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Modeling Tourism-Environment Relationship in Australia: Does Asymmetry Matter?

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Abstract: Prior empirical studies have employed various econometric estimation techniques to study the environmental effect of tourism demand. Prominently, these econometric modeling techniques implicitly assume that the environmental effect of tourism is symmetrical, which could sometimes be problematic. This study, therefore, utilized two econometric estimation techniques, namely, the Pesaran et al. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289–326) symmetric autoregressive distributed lag (ARDL) and Shin et al. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In *Festschrift in Honor of Peter Schmidt*, pp. 281–314. New York: Springer) nonlinear ARDL (NARDL) estimation technique to disentangle the effect of tourism demand on carbon emissions in Australia. The results from the symmetric ARDL model reveal that tourism demand significantly increases carbon emissions in the long run, indicating that a 1% increase in tourism demand contributes to a 0.155% increase in carbon emissions in the long run. Contrarily, the NARDL model shows that a positive shock (an increase) in tourism demand reduces carbon emissions while a negative shock (a decrease) in tourism demand increases carbon emissions in the long run. From the NARDL estimate, a 1% increase in tourism demand is associated with a 0.220% decline in carbon emissions, while a 1% decrease in tourism demand increases carbon emissions by 0.250%. Therefore, I argue that carbon emissions depend not only on the size of tourism demand but also on the pattern — thus the increase and decline — of tourism demand. The implications of these results for policy are discussed.

JEL Classification: O13; Z32

Keywords: Australia; Asymmetric effect; Carbon Emissions; NARDL; Tourism

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1. Introduction

Since the latter half of the 20th century, tourism has become a more significant international business due to transport innovation, communication technology and the progressive deregulation and decoupling of air travel from national airlines (Walton 2018). The rapid expansion in tourism continues to contribute significantly to the global economy. Thus, tourism has generated numerous economic gains, such as serving as the source of foreign exchange, tax revenue, employment generation, international investment, and infrastructure development (Al-Mulali et al. 2015; Alam and Paramati 2016; Eyuboglu and Uzar 2019; Palmer and Riera 2003). Additionally, travel and tourism continue to significantly contribute to the global gross domestic product (GDP). For instance, travel and tourism made a total contribution of approximately $7,444 billion in 2015, $7,674 billion in 2016, $8,240 billion in 2017 and $8,810 billion in 2018 to the global economy (Lock 2020). Recently, the World Travel and Tourism Council (WTTC) (2020) research reveals that travel and tourism experienced a growth rate of 3.5% in 2019, which exceeded the global GDP growth rate of 2.5%. The WTTC (2020) research further suggests that travel and tourism contributed approximately 8.9 trillion to global GDP and generated 330 million jobs in 2019. Furthermore, it is revealed that travel and tourism resulted in 1.7 trillion exports and 948 billion capital investments in 2019 (WTTC 2020).

Despite these economic gains, tourism is argued to have a significant effect on the environment and, specifically, the evolution of carbon emissions (Akadiri et al. 2020; Akadiri, Akadiri, & Alola, 2019; Balsalobre-Lorente et al. 2020; Eyuboglu and Uzar 2019; Lenzen et al. 2018; Paramati et al. 2018). The environmental effect of tourism is *priori uncertain*. For instance, one strand of the literature argues that tourism could increase carbon emissions because it increases the demand for hospitality and transport services, economic growth and energy consumption (Akadiri et al., 2019; Eyuboglu and Uzar 2019; Gössling and Peeters

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2007; Lenzen et al. 2018). A recent study by Lenzen et al. (2018) estimated that tourism's global carbon emissions footprint has risen from 3.9 to 4.5 GtCO2e between 2009 and 2013, accounting for approximately 8% of global greenhouse gas emissions. The study further projected that given the unprecedented increase in tourism demand across the globe, tourism would contribute significantly to global carbon emissions intensity and hence climate change. The authors argue that the rapid expansion in tourism is outstripping the decarbonization of tourism-related technology. Contrarily, another strand of the literature suggests that tourism could reduce carbon emissions when it increases investment in clean technologies, renewable energy, modern transport infrastructure, water and waste management (Paramati et al. 2018; Roxas et al. 2020). Additionally, it is further contested that tourism could improve the environment (carbon emissions) when it operates within its natural capacity to regenerate the future productivity of natural resources (Bramwell and Lane 1993; Lee and Brahmasrene 2013).

Despite the role of tourism on the environment, empirical studies examining the effect of tourism on carbon emissions has not been sufficiently considered by tourism researchers (Koçak et al. 2020; Paramati et al. 2018). Also, the findings from the limited empirical studies on tourism-carbon emissions nexus have been inconsistent. For instance, the majority of these empirical studies found that tourism increases carbon emissions (see, Eyuboglu and Uzar 2019; Katircioglu et al. 2014; Paramati et al. 2016; Sharif et al. 2017; Zaman et al. 2016), while few studies revealed that tourism reduces carbon emissions (see, Dogan and Aslan 2017; Lee and Brahmasrene 2013; Paramati et al. 2018; Shakouri et al. 2017) or have an insignificant effect on carbon emissions (see, Sghaier et al. 2019). Also, there is a paucity of empirical research focusing on Australia.

Further, one of the significant limitations of these prior empirical studies is their econometric estimation techniques (for instance, see Akadiri et al., 2020; Usman et al., 2021;

Yue et al., 2021). The econometric modelling techniques[2] that have been utilized to analyze the tourism-carbon emissions relationship implicitly assume the symmetrical effect of tourism on carbon emission. In other words, the estimation techniques used to study the tourism-carbon emissions relationship overlook the effect of the asymmetric impact of tourism. Ignoring the asymmetric effect of tourism on carbon emissions could yield biased results and conclusions since positive (increase) and negative (decline) variations in tourism could have a distinct effect on carbon emissions. For instance, Lee, Olasehinde-Williams, and Ibikunle (2021) argue that the majority of the studies on the tourism-environment relationship mainly adopt conventional linear estimation techniques. However, the authors contend that tourism might exhibit a non-linear effect on the environment. In the presence of non-linearities, the environment's response to positive changes in tourism might differ from the response to negative changes (Le et al., 2021). Therefore, understanding how positive and negative changes in tourism affect carbon emission is consequential. These research gaps and methodological limitations motivate this study. Thus, to contribute to knowledge, this study aims to bridge these research gaps by comparatively analyzing the symmetric and asymmetric effect of tourism on carbon emissions in Australia.

This study focuses on Australia because tourism has been one of its fastest-growing industries. For instance, international visitors' arrivals to Australia increased from 9.4 million in 2018-19 financial year to 9.8 million in 2019-20, and it is expected to further increase to 10.3 million in 2020-21 and 125.3 million in 2028-29 (Tourism Research Australia 2019a). The increase in demand for Australia's tourism has further increased tourism investment. The Tourism Research Australia (TRA) (2019b) report suggests that Australia tourism investment grew from $1.3 billion in 2017-18 to $45.3 billion in 2018-19. Additionally, the persistent

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[2] See Table 1 for the econometric estimation techniques used in studying the effect of tourism on carbon emissions.

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inflow of tourists into Australia has contributed to numerous economic gains. For instance, Tourism Australia (2019) report suggests that tourism contributed $60.8 billion directly to Australia's GDP in the 2018-19 financial year. This represents the tourism GDP growth rate of 3.5% faster than the national GDP growth rate. The report further indicates that in the 2018-29 financial year, tourism directly employs 666,000 Australians representing 5% of Australia's workforce. Australia's tourism sector is its fourth-largest exporting industry, accounting for approximately 8.2% of its export earnings. Also, in the 2018-19 financial year, international visitors spending was 44.6 billion, making Australia one of the highest yielding destinations in the world (Tourism Australia 2019). Besides Australia's tourism demand boom and its economic contributions, the Australian government aims to reduce greenhouse gas emissions to 26-28% below the 2005 level by 2030 (Australian Government 2015). While the Australian government remains ambitious to reduce greenhouse gas emissions, the recent report by the Climate Council of Australia (2019) indicates that greenhouse gas emissions have been rising for the past four years and would make it impossible for Australia to meet the 2030 emissions reduction target. Also, the Organisation for Economic Cooperation and Development (OECD) (2018) report indicates that carbon emissions per capita have been declining recently in Australia. Still, it is 50% higher than the average OECD per capita carbon emissions, therefore, making Australia one of the highest carbon-emitting countries in the world (Acheampong and Boateng 2019). With these, examining the effect of tourism demand on carbon emissions focusing on Australia will contribute significantly to tourism-environment literature and sustainability policies.

