Environmental Consequence of Australian Agricultural Trade: An Asymmetric Analysis

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ABSTRACT

Link between environmental degradation and agricultural trade balance (ATB) is still an under explored research area. This paper, therefore, investigate this issue for Australia using the quarterly data of 1988 - 2021 under environmental Kuznets curve (EKC) hypothesis framework. In this regard when a linear model is applied, support for short-run impacts is revealed. However, this model is unable to explore the asymmetry of the relationship. Therefore, the nonlinear model is also applied to address this difficulty. This model has supported both short- and long-run asymmetry adjustment by ATB on Australian pollution. The findings reveal that improvement of ATB is harmful for Australian environment, and agro import related economic activities are environmentally more efficient than agro export related activities. However, to improve the environment condition, agricultural commodity import substitution is not a good policy option for Australia. The findings also validate EKC hypothesis, and when environmental pollution is concerned, national income is as important as ATB in Australia.

Keywords: Carbon emissions, Agricultural trade balance, Asymmetry analysis, and Australia.

JEL Classification: B17, E01, and Q5.

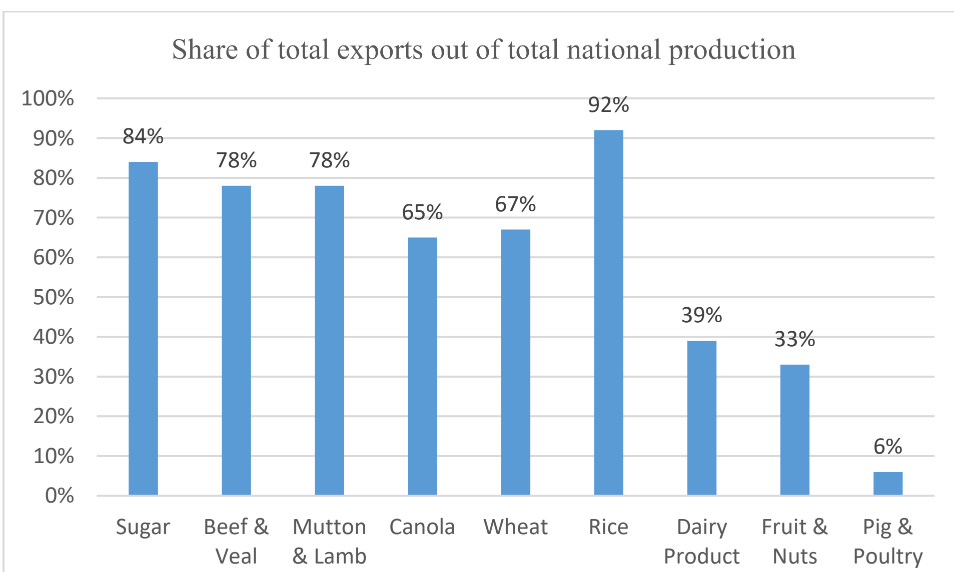
I. Introduction

Environmental damage is considered as a fatal collateral consequence of the human economic activities around the world. Ever increasing international trade is considered one of the prime examples of such activates. Recent trend shows that Australia is one of the worst victimized countries in the world by environmental pollution and climate change. Frequent bush fire, floods, drought, ecological and biodiversity damages in both land and ocean areas are perhaps predominant issues among them. Ultimate impact of such damages falls upon the cost of agricultural production and trading activities of the country. Therefore, the impact of trading activities on environmental pollution is an important research issue among the environmentalists, researchers and policy makers. However, a careful review of existing literature reveals that though some studies on the trade-environment link exist, , research regarding environmental effect of sectorial trade balance is very scarce in general and agricultural trade balance in particular. This paucity of research leads us to investigate the environmental effect of Australian agricultural sector that has a vast contribution on the world agricultural commodity supply chain. .

