete, Z., Gatiso, T. (2016). *The impact of CO2 Emissions on agricultural productivity and household welfare in Ethiopia: A computable general equilibrium analysis*. Environment for Development Discussion Paper Series, EfD DP 16-08, March. https://www.efdinitiative.org/sites/default/files/publications/efd-dp-16-08.pdf

Nissanke, M., Thorbecke, E. (2010). *The Poor under Globalization in Asia, Latin America, and Africa*. University Press Scholarship Online. DOI: 10.1093/acprof:oso/9780199584758.001.0001

Pesaran, M., Shin, Y., Smith, R. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics* **16**(3), 289–326. http://www.jstor.org/stable/2678547

Sah, D., Devakumar, A. (2018). The carbon footprint of agricultural crop cultivation in India. *Carbon Management* **9**(3). DOI: 10.1080/17583004.2018.1457908

Shrestha, M., Bhatta, G. (2018). Selecting appropriate methodological framework for time series data analysis. *The Journal of Finance and Data Science* **4**, 71–89. DOI: https://doi.org/10.1016/j.jfds.2017.11.001

Tsunekawa, K. (2019). Emerging states in Latin America: How and why they differ from their Asian counterparts. In: Tsunekawa, K., Todo, Y. (eds.) *Emerging States at Crossroads. Emerging-Economy State and International Policy Studies*. Singapore: Springer. DOI: 10.1007/978-981-13-2859-6_4

Wiebe, K., Sulser, T., Dunston, S., Rosegrant, M., Fuglie, K., Willenbockel, D., Nelson, G. (2021). Modeling impacts of faster productivity growth to inform the CGIAR initiative on Crops to End Hunger. *PLoS ONE* 16(4), e0249994. DOI: 10.1371/journal.pone.0249994

Zettelmeyer, J. (2006). *Growth and reforms in Latin America: A survey of facts and arguments*. IMF Working Paper WP/06/210. https://www.imf.org/external/pubs/ft/wp/2006/wp06210.pdf