This study contributes to the tourism-carbon emissions debate in the following ways: First, this study presents new knowledge on the environmental effect of tourism by focusing on Australia. As indicated earlier, empirical studies on the impact of tourism on carbon emissions in Australia remain scarce. However, Australia's tourism demand and carbon

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emissions have been rising; therefore, the outcome of this study will inform policymakers in designing and implementing sustainable tourism policies to mitigate carbon emissions. Second, to the best of the author's knowledge, this is the first empirical research to comparatively analyze the symmetric and asymmetric effect of tourism on carbon emissions. Because of this, this study utilized two econometric estimation techniques, namely, the Pesaran et al. (2001) symmetric autoregressive distributed lag (ARDL) and Shin et al. (2014) non-linear autoregressive distributed lag (NARDL) estimation technique to disentangle the effect of tourism demand on carbon emissions. This comparative analysis will reveal how accounting for asymmetry in econometric estimation techniques, which has been overlooked in prior studies, could change the concluding effect of tourism on carbon emissions.

Third, the literature review suggests that most empirical studies are based on panel data modelling techniques. Although estimates from panel data techniques are efficient, their conclusions and policy implications may not apply to individual countries due to their heterogeneities (Acheampong 2018; Coggin 2019). This study further adds to the body of knowledge by utilizing time-series approaches to analyze the effect of tourism on carbon emissions to provide policy guidelines to Australia. Lastly, this study adds to the literature by investigating the environmental impact of tourism within the Stochastic Impacts by Regression on Population, Affluence, and Technology (*STIRPAT*) framework, which controls for affluence, population, energy consumption and urbanization. The rest of the paper is outlined as follows. Section 2 provides a conceptual and empirical literature review. The theoretical model, data and econometric estimation approaches are discussed in Section 3. Section 4 presents the empirical results, while Section 5 summarises the study's concluding remarks and policy implications.

2. Tourism demand and carbon emissions: Conceptual and empirical evidence

Tourism is an activity that involves travelling and enjoying natural and human-made sceneries away from home. In other words, "*tourism is the act and process of spending time away from home in pursuit of recreation, relaxation and pleasure while making use of commercial services*" (Walton 2018). Over the years, the environmental externalities of tourism have become a major concern to researchers and policymakers in both developed and developing countries. Tourism has a critical effect on the environment since its development depends on transport infrastructures, telecommunications, building infrastructures, resorts, and restaurants (Lee and Brahmasrene 2013; Walton 2018). The environmental effect of tourism demand is theoretically ambiguous. Fig.1 summarises the mechanisms/channels through which tourism demand could affect the environment, specifically carbon emissions.

As indicated in Fig. 1, the demand for transport services remains one of the leading channels of tourism affecting carbon emissions. The use of transportation services for carrying tourism activities to and from and within a country increases energy consumption (Scott et al., 2010). Thus, as energy for fuelling transportation to carry out tourism activities are mostly fossil energy, it increases carbon emissions. For instance, the International Energy Agency (IEA) (2019) report revealed that transportation is responsible for 24% of direct carbon emissions from fuel combustion. Especially, road transportation accounts for nearly three-quarters of transport, whereas energy-related carbon emissions with emissions from aviation and shipping continue to rise (IEA, 2019).

Additionally, tourism demand could also affect the environment via economic growth and energy consumption. Tourism is noted for serving as the source of foreign exchange, tax revenue, employment generation, international investment, and infrastructure development (Akadiri, Alola, & Akadiri, 2019; Roudi, Arasli, & Akadiri, 2019; Al-Mulali et al. 2015; Alam

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and Paramati 2016; Eyuboglu and Uzar 2019; Palmer and Riera 2003). These benefits of tourism directly contribute to economic growth and energy consumption, thereby impacting CO_2 emissions. When tourism boosts economic growth, it could either increase or decrease carbon emissions. According to the Environmental Kuznets Curve (EKC) hypothesis, higher economic growth is associated with improvement in environmental quality (Acheampong 2019; Grossman and Krueger 1995). Therefore, when tourism-led growth enables structural change towards the development of the services sector coupled with the transfer and development of green technologies and enforcement of stringent environmental regulations, it could reduce carbon emissions. Contrarily, when tourism-led growth leads to more production and consumption activities without strict environmental regulations, it could worsen carbon emissions. In addition, it is contested that aggregate domestic consumption spending contributes significantly to carbon emissions (Ahmad & Khattak, 2020). Theoretically, tourism demand, considered an export, could cause an expansion in aggregate domestic consumption spending. Therefore, a surge in aggregate domestic consumption spending due to tourism could lead to residential and non-residential energy consumption, leading to higher carbon emissions. Besides, the role of tourism in ensuring infrastructure development and international investment could result in land-use changes such as increasing deforestation, thereby increasing carbon emissions (Al-Mulali et al. 2015; Koçak et al. 2020; Sharif et al. 2017). Contrarily, Paramati et al. (2018) posit that tourism could improve the quality of the environment when it leads to investment in renewable energy, modern transport infrastructure, water and waste management.

[***INSERT FIGURE 1 HERE***]

Furthermore, tourism contributes to the hospitality and entertainment industries (Sharif et al., 2017). The development of the hospitality sector and entertainment venues contribute to

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higher energy use and economic growth, thereby inducing CO_2 emissions. The International Tourism Partnership (ITP) (2017) reports suggest that the hospitality (hotel) industry contributes approximately 1% to global carbon emissions, and it is expected to increase as the industry keeps growing. The report further highlighted that to achieve the target of the Paris climate change agreement on carbon emissions reduction, the hotel industry needs to reduce carbon emissions per room by 66% from the 2010 levels by 2030 and 90% by 2050. Additionally, the entertainment industry has been contributing to carbon emissions. According to the British film organization, a television programme produced in a single hour in the UK generated approximately 13 metric tons of CO_2 emissions. At the same time, another study reveals that the California entertainment industry generated about 8.4 million metric tons of CO_2 while the USA entertainment industry produced 15 million tons of CO_2 emissions[3]. Besides, the hospitality and entertainment industries generate massive waste and, more importantly, food waste (Filimonau and De Coteau 2019; Pirani and Arafat 2016). The rising generation of food waste and disposing of these wastes has a detrimental effect on the environment by increasing greenhouse gas emissions (Filimonau and De Coteau 2019; Pirani and Arafat 2016). It is also contested that food waste is energy wasted. For instance, Cuéllar and Webber (2010) reveal that 1870-2190 trillion BTU of energy were embedded in wastes food in the USA in 2007 and this embedded energy in the wasted food represented about 2% of annual energy consumption in the USA. These estimates reinforce the idea that food waste generated in the hospitality industry could increase energy consumption, thereby increasing carbon emissions.

While there is no clear-cut theoretical effect of tourism on the environment (carbon emissions), the results from previous empirical studies using various econometric estimation techniques are also still conflicting and inconclusive. As summarized in Table 1, some of the

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[3] https://www.vice.com/en_au/article/3kxjvk/behind-every-film-production-is-a-mess-of-environmental-wreckage

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empirical studies report that the effect of tourism on carbon emissions is positive, negative and insignificant. Unarguably, the econometric estimation techniques used by the existing empirical research implicitly assume that the impact of tourism on carbon emissions is symmetrical. The symmetric assumption of these studies raises a critical concern. Thus, the failure of these studies to consider the asymmetric effect when examining the effect of tourism demand on carbon emissions could yield biased results and conclusions. This study argues that the effect of tourism demand on CO_2 emissions could be asymmetrical such that a positive and negative change (shock) in tourism could have a distinct effect on CO_2 emissions. Because of the methodological weakness of previous research, this paper demonstrates how accounting for asymmetry in econometric estimation techniques could change the concluding effect of tourism on the environment. Therefore, to contribute to the literature, this study comparatively analyses the symmetric and asymmetric effect of tourism on carbon emissions in Australia.

[***INSERT TABLE 1 HERE***]

3. Methodology and Data

3.2. Model setting

Similar to the work of Paramati et al. (2016), this study investigates the impact of tourism on carbon emissions with the Dietz and Rosa (1994) Stochastic Impacts by Regression on Population, Affluence, and Technology (*STIRPAT*) framework. This study adopted the STIRPAT model because of its flexibility and the fundamental model for undertaking empirical research on the determinants of environmental pollution (carbon emissions). Previously, most studies on the determinant of environmental pollution were based on the Ehrlich and Holdren (1971) *IPAT* framework, which is expressed as:

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$$I = P \times A \times T \tag{1}$$

where *I* is environmental pollution (carbon emissions) which is influenced by Population (*P*), Affluence (*A*) and Technology (*T*). In extending the *IPAT* model, Dietz and Rosa (1994) formulated the *STIRPAT* model, which can empirically test a hypothesis. *T* represents technology. Therefore, following previous studies, energy consumption, urbanization, and tourism capture technology in the *STIRPAT* model (Dzator and Acheampong 2020; Paramati et al. 2018; Poumanyvong and Kaneko 2010; Sadorsky 2014). Therefore, using the *STIRPAT* model, the carbon emissions function is expressed as follows:

$$CO_{2t} = f(P_t,\ A_t,\ ENER_t, URB_t, TOUR_t) \tag{2}$$

Where carbon emissions (CO_2) is a function of population (*P*), affluence[4] (*A*), energy consumption (*ENER*), urbanization (*URB*) and tourism (*TOUR*). The log-linear form of the equation used to estimate the empirical model is given in Eq. (3).

$$\begin{aligned} ln\mathrm{CO2}_{it} = {} & \alpha_0 + \beta_1 lnP_t + \beta_2 lnA_t + \beta_3 lnENER_t + \beta_4 lnURB_t + \beta_5 lnTOUR_t \\ & + \mu_t \end{aligned} \tag{3}$$

The econometric estimation techniques utilized to estimate the empirical models are discussed in the proceeding pages.