As a matter of fact, it is shown in the past numerous studies that expansion of international trade could deteriorate environmental condition of a country noticeably (Jayantha kumaran *et. al*.,2012; Solarin *et al*.,2017; Raza and Shah,2018). Here the arguments are that international trade can create negative externalities for the environment. Such externalities are originated by the unintended trans-boundary pollution, massive deforestation, setting up new production plants and production relocation disregarding the environmental consequences, increase of backward and upwardly linked industrial plants setting with the dependence of targeted trading activities, and increase domestic and international transportation of the concerned trading goods. Existing literature suggests that each country has own consequences which can be different for an individual country (Managi *et. al*., 2008). Our presently concerned country Australia has also no exception. Some studies suggest that trade harms Australian environment but others show that environmental impact of trade is insignificant in the case of Australia. 'Australia exports 80 percent of its agricultural products, but export-oriented agricultural land use has resulted in serious environmental degradation, including salinisation due to land clearing and over irrigation, water overuse, forest logging and massive land clearing, high greenhouse emissions, soil acidification, and flow on effects like biodiversity loss and water pollution due to increased pesticides and fertilizer use (Cebon, 2003). In contrast, Frankel (2009) points out that empirical studies of cross-country data generally find no detrimental effects of trade on environment. Clearly the issue is inconclusive and country specific. Only a limited number of studies state that a country's environment could benefit from agricultural trade (Karp 2011), and only a few researchers have found that agricultural trade has no significant influence at all or have found the effects on the environment to be ambiguous (Kankesue *et. al.* 2012).

Some studies about the environmental consequences by international trade in Australia exist. . However, though country's agricultural trade contribution is about one fifth of its the total international trade, concentration of the literature on agricultural trade is very rare. A few studies focused on this issue and revealed the mixed results both in short-run and long-run. Such ambiguity may be raised due to data and model specification, and methodology used in the study. Rahman and Mamun (2016) and Uddin, *et. al.* (2016) have assessed the data to check the impact of Australian trade on the environment that has reached in the conclusion that trade has negative impact on Australian trade. However, Elton (2015) found that Australian trade has no influence on environmental degradation. We have inspected almost all available related literature on Australia and found the flaws and lacunas in those studies that can be noted as: (i). data length is short and annual, thus the data did not leave enough degrees of freedom; (ii) data suffers from the aggregation bias and results do not beget any clear decision; (iii) no sector-segregated data is applied in any research; (iv) results are mixed and ambiguous, and thus misleading; (v) results and research technique has high correlation;. (vi). proper and updated econometric techniques were not used; (vii) asymmetric analysis is absent in the literature; (viii) no concentration is found on agricultural trade although agricultural contributes a big part in Australian foreign trade.

Australia exported about 72 and 61 percent of its agro products in 2020 and 2021, respectively (ABARES and DFAT, March 2022). Therefore, Australian agriculture is basically an expor-oriented sector which is very uncommon characteristic of this sector in the world. To realize about the relative importance of this sector in Australian trade, we plot the percentage share of total output exported for some of the major agricultural products in 2020 in the following figure 1. As it is seen, major portions of the national annual outputs are exported almost for all of the listed agricultural items which indicates that Australian agriculture sector is basically a trade dependent sector. Such a sheer dependence in foreign market also urgently appeals to investigate the environmental consequence by the trading activities of the sector.



Source: ABARES and Ministry of Agriculture, Forestry and Fishery of Australia. (https://www.awe.gov.au/abares/products/insights/snapshot-of-australian-agriculture-2022#around-72-of-agricultural-output-is-exported)

Despite the importance of the agricultural trade, the number of studies exploring the trade-agriculture-environment nexus is surprisingly very limited in the case of Australia. Not only has the case of this country, but the issue also suffers from the lack of evidential and empirical knowledge in the rest of the world as well . One of the common features of the earlier studies is that they assume that the impact of trade on environment is always symmetric. They further assume that - each sector like primary mineral, manufacturing, service and agricultural goods – have the same directional impact on environmental pollution which may not be true in reality. This assumption is also arisen by the methodological constraints they have relied. Formulating and implementing environmental and trade policy based on such research outcome may lead abortive results. Understanding this gravity of both methodological and empirical knowledge lacuna this paper aims to provide a concrete outcome about the environmental impacts by agricultural trade balance based on the recently developed estimation techniques in time series econometrics with most recent data. Hence this study is unique, and it is expected that the results, from updated data and estimation techniques would have much policy implications for Australian as well as the global environmental stakeholders. Our research results will have more reliance than available studies as we are using only agricultural sector data not of any aggregate trade data. Reducing or eliminating the malevolent aggregation bias by using individual sector trade balance data will incur originality of this research against the conventional aggregate data-based literature.

The results of this research are expected to be both symmetric and asymmetric. If the result is asymmetric, it will mean that environmental adjustment impact by agro-trade balance is not similar in short and long-runs. If the result is symmetric, the conclusion would be that the impact is uniform regardless of improvement and deterioration of Australian ATB. Policy implication for the second case should be easy. However, in earlier case it would be bit difficult since in that case time, direction and magnitude of the ramification will have complex dynamics. So, our target in this study is to define whether Australian ATB has a symmetric or an asymmetric influence on CO_2 emissions so that gravity of the complexity can be clear to the environmental policy making and implementing authorities.