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[4] The affluence variable in the STIRPAT model captures income. In the existing literature, various scholars such as Dzator et al. (2020), Paramati et al. (2018); Poumanyvong and Kaneko (2010) and Sadorsky (2014) have used economic growth (gross domestic product variables) to capture affluence in the STIRPAT model.

3.3. Econometric estimation approach

3.3.1 Symmetric ARDL model specification

This study employed the Pesaran et al. (2001) ARDL co-integration approach to provide an empirical analysis of the long-run and short-run symmetric effects of tourism demand on CO_2 emissions. The Pesaran et al. (2001) ARDL co-integration approach is important since it can be applied if variables are stationary at levels I(0), the first difference I(1) or both [a mixture of I(0) and I(1)]. It can also estimate the short-run and long-run relationships between the variables. However, one of the major limitations of the Pesaran et al. (2001) ARDL model is its inability to account for the asymmetric and non-linear co-integration between the variables under consideration. The empirical ARDL model for estimating the long-run and short-run symmetric effect of tourism on carbon emissions is specified in the unrestricted Error Correction Model (ECM) below:

$$\begin{aligned} \Delta lnCO_{2t} = \delta_0 &+ \sum_{i=1}^{P} \alpha_1 \, \Delta lnCO_{2t-i} + \sum_{i=1}^{q} \alpha_2 \, \Delta lnP_{t-1} + \sum_{i=1}^{q} \alpha_3 \, \Delta lnA_{t-1} + \sum_{i=1}^{q} \alpha_4 \, \Delta lnENER_{t-1} \\ &+ \sum_{i=1}^{q} \alpha_5 \, \Delta lnURB_{t-1} + \sum_{i=1}^{q} \alpha_6 \, \Delta lnTOUR_{t-1} + \beta_1 lnP_{t-1} + \beta_2 lnA_{t-1} \\ &+ \beta_3 lnENER_{t-1} + \beta_4 lnURB_{t-1} + \beta_5 lnTOUR_{t-1} \\ &+ \mu_t \qquad (4) \end{aligned}$$

Where Δ is the difference operator, δ_0 indicate constant parameter, μ_t is the error term, p represents the lag of the dependent variable, while q shows the lag of the independent variables. $\alpha_1 - \alpha_5$ shows the short-run coefficients to be estimated while $\beta_1 - \beta_4$ represents the long-run coefficients to be estimated. The *F*-statistics is used to determine the long-run co-integration between the variables. The null hypothesis states that there is no co-integration ($\beta_1 = \beta_2 =$

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$\beta_3 = \beta_4 = \beta_5$) among the variables while the alternative hypothesis suggests that there is co-integration ($\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5$) among the variables. If the *F*-statistics is above the upper critical values, the null hypothesis is rejected, and the alternative hypothesis is accepted. Contrarily, if the *F*-statistics is below the lower critical values, the null hypothesis is accepted, and the alternative hypothesis is rejected. Inference becomes inconclusive if the *F*-statistics lies between the lower and upper bounds of the critical values.

The Error Correction Model (ECM) specified in Eq. (5) is used to estimate the short-run relationships if long-run co-integration exists among the independent covariates.

$$\Delta lnCO2_t = \delta_0 + \sum_{i=1}^{P} a_1\,\Delta lnCO2_{t-i} + \sum_{i=1}^{q} a_2\,\Delta lnP_{t-1} + \sum_{i=1}^{q} a_3\,\Delta lnA_{t-1} + \sum_{i=1}^{q} a_4\,\Delta lnENER_{t-1} + \sum_{i=1}^{q} a_5\,\Delta lnURB_{t-1} + \sum_{i=1}^{q} a_6\,\Delta lnTOUR_{t-1} + a_7 ECT_{t-1} + \mu_t \qquad (5)$$

Where, a_7 denotes the estimate for the error correction term ECT_{t-1}, which indicates the speed of adjustment of the short-run to the long-run equilibrium path. Theoretically, the coefficient of the ECT_{t-1} must be less than one (1) in magnitude, statistically significant and negative.

3.3.2 Asymmetric ARDL model specification

Additionally, to examine the asymmetric effect of tourism on carbon emissions, this study utilizes the Shin et al. (2014) multivariate non-linear autoregressive distributed lag (NARDL) bound testing approach. The NARDL is essential for this study since it can account for the asymmetric and non-linear co-integration between the variables under consideration. The NARDL can also differentiate between the short-run and long-run impact of globalization variables and other variables such as affluence/economic growth, energy consumption, population and urbanization on CO_2 emissions. The NARDL also produce robust estimates even when variables

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are integrated at different combination of orders (Ahmad, Khattak, Khan, & Rahman, 2020; Rahman, & Ahmad, 2019; Shahbaz et al. 2017b). Additionally, the NARDL model does not suffer from convergence problems compared to other non-linear models like the smooth transition model (Shahbaz et al., 2017b). Also, Shin et al. (2014) argued that the NARDL prevents multicollinearity among independent variables since it chooses the appropriate lag order for the variables. The NARDL also helps differentiate between non-linear and linear co-integration (Ur Rahman, Chongbo & Ahmad, 2019). Also, as indicated by Ur Rahman et al. (2019), the NARDL enables the testing for hidden co-integration.

To examine the asymmetric effect of tourism on carbon emissions, we re-specify Eq. (3) to have an empirical asymmetric model as presented in Eq. (6). Thus, following Shin et al. (2014), we specify the empirical NARDL asymmetric error correction model as follows:

$$\begin{aligned}\Delta lnCO2_t = {} & \alpha_0 + \gamma lnCO2_{t-1} + {\beta_1}^{+} lnA^{+}_{t-1} + {\beta_2}^{-} lnA^{-}_{t-1} + {\beta_3}^{+} lnP^{+}_{t-1} + {\beta_4}^{-} lnP^{-}_{t-1} \\ & + {\beta_5}^{+} lnENER^{+}_{t-1} + {\beta_6}^{-} lnENER^{-}_{t-1} + {\beta_7}^{+} lnURB^{+}_{t-1} + {\beta_8}^{-} lnURB^{-}_{t-1} \\ & + {\beta_9}^{+} lnTOUR^{+}_{t-1} + {\beta_{10}}^{-} lnTOUR^{-}_{t-1} + \sum_{i=1}^{P} \alpha_1 \Delta lnCO2_{t-i} + \sum_{i=1}^{q} \alpha_2 \Delta lnA^{+}_{t-i} \\ & + \sum_{i=1}^{q} \alpha_3 \Delta lnA^{-}_{t-i} + \sum_{i=1}^{q} \alpha_4 \Delta lnP^{+}_{t-i} + \sum_{i=1}^{q} \alpha_5 \Delta lnP^{-}_{t-i} + \sum_{i=1}^{q} \alpha_6 \Delta lnENER^{+}_{t-i} \\ & + \sum_{i=1}^{q} \alpha_7 \Delta lnENER^{-}_{t-i} + \sum_{i=1}^{q} \alpha_8 \Delta lnURB^{+}_{t-i} + \sum_{i=1}^{q} \alpha_9 \Delta lnURB^{-}_{t-i} \\ & + \sum_{i=1}^{q} \alpha_{10} \Delta lnTOUR^{+}_{t-i} + \sum_{i=1}^{q} \alpha_{11} \Delta lnTOUR^{-}_{t-i} \\ & + \mu_t \qquad (6)\end{aligned}$$

From Eq. (6), α_i denotes the short-run coefficients to be estimated, whereas β_i represents the estimates for long-run relationships, with $i = 1 \ldots 9$. The short-run analysis provides the immediate impact of the changes in the exogenous variable (in the case of this study population, affluence, energy consumption, urbanization, and tourism demand) on the outcome variable (in this study, CO_2 emissions). On the other hand, the reaction time and speed of adjustment towards an equilibrium level are identified using the long-run analysis (Shahbaz et al. 2017b; Shahbaz et al. 2016). The Wald test is applied to check the short-run ($\alpha = \alpha^+ = \alpha^-$) and the long-run asymmetry ($\beta = \beta^+ = \beta^-$) for all the variables. $lnCO2_t$ represents the natural logarithm of carbon emissions; lnA_t represents the natural logarithm of affluence/economic growth; lnP_t represents the natural logarithm of population; $lnENER_t$ denotes the natural logarithm of energy consumption; $lnURB_t$ denotes urbanization and $lnTOUR_t$ represents the natural logarithm of tourism demand. The Akaike information criterion is used to determine the optimal lags for the dependent variable ($lnCO2_t$) and independent variables ($lnA_t, lnP_t, lnENER_t, lnURB_t, lnTOUR_t$) are represented with p and q respectively.

The effect of the independent variables ($lnA_t, lnP_t, lnENER_t, lnURB_t, lnTOUR_t$) on the outcome variable ($CO2_t$) are disaggregated into their respective positive and negative partial sums for the increase and decrease, which is expressed as:

$$X_t^+ = \sum_{j=1}^{t} \Delta X_j^+ = \sum_{j=1}^{t} \max\left(\Delta X_j, 0\right) \; and \; X_t^- = \sum_{j=1}^{t} \Delta X_j^- = \sum_{j=1}^{t} \min\left(\Delta X_j, 0\right) \qquad (7)$$

Where $X_t \; respresents \; lnA_t, lnP_t, lnENER_t, \; lnURB_t \; and \; TOUR_t$

Shin et al. (2014) propose the bound test, which is a joint test of all the lagged levels of the independent variables, to test the asymmetric long run co-integration. Two main tests are used: the Banerjee et al. (1998) t-statistics and the Pesaran et al. (2001) F-statistics. The null hypothesis of the t-statistics test is $\beta = 0$ as against the alternative hypothesis of $\beta < 0$. Also, the null hypothesis of the F-statistics test is $\beta^+ = \beta^- = \beta = 0$. Both t-statistics and F-statistics

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are utilized in this study. If the null hypothesis is rejected, it implies no long-run co-integration among the variables.

In this study, the long-run asymmetric coefficients of the regressors are estimated based on $L_{mi^+} = {}^{\beta^+}\!/_{\gamma}$ and $L_{mi^-} = {}^{\beta^-}\!/_{\gamma}$. The long-run estimated coefficients measure the long-run equilibrium relationship between the variables concerning the positive and negative changes. Eq. (8) is followed to assess the asymmetric dynamic multiplier effects. The dynamic multipliers indicate the asymmetric responses of the dependent variables to positive and negative changes in the regressors.

$$\begin{aligned} m_h^+ &= \sum_{j=0}^{h} \frac{\partial lnCO2_{t+j}}{\partial lnA_t^+}, m_h^- = \sum_{j=0}^{h} \frac{\partial lnCO2_{t+j}}{\partial lnA_t^-}, m_h^+ = \sum_{j=0}^{h} \frac{\partial lnCO2_{t+j}}{\partial lnP_t^+}, m_h^- \\ &= \sum_{j=0}^{h} \frac{\partial lnCO2_{t+j}}{\partial lnP_t^-}, m_h^+ = \sum_{j=0}^{h} \frac{\partial lnCO2_{t+j}}{\partial lnENER_t^+}, m_h^- = \sum_{j=0}^{h} \frac{\partial lnCO2_{t+j}}{\partial lnENER_t^-}, m_h^+ \\ &= \sum_{j=0}^{h} \frac{\partial lnCO2_{t+j}}{\partial lnURB_t^+}, m_h^- = \sum_{j=0}^{h} \frac{\partial lnCO2_{t+j}}{\partial lnURB_t^-}, m_h^+ = \sum_{j=0}^{h} \frac{\partial lnCO2_{t+j}}{\partial lnTOUR_t^+}, m_h^- \\ &= \sum_{j=0}^{h} \frac{\partial lnCO2_{t+j}}{\partial lnTOUR_t^-} \qquad (8) \end{aligned}$$

For $h = 0, 1, 2, 3 \ldots\ldots$ Where, if $h \to \infty$ then $m_h^+ \to L_{mi^+}$ and $m_h^- \to L_{mi^-}$.

The estimated multipliers help to understand the dynamic adjustments from the initial equilibrium to a new equilibrium among the variables within the system following a change that impact the system.

3.4. Nature of Data

This section describes the variables used in this study. The dataset for this study ranges between the period 1995-2017. To have higher frequency data, this study follows some of the

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important existing empirical studies such as Acheampong and Boateng (2019), Sbia, Shahbaz, & Hamdi (2014), Shahbaz, Shahzad, Ahmad and Alam (2016) and Shahbaz et al. (2017b) to employ the quadratic-sum approach to convert the yearly data into quarterly data. Using the quadratic-match sum approach to convert the data from low-frequency to high-frequency data increases the accuracy of the empirical findings (Acheampong and Boateng, 2019; Shahbaz et al., 2017b). For variables measurements, this study follows Abid (2017), Apergis and Ozturk (2015), Acheampong (2018) to use CO_2 emissions (kg per 2010 US$ of GDP) as a measure for carbon emissions (CO_2) while affluence (A) was measured using GDP growth (annual %). Population (P) and energy consumption ($ENER$) was measured using population growth (annual %) and energy use (kg of oil equivalent per capita), respectively. Urbanization (URB) was measured using urban population growth (annual %). Following Koçak et al. (2020), Paramati et al. (2017) and Paramati et al. (2016), international tourism receipts was used as the proxy for tourism demand ($TOUR$). These variables are transformed into natural their natural logarithm, except economic growth. The raw data for these variables are presented in Appendix Fig.1. These variables were obtained from the World Bank (2019) WDI database.

[***INSERT TABLE 2 HERE***]

From the descriptive statistics, CO_2 emissions have a negative mean of 1.021%. Affluence/economic growth and population have an average growth rate of 3.253% and 0.303%, respectively. Energy consumption has a higher mean of 8.628%, and urbanization has an average growth of 16.691%. The mean for tourism demand is 23.729%. Additionally, carbon emissions, tourism demand, population and energy consumption are skewed to the left, while economic growth and urbanization are skewed to the right. Similarly, Jarque-Bera statistics indicate that tourism demand, urbanization and population are not normally distributed.

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4. Results and Discussions

4.1. Stationarity test

Before estimating the empirical models, the stationarity properties of the variables were tested. Both Pesaran et al. (2001) ARDL and Shin et al. (2014) NARDL model requires that variables are stationary/integrated at levels I(0) or first different I(1) or both [a mixture of I(0) and I(1)] to probe the long-run relationship (co-integration) between the variables. In regards, the Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) tests were utilized to investigate the stationarity of the variables. From Table 3, both ADF and PP tests indicate that *A* and *P* are stationarity at levels while CO_2, *ENER, URB* and *TOUR* are non-stationary at levels. However, at the first difference, both tests indicate that all the series are stationary or integrated at $I(1)$.

[***INSERT TABLE 3 HERE***]

In addition to the above unit root tests, the Zivot-Andrew (2002) unit root test is further utilized to test for structural breaks in the variables. From Table 4, Zivot-Andrew (2002) suggests that the null hypothesis of unit root is rejected for carbon emissions, population, energy consumption and tourism demand, while the null hypothesis is not rejected for affluence and urbanization. From the Zivot-Andrew tests, the break date for carbon emissions is 2012Q1; affluence is 2000Q3; population is 2008Q4; energy consumption is 2006Q4; urbanization is 2001Q4, and tourism demand is 2006Q2. These break dates indicate the importance of policies and other shocks that might have changed these variables. The 2012Q1 break in carbon emissions could be attributed to the policies implemented by the Australian government to cut down greenhouse gas emissions to 26-28% by 2030. It must be noted that Australia outperformed its Kyoto Protocol first commitment period target between 2008-2012 (Australian Government, 2015). Also, the late 1980s and early 1990s economic reforms in various sectors such as telecommunication, energy and transport infrastructures affected the

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country's economic growth and energy consumption in the early 2000s (Kirchner 2018; Sims, 2013). Also, given that immigration was seen as closely related to the country's economic growth, the Australian migration programme resulted in the highest visa granted for the 2008-2009 period, thereby resulting in (Spinks, 2010). The migration programme increased the Net Overseas Migration (NOM) in 2008[5], influencing the 2008Q4 break in Australia population growth. Besides, the 2006Q2 break in tourism demand could be attributed to the decline in the number of visitors from New Zealand in 2006. Other shocks such as the 9-11 terrorist attacks, Bali bombings, and the SARS epidemic that caused a decline in international tourist arrivals in 2002-2003 may have also impacted the 2006 break[6]. The presence of a significant structural break in some of the variables and, more importantly, in tourism demand reinforces the need to comparatively investigate the symmetric and asymmetric effect of tourism demand on CO_2 emissions in Australia.

[***INSERT TABLE 4 HERE***]

4.2. Symmetric ARDL Results

Testing the co-integration relationship among the variables is critical to estimating the short-run and long-run relationships. Table 4 shows the results for co-integration among the variables. From Table 5, the ARDL bound tests reveal that there is co-integration among the variables. Thus, the *F*-statistics (6.840) exceeds the upper bound of the critical values. I estimate the long-run and short-run relationships among the variables since there is evidence of co-integration. Note that the estimated coefficients from the models are reported in natural logarithms.

The results from Pesaran et al. (2001) ARDL model are presented in Table 6. From Table 6, Panel A gives the long-run estimates, while Panel B shows the short-run estimates.