The rest of the paper is structured as follows: Section II reviews the existing literature to identify the research gap; Section III explains data, models and econometric methods. Empirical results and analysis are presented in Section IV, and concluding remarks are noted in Section V.

Literature Review

Trade and environmental pollution is widely explored in the research [Rahman *et.al.* (2022), Rahman *et. al.* (2021)]. Michieka *et al.* (2013) analyzed the association between the exports and pollution for China. Further, Knight and Schor (2014), Khan *et al.* (2020) and Wahab *et al.* (2020) have showed that exports and imports increase the production of carbon intensive outputs and thus carbon emissions. Wahab *et. al* (2020) have also shown that both imports and exports have positive effect on CO_2 emissions.

Besides some researchers have focused on whether trade balance has any impact on environment. The findings of Fawzia *et. al.* (2012) expressed the evidence of a co-integration relationship and short-run impacts of trade balance on CO2 emissions. Almost same result for long-run is revealed by Ben Jebli and Ben Youssef (2017), Jebli *et al.* (2016), and Chen *et al.* (2019). An extensive literature has also come out in regard to trade openness and environmental pollution nexus. Al-Mulali and Ozturk (2015), Michieka *et al.* (2013), Omri *et al.* (2015), Shahbaz *et al.* (2013), Tamazian *et al.* (2009) and Yang and Zhao (2014) have found strong correspondence between trade openness and CO_2 emissions for their sample based on different countries. Their findings are also supported by Aziz et al., (2013); Zakarya *et al.,* (2015); Khuong, (2017); Halicioglu, (2009); Kohler, (2013); Farhani *et al.,* (2014). Even causal linkages between CO_2 emissions and trade openness are discovered by Al Mulali *et al.* (2015); Farhani and Ozturk (2015); and Yang and Zhao (2014); and, Sarkodie, *et. al.* (2019). A vast number of studies have revealed the dynamic linkage between trade openness and CO_2 emissions too [Musah *et al.* (2021); Mutascu (2018); Zamil *et al.* (2019); Zhang *et al.* (2017); and Mutascu and Sokic (2020)].

The relationship between agriculture activities and CO_2 emissions has been studied and has found the diversified outcomes. A group of studies such as Özilgen and Sorgüven, (2011); Santiago-De la Rosa *et al.,* (2017); and Waheed *et al.,* (2018). , have shown the positive relationship between CO_2 emissions and agriculture outputs Additionally, Alamdarlo, (2016) has conducted a study and has given evidence that CO_2 emissions has a direct relationship with agriculture and its related services. The findings from these studies have further showed that agriculture activities (pre-harvest, harvest and post-harvest activities) affect CO_2 emissions differently. The result of this study is reinforced by the findings of Gagnon *et al.,* (2016), Dogan, (2016), and Farhani *et al.* (2014).

Overall, the past literature suggests an individual linkage of international trade level, trade balance, and trade openness with environmental pollution. Further, empirical literature also shows extensive evidence of association between environmental pollution (carbon emissions) and agricultural sector production. However, no paper has attempted to explore the link between agricultural trade and environmental pollution. We were able to discover only one paper on the topic like agro export and environmental pollution - the nearest topic to our present papers' issue. This paper has postulated a positive relationship between agricultural export and environmental pollution level of Pakistan (Zaid *et. al.* 2021).

However, to the best of the authors' knowledge, no past research has explored the asymmetric analysis between the agricultural trade balance (ATB) and environmental pollution for any country in the world ever. Therefore, there is a long and gigantic research gap yet to be filled up by the researchers. In short, we have found that the following research gaps (i) n research on asymmetric analysis between environmental pollution (CO_2 emissions) and agro trade balance (ATB); (ii) no research on agricultural trade and pollution level except agri-exports and Pollution in Pakistan; (iii) no research in case of Australia. Thus, the present research intends to fill this overdue research gap of the existing literature across the world. This is also evidence of the originality and urgent necessity of our research.

III. Data, Models and Econometric Methods

To carry out the empirical analysis the data period covered by the study is 1988Q1-2021Q4. There is no missing data in any of the selected series. We were needed to rely on three sources for the required data. Australian agricultural Trade Balance (ATB) data with the rest of the world are collected from the Department of Foreign Affairs and Trade (DFAT), Government of Australia. The ATB is defined as Australian imports from the rest of the world over her exports to the rest of the world which can be mathematically shown as (M_t/X_t). Since ATB is a ratio it has unit. Data on Australian Real GDP (Y_t) series (with base year 2010) are collected from International Financial Statistics (IFS) of International Monetary Fund (IMF).. Finally annual Australian carbon emissions (E_t) data are retrieved from the World Development Indicators (WDI) by World Bank (.) The unit of the data is in metric tons.

The theoretical foundation for our empirical model is based on environmental Kuznets Curve (EKC) hypothesis, which shows an inverted u-shaped relationship between economic growth and environmental degradation; environmental degradation increases with the increase of economic growth at the initial level of development of a country. After certain level of development when the country can afford green technology, environmental quality improves with the increase of economic growth. We rely on Bahmani-Oskooee, Rahman and Kashem's (2019) model to make inference. This model is used in number of empirical investigation for asymmetry analysis especially in the trade related issues. So, we decide to use this advancement of knowledge in Environmental Economics asymmetric analysis for the first time and hope that this will open a new window for the analysis of environmental issue in the days to come. Our specification in this regard is as follows:

$$LnE_t = \alpha + \beta\ LnY_t + \gamma\ LnY^2_t + \delta\ LnATB_t + €_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

where Ln means natural logarithm and E_t is Australian pollution is measured by the carbon emissions at the year t. Y_t is the Australian GDP at the year t. ATB_t is the Australian agricultural trade balance (ATB) with rest of the world at time t where agricultural trade balance (ATB) is defined as the ratio of Australian agricultural imports from the rest of the world over her agricultural exports to the rest of the world at time t. It is a modified version of Kashem and Rahman (2020) model where pollution is a function of national income and trade ratio. To define ATB we use ratio of imports over exports by following Bahmani-Oskooee (1991) and an increase in the ratio means deterioration of trade balance and vice versa. In using the term GDP-squared (Y^2) is followed by the Kashem and Rahman (2020) since they have thought that relationship between pollution or emission and GDP is quadratic means that as per EKC hypothesis pollution may increase in the initial period of increase of the income and may decrease after some times. If the GDP-squared variable gives a significant negative sign EKC hypothesis will be supported otherwise not. Here the target variable is ATB as our intention is to infer the impact of agricultural trade balance on Australian pollution level. Australian GDP (or Y) is the control variable in the model. National income or GDP is an inevitable variable for CO_2 emission function since economists believe that there is a one to one association between national income and CO_2 emissions over the history. Since the model is in logarithmic form we will get the estimates of impact by the change of the explanatory variable directly as elasticity. Since in the above equation Y_t is the Australian GDP and an increase in Australian GDP is expected to increase Australian carbon emission, an estimate of β is expected to be positive. In contrast, since we assume that the relationship is perhaps quadratic, an estimate of δ is expected to be negative. Finally, since some findings have concluded that relationship between emission and trade balance is positive [Rahman and Vu (2020), and Rahman (2017)] and some other have said negative (Mahmud *et. al*. 2020), the sign of δ can be positive or negative.

Now that we have a well specified model our next task in this regard should be incorporating the short-run dynamic adjustment process into our model which is just an error-correction type short-run dynamic adjustment process along with probable long-run effects or relationships, and the model can be specified by equation (2) as follows:

$$\Delta LnE_t = \alpha_\tau + \sum_{j=1}^{n} \beta_{t-j}\, \Delta LnE_{t-j} + \sum_{j=0}^{n} \gamma_{t-j}\, \Delta LnY_{t-j} + \sum_{j=0}^{n} \delta_{t-j}\, \Delta LnY^2{}_{t-j} + \sum_{j=0}^{n} \lambda_{t-j}\, \Delta LnATB_{t-j} + \theta_1 \text{ Ln } E_{t-1} + \theta_2 \text{ Ln } Y_{t-1} + \theta_3 \text{ Ln } Y^2{}_{t-1} + \theta_4 \text{ Ln ATB}_{t-1} + \upsilon_t \quad \ldots\ldots(2)$$

In the above equation (2), clearly it is an error-correction model where the short-run effects of each explanatory variable on the environmental pollution level (total carbon emissions) is inferred by the respective estimate of coefficients related to the first-differenced variables and justifiably the long-run effects are reckoned by the estimate of θ_1- θ_4 normalized on θ_1. However, for these normalized estimates to be consequential, we need to establish co-integration. Since the approach comes from Pesaran *et. al.* (2001), they have recommended to apply the F-test for which they have also tabulated new critical values. According to the Pesaran *et. al.* (2001) since the critical values is calculated considering with the degrees of integration of the variables, there is no need to conduct unit root test, and thus, there is no problem if the attempted variables are an admixture of I(0) and I(1).