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[5] https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook44p/AustPopulation

[6] aph.gov.au/.../services/report/chapter4.pdf&_sm_au_=iVVSZsVNJVQ4Dnvv

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From Panel A of Table 6, the results indicate that tourism demand significantly increases CO_2 emissions. Thus, a percentage increase in tourism demand is associated with a 0.155% increase in CO_2 emissions in Australia. The implication is that increasing tourist arrival in Australia spurs carbon emissions, and this finding confirms the results of previous studies that found that tourism increases carbon emissions (Eluwole et al.,2020; Eyuboglu and Uzar 2019; Nepal et al. 2019; Sharif et al., 2017; Solarin 2014; Uzuner, Akadiri, & Lasisi, 2020).

The result also suggests that affluence (economic growth) has a significant negative effect on CO_2 emissions in the long run, and the estimated coefficient is -0.022%. The implication is that Australia's robust economic growth contributes to a reduction in carbon emissions. The negative effect of economic growth on carbon emissions reflects the Australian government's commitment to decouple the economy from the environment. The Australian government has implemented several climate change strategies to boost economic activities while reducing carbon emissions. Some of these policies measures include strategies to enhance the utilization of solar power, developing a low emissions technology roadmap, phasing down hydrofluorocarbons, and a national energy productivity plan[7]. Thus, Australia's economic growth is not carbon-intensive, which confirms the results of Acheampong (2018) and Shahbaz et al. (2017a).

Additionally, the ARDL results suggest that population and energy consumption have significant a positive effect on carbon emissions in the long run. Thus, a 1% increase in population and energy use spurs CO_2 emissions by 0.061% and 0.969%, respectively. This outcome implies that a rise in population and energy consumption is associated with higher carbon emissions, and this result agrees with the findings of previous studies, which revealed that population and energy consumption induce higher carbon emissions (see, Acheampong

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[7] https://www.environment.gov.au/system/files/resources/f52d7587-8103-49a3-aeb6-651885fa6095/files/summary-australias-2030-emissions-reduction-target.pdf

2019; Acheampong et al. 2019; Acheampong and Dzator 2020; Shahbaz et al. 2017a). The result also suggests that urbanization significantly reduces CO_2 emissions. Thus, a 1% increase in urbanization reduces CO_2 emissions by 2.555%. Thus, with Australia higher economic development, an increase in urbanization is associated with environmental regulation, technological progress and structural change that contribute to reducing CO_2 emissions, and this is consistent with the argument the ecological modernization theory and empirical results of Acheampong (2019), Acheampong, Amponsah and Boateng (2020) and Poumanyvong and Kaneko (2010).

[***INSERT TABLE 5 HERE***]

Panel B of Table 6 indicates that tourism demand contributes significantly to carbon emissions reduction in the short run. Thus, like the long-run results, increasing tourist arrival in Australia induce higher carbon emissions. Also, the estimates suggest that economic growth and energy consumption generate higher CO_2 emissions. The implication is that increasing economic growth and energy use increases carbon emissions in the short run. In the same vein, Németh-Durkó (2021) confirmed that economic growth and energy consumption increase CO_2 emissions in the short run in European emerging economies. It further observed that population significantly increases carbon emissions at the current period (lag 0), while it significantly reduces carbon emissions in the previous period (lag 1). However, the cumulative effect suggests that a higher increasing population generates more carbon emissions in the short run. This result contradicts Shahbaz et al. (2017a) result, which indicated that population has an inverse relationship with carbon emissions in Australia in the short run. Also, the estimate shows that increasing urbanization (at lag 0) substantially reduces carbon emissions, while urbanization (at lag 2 and 3) significantly increases carbon emissions. However, the cumulative effect suggests that urbanization increases carbon emissions in the short run. This result is inconsistent with Lee et al. (2021) results, which indicated that urbanization has a neutral effect on CO_2 emissions in the short run. The estimates for ECT_{t-1} is negative and statistically significant with the speed of adjustment of carbon emissions of 8%. The significant and negative sign of the error correction term further confirms the co-integration among the variables. It could be observed from Table 6 that the long-run coefficients are relatively larger than the short-run coefficients.

[***INSERT TABLE 6 HERE***]

4.3. Asymmetric ARDL Results

With the asymmetric limitation of the Pesaran et al. (2001) ARDL, this section discusses results from the Shin et al. (2014) NARDL model. Thus, asymmetric co-integration, short-run and long-run estimates and asymmetric dynamic multiplier effects results are discussed. To estimate the Shin et al. (2014) NARDL model, I test the asymmetric co-integration among the variables. From Table 7, the *F*-statistics (*F_PSS*) indicates an asymmetric co-integration relationship among *CO_2, P, A, ENER, URB and TOUR*. At the same time, the t-statistics (*T_BDM*) also confirms co-integration among the variables. These results support the need to account for asymmetry when empirically probing the relationship between carbon emissions, economic growth, population, energy consumption, urbanization and tourism demand. For easy interpretation, a positive change/shock in affluence, population, energy consumption, urbanization and tourism demand represent an increase, while negative changes/shocks indicate a decrease.

From Table 7, the asymmetric ARDL results indicate that a positive shock in tourism demand significantly reduces carbon emissions while a negative shock in tourism demand significantly increases carbon emissions. Thus, unlike the symmetric ARDL results, which reveal that tourism symmetrically increases carbon emissions, the asymmetric ARDL suggest that a positive shock (an increase) in tourism demand reduces carbon emissions while a negative shock (a decrease) in tourism demand increases carbon emissions. Thus, from the asymmetric ARDL results, a percentage increase in tourism demand is associated with a 0.220% decline in carbon emissions, while a 1% decline in tourism demand increases CO_2 emissions by 0.250% in the long run. In terms of economic significance, it could be observed that the impact (magnitude of the estimate) of the negative shock in tourism demand dominate that of the positive shock. Technically, the observed symmetric results could be attributed to the negative shock in tourism demand dominating the positive shock. Therefore, it could be misleading to conclude from the symmetric ARDL results that tourism demand increases carbon emissions. This result is consistent with Lee et al. (2021) results which indicated that a positive shock to tourism reduces carbon emissions while a negative shock to tourism increases carbon emissions in China. Furthermore, this empirical result aligns with Chishti, Ullah, Ozturk and Usman (2020) findings which highlighted that positive shock to tourism shock reduces carbon emissions in Nepal and Sri Lanka while a negative shock to tourism spurs carbon emissions in South Asia but is inconsistent with their results for Bangladesh, India, and Pakistan.

The positive shock in tourism resulting in reducing CO_2 emissions could be attributed to the pragmatic strategies and policies that Australian central and state governments have over the years implemented to make the tourism sector environmentally sustainable. For instance, like any other Australian state, the 2009-2012 Environmentally Sustainable Tourism Strategic Plan (ESTSP) of the Victoria state sought to promote environmentally sustainable tourism practices by encouraging businesses to adopt more sustainable practices to reduce the tourism industry's carbon footprint (Victoria Tourism, n.d). The actions plans of the ESTSP includes promoting business that demonstrates environmental credentials through accreditation programmes; developing and implementing a carbon footprint toolkit for use by tourism business and destination; preparing guidelines notes for events' organizers on carbon footprint measurement and reduction strategies, and the integration of the tourism sector to the “Grow me the Money” and “Carbon Down’ programmes (Victoria Tourism, n.d). These action plans implemented at the national and state level have enabled the growing tourism sector to mitigate carbon emissions.

On the other hand, the adverse effect of the negative shock in tourism on CO_2 emissions suggests that policies that impede the tourism sector development could further worsen carbon emissions. Thus, given the role of the tourism industry in the development of innovations (R&D), policies that are inimical to the development of the tourism industry could also stifle competition and R&D development, thereby worsening carbon emissions. On the other hand, policymakers sometimes implement less stringent environmental policies to regulate the less-developed tourism industry. Therefore, implementing such less strict environmental regulations could make the tourism industry adopt unfriendly environmental practices, resulting in higher carbon emissions.

The results further indicate that a positive shock in affluence is associated with increased CO_2 emissions but is statistically insignificant. Contrarily, a negative shock in affluence significantly reduces CO_2 emissions. Thus, limiting economic growth is associated with lower carbon emissions. Also, the results show that in the long run, a positive and negative shock in the population exerts an insignificant negative effect on carbon emissions. Thus, when asymmetry is considered, population plays an insignificant role in carbon emissions, and this result contradicts Shahbaz et al. (2017a) findings that population increases carbon emissions in Australia. In contrast, a positive and negative shock in energy consumption is associated with a significant increase in CO_2 emissions. Thus, energy consumption induces higher CO_2 emissions. This result is expected since Australia’s total energy mix is dominated by fossil energy (coal) used for electricity generation. The policy implication is that reducing energy consumption by increasing the share of renewable energy use and generating electricity from a renewable energy source such as solar, wind, etc., is imperative for reducing carbon emissions. This result confirms Shahbaz et al. (2017a) finding for Australia. Also, from Table 7, a positive shock in urbanization significantly increases CO_2 emissions, while a negative shock in urbanization significantly reduces CO_2 emissions in the long run. Thus, when asymmetric is considered, Australia's higher urbanization is associated with higher carbon emissions and vice versa. Australia has experienced rapid urbanization associated with traffic congestion, overcrowding, energy consumption, and higher CO_2 emissions. This result differs from Acheampong (2019), Acheampong, Amponsah and Boateng (2020) and Poumanyvong and Kaneko (2010) findings when I account for asymmetry.