One of the fundamental conditions of equation (2) to be applied is that changes in any of the independent variable of equation must have symmetric effect on the dependent variable - carbon emissions level in our present case. Now concentrating on the agricultural trade balance (our target variable), the symmetry assumption unequivocally indicates that an increase of the agricultural trade balance has the same effect on carbon emissions level as a decrease of the agricultural trade balance in size but of course not in sign. However, it can be argued to the contrary that since most of the time business community ignore the socioeconomic consequence of the environmental pollution in doing their business activities, and as government and environmental bargaining groups reaction could be different in these two different periods, emission level could be different in case of increase as compared to decrease of agricultural trade balance.

Therefore, tackling such two opposite scenarios of traders' attitudes we have resorted to Shin *et. al.* (2014) asymmetry analytical model. To do that we have to modify the above model (2) into a totally new and different type of specification which could be applied to evaluate the asymmetric effects of agricultural trade balance changes as follows:

$$\Delta LnE_t = a_\tau + \sum_{j=1}^{n} b_j\, \Delta LnE_{t-j} + \sum_{j=0}^{n} c_j\, \Delta LnY_{t-j} + \sum_{j=0}^{n} d_j\, \Delta LnY^2{}_{t-j} + \sum_{j=0}^{n} e_j\, \Delta P_{t-j} + \sum_{j=0}^{n} f_j\, \Delta N_{t-j} + \omega_1 \text{ Ln } E_{t-1} + \omega_2 \text{ Ln } Y_{t-1} + \omega_3 \text{ Ln } Y^2{}_{t-1} + \omega_4 P_{t-1} + \omega_5 N_{t-1} + \psi_t \quad \ldots\ldots.(3)$$

As can be perceived, in turning equation (2) into (3), the LnATB variable is replaced by a couple of new variables named as, P and N as a surrogate of Positive and Negative changes of ATB respectively. Here P indicates the partial sum of positive changes in LnATB and reflects the deterioration of agricultural trade balance. Likewise, the variable N reveals the partial sum of negative changes in LnATB and shows only agricultural trade balance improvements.[1] As introducing the two partial sum variables include nonlinear adjustment of agricultural trade balance changes into error-correction model, this type of specification, like (3) above, is known as nonlinear ARDL models, while the ARDL model like (2) that assumes symmetric effects only .

Further, Shin *et al.* (2014) have shown that by estimating equation (3) resorting OLS techniquecould be applied for the assessment of asymmetric co-integration and many other asymmetric effects (if any) analysis. We attempt here to use this model to assess the impact of agricultural trade balance changes on the environmental pollution (i.e., emissions) level of Australia. We want to follow the way to move forward as below:

First, to establish the joint significance of lagged variables the similar F-test would be used as a technique of asymmetry co-integration. It is worth to mention here that Shin *et. al.* (2014)) suggest to treat the new found P and N variables as a single variable so that the critical values of the F-test to keep at the same level while we would switch to (3) from (2), even though the model (3) has incorporated one additional variable in it.

Secondly, for model (3) almost a completely similar type of test is considered for searching the co-integration in case of the linear ARDL model (2). In the case of this alternative test, which is known as error-correction test (ECM_{t-1} test), the normalized long-run estimates from (3) where LnATB is replaced by P and N variables, are brought to generate the error-term which is connoted as ECM. By replacing the lagged variables from equation (3) by ECM_{t-1}, the newly specified model can also be estimated at the optimum values of lagged variable as before. Now a significant negative value of the coefficient of ECM_{t-1} should be just an alternative value of supporting the co-integration hypothesis. Here, just as the traditional F-test, that is used to evaluate the significance of this estimate has a new type of F-distribution which is proposed by Pesaran *et. al.* (2001) and formulated a new table for the upper and lower bounds or critical values.

Thirdly, if in case of each lag j, an estimate of e'j is significantly different than estimate of f'j that should be an indication of the short-run asymmetric effects of the Australian agricultural trade balance on the Australian carbon emission level; but as per Shin *et. al.* (2014) if $\sum \hat{e_t} \neq \sum \hat{f_t}$ this will be considered as a symptom of the short-run cumulative asymmetry or 'impact asymmetry'. In this case, they have suggested to apply the traditional Wald test to check the significance of this inequality.

Fourthly, if the optimum number of lag value of ΔP is not the same of the optimum number of lag values of ΔN, that will be an indication of short-run 'adjustment asymmetry'. *Finally*, if we can establish that $\hat{\theta}_3/\hat{\theta}_0$ = - $\hat{\theta}_4/\hat{\theta}_0$, i.e., i.e., normalized estimate related to the variable P is significantly different from normalized estimate related to the variable N, it will be a confirmed indication of

[1] Notes that to generate the two partial sum variables, we first counted ΔATB which has positive and negative changes. After that P_t at time t is defined as cumulative sum all observations in ΔATB_t where negative values are replaced by zero. Then the N_t is defined as the same way where positive values of ΔATB_t are replaced by zero. For details of calculation of these two partial sums see Bahmani-Oskooee, Rahman and Kashem (2017).

the 'long-run asymmetric' effects. Like before, again in this case the conventional Wald test would be used to be econometrically confirmed this inequality.

IV. Empirical Results and Analysis

We have estimated proposed both models in last section of Australian carbon emissions for the agricultural trade balance with the rest of the world with a view to investigate the consequence of agricultural trade balance on its environmental pollution. Yearly environmental pollution is measured by the annual CO_2 emissions of Australia. Quarterly data over the period 1988Q1-2021Q4 is used to conduct the empirical examinations. To determine the optimal lag levels of the model we relied on Akaike Information Criteria (AIC) and accordingly maximum of '4' lags are imposed on each of the first-differenced variable. We have considered critical values up to 10 percent level of significance to count statistical significance of both coefficient and diagnostic statistic which are presented in the Table 1 below. Further notation is that an estimation of the linear and nonlinear ARDL models are described as L-ARDL and NL-ARDL respectively.

Table 1: Results of Linear ARDL (L-ARDL) and Nonlinear ARDL (NL-ARDL) Models

Panel I: Estimates of Short Run Model		
	L - ARDL	**NL - ARDL**
	Coefficient	**Coefficient**
ΔlnYA,t	0.37 (0.89)	0.46 (1.08)
ΔlnYA,t-1	0.33 (0.52)	0.29 (0.48)
ΔlnYA,t-2	1.55 (2.53)**	1.36 (2.26)**
ΔlnYA,t-3	1.13 (2.00)**	1.22 (2.09)**
ΔlnYA,t-4	0.74 (1.70)*	0.98 (2.27) **
ΔlnY2,t	1.76 (0.35)	3.94(0.66)
ΔlnY2,t-1	-3.56(2.17)*	-3.22(2.05)*
ΔlnY2,t-2	0.43(0.29)	1.11(0.80)
ΔlnY2,t-3	0.78(0.54)	0.55(0.40)
ΔlnY2,t-4	3.47(2.29)*	-0.53(0.41)
ΔlnATBt	1.82(0.94)	
ΔlnATBt-1	-2.87(3.25)**	
ΔlnATBt-2	0.63(0.82)	
ΔlnATBt-3	0.67(0.82)	
ΔlnATBt-4	-1.25(1.64)*	
ΔPt		-23.48(2.63)**
ΔPt-1		-18.78(2.54)**
ΔPt-2		-14.34(2.61)**
ΔPt-3		-7.73 (1.81)*
ΔPt-4		-2.98(1.97)
ΔNt		5.12(0.83)
ΔNt-1		4.06(0.89)
ΔNt-2		1.15(1.21)
ΔNt-3		3.59(1.79)*
ΔNt-4		3.43(2.38)*
Panel II: Estimates of Long-Run Model		
ln Yt	0.93 (1.78)*	1.12 (2.24)**
ln Y^2 t	-2.24 (2.86) **	3.03(3.81) ***
lnATBt	0.71 (1.22)	
P		2.86(1.53)
N		-5.94(2.81) **
Constant	22.21 (3.34)**	27.95(3.95)**
Panel III: Statistics of Diagnostic tests		
F	24.00**	20.25**
LM	0.54	1.23
RESET	1.33	0.87
Adjusted R^2	0.54	0.56

CS (CS2)	S(S)	S(UNS)
WALD - Short		6.32**
WALD - Long		8.19**

Necessary Notes for the empirical results:

a) Figures within the first bracket are absolute values of the t-statistic. ***, ** and * means, 1%, 5% and 10% level of significance,respectively.
b) In co-integration test the critical value of the upper bound when there are three exogenous variables is 3.77 (4.35) at the 10 % (5%) statistical level. [Pesaran et al (2001, Table CI, Case, P 300]
c) For significant ECM_{t-1} the critical value is -3.47 (-3.82) at the 10 % (5%) level respectively when k = 3. [Banarjee et al (1998, Table 1)]
d) LM is the Lagrange multiplier test for autocorrelation. It has a $\chi2$ distribution with 2 degrees of freedom. The critical value at the 5% level of significance is 9.48.
e) In case of specification the Ramsey RESET test has a $\chi2$ distribution with 1 degrees of freedom. The critical values at the 5% and 10% level of significance are 3.84 and 2.70 respectively.