[***INSERT TABLE 7 HERE***]

From Table 7, the short-run estimates suggest that a positive shock in tourism demand (at lag 0) significantly reduces CO_2 emissions, while a positive shock in tourism demand (at lag 1) significantly increase CO_2 emissions. The estimates also suggest that a negative shock in tourism demand (at lag 0-3) significantly reduces CO_2 emissions. Also, a positive shock in affluence (at lag 0-3) increases CO_2 emissions, but the impact is significant at lag 2 and 3. Additionally, a negative shock in affluence (at lag 0-3) significantly contributes to an increment in CO_2 emissions in the short run. It is observed from Table 6 that a positive and negative shock in the population has a negligible effect on CO_2 emissions. A positive shock in energy consumption (at lag 0) significantly increases CO_2 emissions, while a positive shock in energy consumption (at lag 2 and 3) significantly reduces CO_2 emissions. Additionally, a negative shock in energy consumption (at lag 0-4) contribute significantly to CO_2 emissions reduction in the short run. A positive shock in urbanization (at lag 3) significantly increases CO_2 emissions, while negative shock in urbanization (at lag 0) negatively affects CO_2 emissions.

4.3.1 Asymmetric dynamic multiplier effects

Eq. (8) shows the asymmetric dynamic multiplier effects of affluence, population, energy consumption, urbanization, and tourism demand. These multipliers indicate the asymmetric and symmetric adjustment of CO_2 emissions to its new long-run equilibrium following positive and negative unitary variations of affluence, population, energy consumption, urbanization, and tourism demand. The positive and negative changes curves indicate the adjustment of CO_2 emissions to unitary positive and negative variations of the variables above at a given forecast horizon. The broken red lines denote a negative change, while the broken green lines indicate a positive change. The continuous blue line denotes the asymmetric curve, representing the symmetric combination of positive and negative changes of the variables under consideration. The lower and upper bands for the asymmetry (continuous blue line) with 95% confidence intervals are also displayed.

Fig. 2 confirms the existence of an overall negative effect of tourism demand on CO_2 emissions. There is an overall positive effect of affluence on CO_2 emissions. The positive shock in affluence dominates the negative shock. Similarly, an overall positive relationship exists between urbanization and CO_2 emissions. Thus, a negative shock in urbanization is found to dominate the positive shock. Energy consumption has an overall negative effect on CO_2 emissions. The impact of the negative shock in energy consumption exceeds that of the positive shock. Also, there is an overall negative association between population and CO_2 emissions, which confirms that the impact of the positive shock in population dominates that of the negative shock.

[***INSERT FIGURE 2 HERE***]

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5. Conclusions, Policy Implications and Direction for Future Research

The environmental externalities associated with tourism demand has become a relevant policy concern. Theoretically, the effect of tourism demand on the environment is ambiguous. Additionally, the findings from prior empirical studies are still inconclusive. Although previous empirical research on the environmental impact of tourism has contributed significantly to the literature, the econometric estimation techniques utilized to study the environmental effect of tourism demand implicitly assume that the environmental effect of tourism is symmetrical. This assumption raises an important concern because increasing and declining tourism demand could have distinct environmental implications. With the symmetric assumption of the prior studies, I demonstrate how accounting for asymmetry in the econometric estimation technique could change the concluding effect of tourism demand on the environment. To achieve this goal, the current study utilized two econometric estimation techniques, namely, the Pesaran et al. (2001) symmetric autoregressive distributed lag (ARDL) and Shin et al. (2014) non-linear autoregressive distributed lag (NARDL) estimation technique to disentangle the effect of tourism demand on CO_2 emissions using Australia as the case study.

The results from the symmetric ARDL model reveal that tourism demand significantly increases CO_2 emissions in the long run, indicating that increasing tourism demand is detrimental to Australia's environment. Contrarily, when the NARDL technique is applied, the finding reveals that a positive shock (an increase) in tourism demand significantly reduces CO_2 emissions, while a negative shock (a decrease) in tourism demand significantly increases CO_2 emissions in the long run. From the NARDL estimates, the long-run elasticity of a negative change in tourism demand exceeds the positive change in tourism demand. From these empirical observations, it could be misleading to conclude from the symmetric ARDL results that Australia's tourism demand is harmful to the environment. Consequently, I argue that the environment (CO_2 emissions) depends not only on the size of tourism but also the pattern - thus

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the increase and decline - of tourism demand. Therefore, failure to account for asymmetry when investigating tourism-environment relationships could result in biased results and conclusions.

Apart from the knowledge contribution of this paper, the results present some critical policy implications. The results suggest that an increase in tourism could help in mitigating CO_2 emissions in Australia. Therefore, policies to boost tourism demand and sustainable tourism remain imperative for contributing to CO_2 emissions mitigation. Boosting tourism demand or attracting more international tourists requires innovative marketing strategies that would not conflict with climate change policies. Also, policymakers should promote tourism and its related business that demonstrate environmental sustainability in their practice by granting these businesses with tax reliefs and accreditation. Also, given that transportation remains one of the critical ingredients of tourism, policymakers should continue to implement sustainable transport systems by investing in carbon-neutral or low carbon-emitting transport infrastructures. Besides, adding more carbon-neutral buses to public transport is critical for promoting sustainable tourism in Australia. Also, national and regional tourism authorities should continue to raise awareness programmes and educate tourism businesses and consumers on environmental sustainability issues that are crucial for promoting sustainable tourism. The hospitality industry, which is also at the heart of tourism development, contributes significantly to CO_2 emissions through energy use. Therefore, fostering low energy consumption in hotels accommodations and adopting clean energy could improve sustainable tourism. To future researchers, the demonstrations and findings from this study call for new thinking in modelling strategies for investigating or discussing the tourism-environment debate. This study, therefore, recommends future studies investigating the tourism-environment relationship to consider asymmetry in their modelling approach to avoid presenting biased results and misleading conclusions.

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The findings should be interpreted with caution due to the following limitations. First, this study uses CO_2 emissions as an indicator of the environment. However, given that CO_2 emissions is one of the environment's dimensions, future studies can replicate this study by using a comprehensive indicator such as the ecological footprint for the environment. Additionally, this study focused on Australia as a case study. Focusing on a single country helps recommend important policy guidelines (Acheampong 2018; Coggin 2019). However, given that estimates from panel data techniques are also efficient, future research could also test the argument of this paper using a panel data approach. The functional form test suggests that the empirical models used in this study were well-specified. However, some emerging literature argues that the inclusion of energy variables as a determinant of CO_2 emissions could lead to biased estimation since energy variables and CO_2 emissions are technically related (Burnett, Bergstrom, & Wetzstein, 2013; Jaforullah & King, 2017; Itkonen, 2012). Because of this argument, future research can extend this study by analyzing how the inclusions of energy variables in the CO_2 emissions model could affect the conclusion presented in this study. Lastly, as this study was conducted within the STIRPAT model, future studies could examine the central argument of this paper with the Environmental Kuznets Curve framework. Notwithstanding the limitations, this study contributes to the literature by demonstrating that asymmetry matters when modelling tourism—environment relationships.