WALD tests also follows a $\chi2$ distribution with degrees of freedom 1. The critical values at the 5 % and 10% level of significance are 3.84 and 2.70 respectively.

The estimates of short-run coefficients of the L-ARDL model are reported in Panel I. The results indicate that ATB carries multiple significant coefficients in the L-ARDL model. Likewise, in case of NL-ARDL model it looks that either ΔP or ΔN carry more than one significant coefficients with due signs meaning that a deterioration of ATB improves pollution and improvement of ATB degrades Australian pollution. The result is very much in line with our theoretical expectation as well as supports our hypothesis that improving of agro-trade balance (i.e. increase of exports is more than the increase of imports) is environmentally harmful in Australia.

Additionally, to examine the support in the short-run effects of ATB on Australian CO_2 emissions level, the nonlinear models also support short-run adjustment asymmetry in the models since in the case of ΔP takes a different significant lag order than ΔN with due signs. Moreover, the magnitude of the estimates of short-run coefficient related to ΔP and ΔN is different in numerical values almost in all cases of the same lag level (i.e., absolute numerical value of the estimates of ΔP is higher than the estimates of ΔN). This is in turn supports the asymmetric effects in short-run by ATB on carbon emissions.

Further, in NL-ARDL model, ΔP is significant in case of shorter and more number of lags than ΔN and, similarly, the coefficients of ΔP are relatively larger than the coefficients of ΔN. It means that ramification of ΔP is immediate, higher in magnitude, and longer in time than ΔN meaning that when ATB deteriorates, CO_2 emissions does not fall in quicker and higher quantity. However, when ATB improves, CO_2 emissions increases relatively in a lower level and takes relatively larger time for influence to be effective into validation. Moreover, since, in case of ΔP and ΔN, lag effects are different in terms of time and magnitude, the impact of ATB on CO_2 emission is asymmetric.

Likewise, the sum of coefficients associated to ΔP are significantly different than the sum related to ΔN, as in these case of the Wald test statistic reported as the Wald-S in Panel III are significant. So, each direction of assessment confirms that short-run impact of ATB on Australian CO_2

emissions is asymmetric. Now, the question is, "does this short-run asymmetric effect sustain also in the long-run?"

The long-run coefficients are reported in the Panel II of Table 1. Estimates of the L-ARDL model exhibit that Australian ATB with the rest of the world has an insignificant coefficient with negative sign meaning that a deterioration or improvement of ATB will have no impact on Australian carbon emissions level. However,, when we shift to the corresponding NL-ARDL model, we see that P has an insignificant long-run coefficient but N is significant. It means that Australian ATB improvement has adverse long-run impact on environmental pollution but deterioration of ATB has no beneficial impact on the environmental condition. This could be due to the fact that Australian carbon emission may have no association with Australian agricultural trading goods production, packaging, marketing and consumption activities. It means that ATB has asymmetric impact on Australian environmental condition. This result is further supported by the Wald test since this test reveals that the Wald-Long in Panel III is significant. It means that like short-run coefficient, the long-run coefficient of P and N are statistically different to each other. So, evidently the impact is asymmetric both in short- and long-runs.

Clearly, the results are model-specific. If we were to rely only on N-ARDL model, we would have reached in the conclusion that the ATB improvement with the rest of the world has no long-run impacts on the Australian carbon emissions. However, this NL-ARDL predicts that while ATB improvement has negative effect on emissions level, and ATB deterioration has no positive impact on Australian pollution level. Moreover, from NL-ARDL model we get an asymmetric impact by ATB on Australian pollution both in short- and Long-runs. Based on this finding we can reach the following decisions:
i. . Australian income, agro trade balance, and CO_2 emissions are highly co-integrated.
ii.. It is true that ATB is harmful for Australian environment but deterioration of ATB does not ensure significant improvement of CO_2 emissions.
3. Both linier and non-linear ARDL model for environmental pollution confirms that national income is as harmful as agricultural trade balance in case of Australia in both short- and long-run.
4. If the government wants to improve Australian environment, decrease of agro commodity imports or agro commodity import substitution strategy is not a good policy choice.
5. Perhaps agro import related economic activities are environmentally more efficient than agro export related activities in Australia.
6. Since the coefficient of the income-squared is significant with negative values,EKC notion is valid for Australia.

Oor findings supports and disagrees with the prior findings by other researchers. For example, the research outcome regarding ATB supports the findings of Fawzia *et. al.* (2012), Jebli *et. al.* (2016) and Chen *et. al.* (2019. our findings related to GDP is similar to the findings of Rahman *et. al.* (2021), Michieka *et. al.* (2013) and Wahab *et. al.* (2020). Finally, hypothesis related to EKC supports the findings of Faridul *et. al.* (2013), and Lean and Smyth (2010). However, this finding opposes the results of Romero-Ávila (2008 and Apergis and Payne (2009).

All the long-run estimates reviewed above are econometrically valid since co-integration among the variables incorporated in the models is supported by the F-test, as its statistic is significant with negative sign (Panel III). To reach in a solid conclusion we have also conducted and subsequently have reported some more required diagnostic tests in the Panel III. Lagrange Multiplier (LM) test is conducted and test statistic is also reported. As the test statistic is insignificant in our (L-ARDL & NL-ARDL) models we can claim that the error terms is free from autocorrelation. To test whether the proposed models are wrongly specified we have done Ramsey RESET test. As per the results reported, we can infer that perhaps models are correctly specified too. Another important diagnostic test is investigation of the models' stability throughout the sample period. To enquire the stability of the short- and long-run estimates we have relied upon CUSUM and CUSUMSQ tests. The results of the test are given in the Panel III. Here, 'S' and 'UNS' indicate that the estimates are 'stable' and 'unstable', respectively. It is observed that both L-ARDL and NL-ARDL estimates are 'stable' by CUSUM. Finally, the value of adjusted-R^2 indicates the robust goodness of fit of the models i.e., explanatory variables explain the most variations of the carbon emissions of Australia.

V. Conclusion

The nexus between carbon emissions and trade balance has now entered into a new climax since the world is increasingly interconnecting day by day. However, it is yet to be investigated by the researchers for the nexus of environment and agricultural trade balance (ATB). Moreover, asymmetric analysis of this relationship has been ignored by researchers. Thus, there is stark research lacuna on this issue across the literature. In this paper we attempt to fill up this research gap. With this intension, we have selected to explore Australian environment and ATB linkage for a case study as this country's agricultural sector is one of the highest exports oriented in the world with an intensively mechanized production technique. Since the existing literature does not provide anything about asymmetric analysis of this linkage, ours is the first of this kind of research. An asymmetry analysis usually needs application of a nonlinear model, and, thus, nonlinear adjustment of the ATB on environmental pollution is assumed to be the main contribution of this paper. Australia is a land abundant country and land is intensively used input in agriculture. The country has a substantial reliance on agro-based trade with the rest of the world.. To conduct this study, we have used quarterly data for the period of 1988-2021.

When we have used the linear ARDL approach of Pesaran *et al.* (2001) for modeling Australian carbon emissions level, we have found short-run support of the impact of ATB on carbon emissions of Australia with no long-run impact. However, when we have separated positive and negative changes of ATB and relied upon Shin *et. al.*'s (2014) asymmetric analysis by nonlinear ARDL approach, support for the asymmetry is found both in short- and long-runs. Estimates from the NL-ARDL model imply that response of Australian carbon emissions to agricultural trade balance is not the same during the cases of improvement and deterioration of ATB.

Precisely, the overall empirical findings of the research support the conventional theoretical guidelines of environmental economics. Australian income, agricultural trade balance, and CO_2 emissions have the long-run equilibrium relationships for the sample period. The findings also revealthat ATB is harmful for Australian environment both in short- and long-runs. However, since the deterioration of ATB has longer lagged effect on CO_2 emissions, it indicates a delayed improvement of environmental condition due to the fall of ATB. Additionally, findings also postulate that agricultural goods import related economic activities are environmentally more efficient than export related activities, and Environmental Kuznet Curve (EKC) hypothesis is empirically supported in the case of Australia.

Therefore, the policy implication is: if the government wants to improve the Australian environmental quality by agricultural commodity import substitution, the policy may not bring immediate positive results for the environment. Thus, government should concentrate on extension of environment friendly technology for the agricultural production and trade related activities not the direct control of agricultural exports and imports of Australia.

As per our perception future research should be conducted by concentrating on Australian environmental pollution with the bilateral level disaggregated trading data. if possible, by further segregated trade flows by commodity level to define how each industry responds to asymmetric effects of agro and non-agro based trade balance changes.

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