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FIGURES

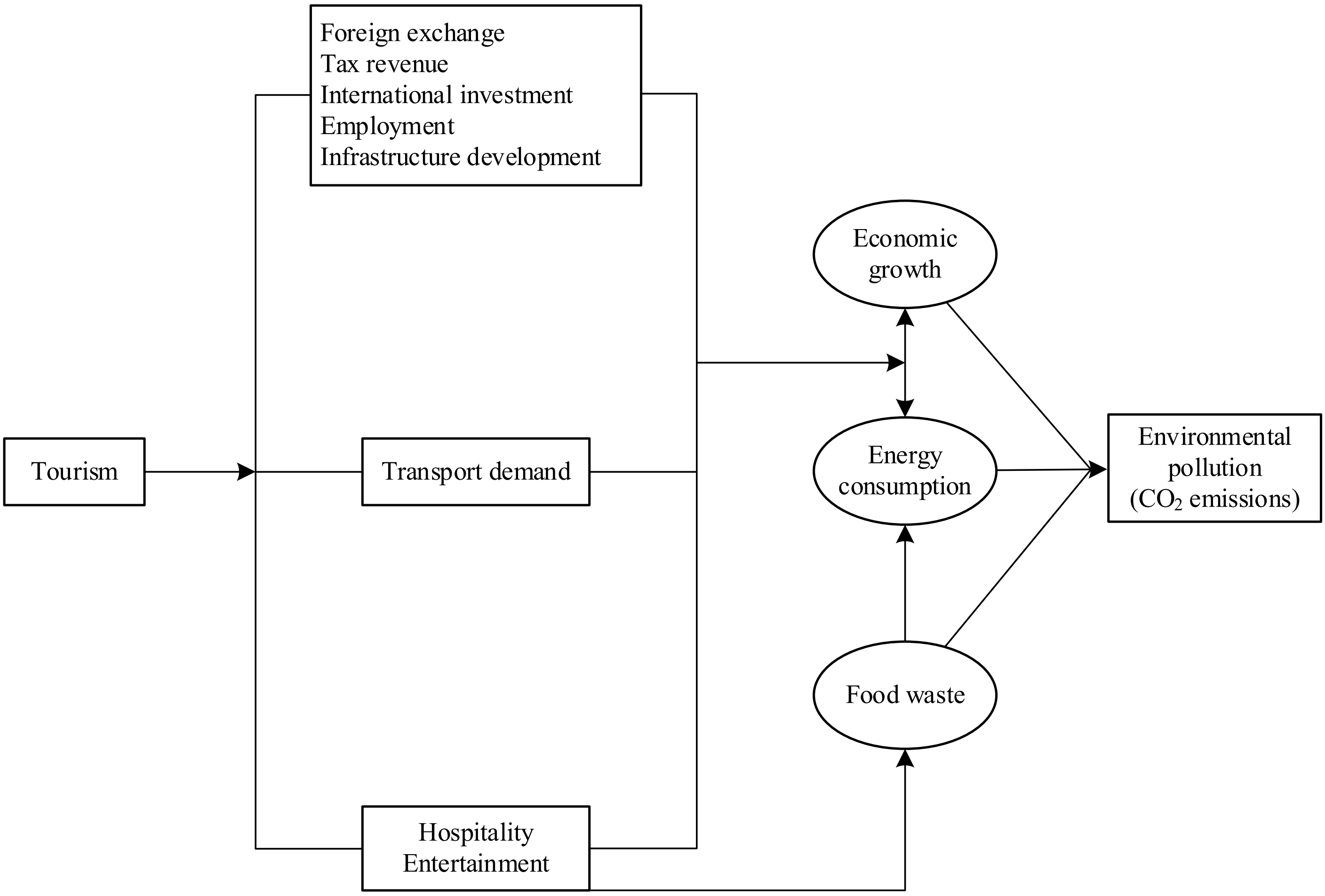
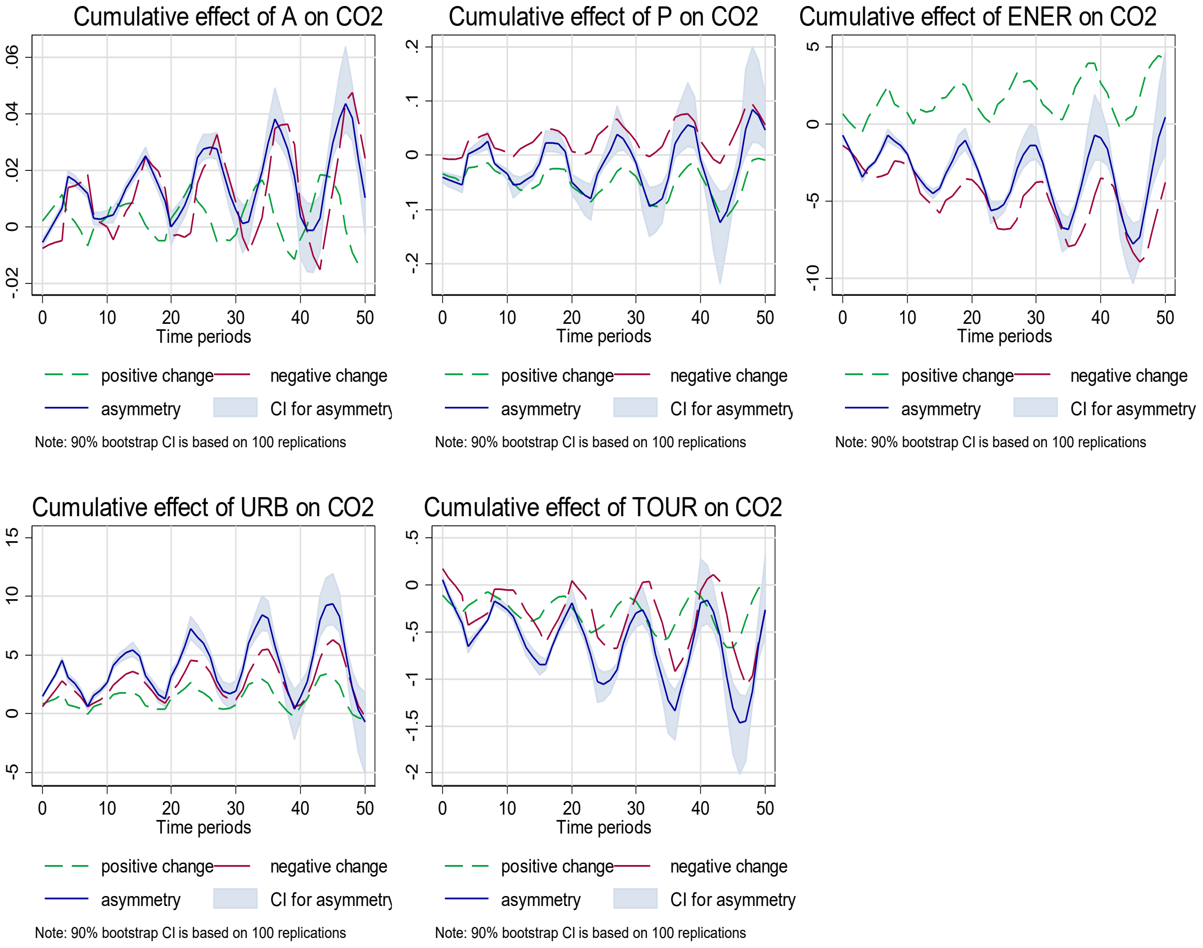


Fig.1: *Conceptual model linking tourism demand and environmental pollution*



Note: 90% bootstrap CI is based on 100 replications

Fig. 2: Dynamic multipliers adjustment of carbon emissions to a change in affluence, energy consumption, population growth, urbanization and tourism demand

TABLES

Table 1: Summary of selected empirical studies on tourism-carbon emissions relationship

Author	**Study period**	**Countries**	**Econometric approach**	**Results**
Time series studies				
Eyuboglu and Uzar (2019)	1960-2014	Turkey	Bayer and Fourier ARDL and ARDL	Tourism increases carbon emissions
Sharif et al. (2017)	1972-2013	Pakistan	ARDL	Tourism increases carbon emissions
Solarin (2014)	1972-2010	Malaysia	ARDL	Tourism increases carbon emissions
Azam et al. (2018)	1990-2014	Malaysia, Thailand and Singapore	FMOLS	Tourism increases carbon emissions in Malaysia while it reduces carbon emissions in Thailand and Singapore
Katircioglu (2014)	1960-2010	Turkey	ARDL	Tourism increases carbon emissions
Raza et al. (2017)	1996(1)-2015(3)	USA	Wavelet-based analysis	Tourism increases carbon emissions
(Katircioglu et al. 2014)	1970-2009	Cyprus	ARDL	Tourism increases carbon emissions
Sghaier et al. (2019)	1980-2014	Tunisia, Morocco & Egypt	ARDL	Tourism reduces carbon emissions in Egypt while increasing carbon emissions in Tunisia. Tourism has no significant effect on carbon emissions in Morocco
Nepal et al. (2019)	1975-2014	Nepal	ARDL	Tourism increases carbon emissions
Panel data studies				
Akadiri et al. (2020)	1995-2014	16 island developing countries	Bootstrap panel granger causality technique	Tourism increases carbon emissions
Lee and Brahmasrene (2013)	1988-2009	27 European Union countries	Fixed effect and panel cointegration techniques	Tourism reduces carbon emissions
Balli et al. (2019)	1995-2014	Mediterranean countries	Panel cointegration techniques	Tourism increases carbon emissions
Al-Mulali et al. (2015)		48 top international tourism destinations	FMOLS	Tourism increases transportation carbon emissions
Dogan et al. (2017)	1995-2010	OECD countries	Panel DOLS	Tourism increase in carbon emissions
Paramati et al. (2016)	1995-2012	26 developed countries and 18 developing countries	FMOLS	Tourism increases carbon emissions
Shakouri et al. (2017)	1995-2013	12 Asia-Pacific countries	GMM	Tourism reduces carbon emissions
Koçak et al. (2020)	1995-2014	10 most visited countries	CUP-FM & CUP-BC	Tourism arrival reduces carbon emissions while tourism receipt increases carbon emissions
Balsalobre-Lorente et al. (2020)	1994-2014	24 OECD countries	FMOLS	An inverted U-shaped relationship exists between tourism and carbon emissions
Fethi and Senyucel (2020)	1996-2016	50 tourist destination countries	DH panel dynamic causality analysis	Tourism could either increase or reduce carbon emissions
Paramati et al. (2017)	1995-2013	17 Western and 11 Eastern European countries	FMOLS and causality technique	Tourism reduces carbon emissions in Western Europe while increasing carbon emissions in Eastern Europe
Dogan and Aslan (2017)	1995-2011	EU countries	OLS, FMOLS, DOLS & Mean Group Estimator	Tourism reduces carbon emissions
Zaman et al. (2016)	2005-2013	34 developed and developing countries	Two-stage least squares	Tourism increases carbon emissions
Sherafatian-Jahromi et al. (2017)	1979-2010	Southeast Asian countries	Pooled Mean Group	Inverted U-shaped relationship exists between tourism and carbon emissions
León et al. (2014)	1998-2006	14 developed and 31 developing countries	GMM	Tourism increases carbon emission in both developed and developing countries
Paramati et al. (2018)	1990-2013	28 EU countries	Panel ARDL	Tourism reduces carbon emissions

Table 2: Variables descriptive statistics

	CO2	A	P	ENER	URB	TOUR
Mean	-1.021	3.253	0.303	8.628	16.691	23.729
Median	-1.031	3.182	0.300	8.627	16.699	23.738
Maximum	-0.859	5.165	0.803	8.695	16.867	24.573
Minimum	-1.286	1.697	-0.650	8.533	16.513	22.968
Std. Dev.	0.106	0.890	0.251	0.035	0.097	0.489
Skewness	-0.561	0.135	-1.069	-0.255	0.192	-0.079
Kurtosis	2.920	2.022	6.112	3.272	1.907	1.448
Jarque-Bera	4.220	3.947	54.660	1.167	5.145	9.328
P-value	0.121	0.139	0.000	0.558	0.076	0.009

Table 3: Time series unit root tests

Variables	Augmented Dickey-Fuller (ADF) test		Philips-Perron (PP) test	
	Level	1st difference	Level	1st difference
CO_2	1.152	-3.376^{**}	2.278	-4.233^{***}
A	-2.551	-3.516^{***}	-2.614^{*}	-5.771^{***}
P	-3.167^{**}	-6.274^{***}	-3.186^{**}	-5.954^{***}
ENER	0.379	-2.346^{**}	0.863	-3.623^{***}
URB	0.860	-5.914^{***}	-0.771	-5.600^{***}
TOUR	0.165	-3.217^{***}	-0.246	-4.563^{***}

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 4: Zivot-Andrew unit toot test with a structural break

Variables	T-statistics	Break Date
CO_2	-1.469**	2012Q1
A	-3.333	2000Q3
P	-4.860***	2008Q4
ENER	-2.874**	2006Q4
URB	-3. 566	20001Q4
TOUR	-2.919**	2006Q2

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. 1% critical value = -5.57; 5% critical value = -5.08; 10% critical value = -4.82

Table 5: ARDL cointegration bound test

Equation	**Optimal lag length**	**Bound-tests (F-statistics)**
$CO2_t = f(A_t, P_t, ENER_t, URB_t, TOUR_t)$	2, 1, 1, 2, 1, 4	**6.840**
Critical value Bounds	**Lower (I0) Bound**	**Upper (I1) Bound**
10%	2.08	3
5%	2.39	3.38
2.5%	2.7	3.73
1%	3.06	4.15

Table 6: Symmetric/linear ARDL results

Variable	Coefficient	T-Statistic	P-value
Dependent variable: $CO2_t$			
Panel A: Long-run analysis			
$TOUR_t$	0.155^{**}	2.496	0.015
A_t	-0.022^{**}	-2.056	0.044
P_t	0.061	1.600	0.115
$ENER_t$	0.969^{***}	3.846	0.000
URB_t	-2.555^{***}	-6.342	0.000
Constant	29.536^{***}	5.067	0.000
Panel B: Short-run analysis			
$\Delta CO2_{t-1}$	0.231^{***}	3.290	0.002
$\Delta TOUR_t$	-0.060^{***}	-4.184	0.000
ΔA_t	0.003^{**}	2.582	0.012
ΔP_t	0.013^{***}	3.774	0.000
ΔP_{t-1}	-0.006^{*}	-1.940	0.057
$\Delta ENER_t$	0.768^{***}	8.305	0.000
ΔURB_t	-0.147^{**}	-2.160	0.035
ΔURB_{t-1}	0.023	0.356	0.723
ΔURB_{t-2}	0.116^{**}	2.060	0.044
ΔURB_{t-3}	0.127^{**}	2.300	0.025
ECT_{t-1}	-0.080^{***}	-8.233	0.000
R^2	0.9990		
Adjusted R^2	0.9987		
$\chi^2 HET$	0.5333		0.918
$\chi^2 SC$	0.0101		0.990
$\chi^2 FF$	0.016		0.988
CUSUM test	Stable		

A = Affluence/economic growth; *P* = Population; *ENER*= Energy consumption; *URB* =Urbanisation; *TOUR* = Tourism demand. $\chi^2 SC$; $\chi^2 HET$; $\chi^2 FF$ represent LM test for serial correlation, heteroscedasticity and Ramsay Reset test (functional form) respectively. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 7: ***Asymmetric/Nonlinear ARDL results***

Dependent variable: $CO2_t$			
Variables	**Coefficient**	**T-statistics**	**P-value**
$CO2_{t-1}$	-0.575^{***}	-4.87	0.005
A^{+}_{t-1}	0.002	0.94	0.392
A^{-}_{t-1}	-0.009^{**}	-2.95	0.032
P^{+}_{t-1}	-0.037	-1.25	0.266
P^{-}_{t-1}	-0.022	-0.89	0.415
$ENER^{+}_{t-1}$	1.221^{**}	3.38	0.020
$ENER^{-}_{t-1}$	3.662^{***}	9.42	0.000
URB^{+}_{t-1}	0.968^{***}	5.98	0.002
URB^{-}_{t-1}	-1.986^{**}	-3.13	0.026
$TOUR^{+}_{t-1}$	-0.220^{***}	-5.14	0.004
$TOUR^{-}_{t-1}$	0.250^{**}	3.88	0.012
$\Delta CO2_{t-1}$	-0.294	-1.91	0.114
$\Delta CO2_{t-2}$	-0.143	-0.72	0.502
ΔA^{+}_{t}	0.002	1.09	0.325
ΔA^{+}_{t-1}	0.002	1.68	0.153
ΔA^{+}_{t-2}	0.005^{**}	3.81	0.013
ΔA^{+}_{t-3}	0.007^{***}	5.19	0.004
ΔA^{-}_{t}	0.008^{*}	2.46	0.058
ΔA^{-}_{t-1}	0.014^{***}	9.88	0.000
ΔA^{-}_{t-2}	0.012^{***}	9.07	0.000
ΔA^{-}_{t-3}	0.010^{***}	6.33	0.001
ΔP^{+}_{t}	-0.034	-1.33	0.240
ΔP^{+}_{t-1}	0.003	0.58	0.586
ΔP^{-}_{t}	0.006	1.15	0.303
ΔP^{-}_{t-1}	0.029	1.33	0.242
$\Delta ENER^{+}_{t}$	0.667^{**}	4.01	0.010
$\Delta ENER^{+}_{t-1}$	-1.148	-1.99	0.104
$\Delta ENER^{+}_{t-2}$	-1.627^{*}	-2.49	0.055
$\Delta ENER^{+}_{t-3}$	-1.992^{**}	-2.77	0.039
$\Delta ENER^{-}_{t}$	1.403^{***}	27.15	0.000
$\Delta ENER^{-}_{t-1}$	-2.168^{***}	-5.68	0.002
$\Delta ENER^{-}_{t-3}$	-1.912^{***}	-5.13	0.004
$\Delta ENER^{-}_{t-4}$	-1.697^{***}	-4.53	0.006
ΔURB^{+}_{t}	0.840^{***}	6.23	0.002
ΔURB^{+}_{t-1}	-0.038	-1.04	0.347
ΔURB^{+}_{t-2}	0.063	1.44	0.210
ΔURB^{+}_{t-3}	0.187^{**}	3.84	0.012
ΔURB^{-}_{t}	-0.637^{**}	-2.95	0.032
ΔURB^{-}_{t-1}	0.761	1.39	0.222
$\Delta TOUR^{+}_{t}$	-0.116^{**}	-3.62	0.015
$\Delta TOUR^{+}_{t-1}$	0.053^{**}	4.01	0.010
$\Delta TOUR^{-}_{t}$	-0.172^{**}	-2.54	0.052
$\Delta TOUR^{-}_{t-1}$	-0.296^{***}	-8.98	0.000
$\Delta TOUR^{-}_{t-2}$	-0.199^{***}	-9.32	0.000
$\Delta TOUR^{-}_{t-3}$	-0.087^{**}	-3.25	0.023
Constant	-0.643^{***}	-5.16	0.004
R^2	0.9998		
Adjusted R^2	0.9976		
T_BDM	-4.8713		
F_PSS	90.0263		
$\chi^2 SC$	87.47		0.0000
$\chi^2 HET$	0.5269		0.4679
$\chi^2 FF$	1.519		0.4206
Jarque-Bera test	0.3215		0.8515

Exogenous variables	Long-run effect [+]	Long-run effect [-]
A	0.004	0.015
P	-0.064	0.039
ENER	2.125^{***}	-6.375^{***}
URB	1.685^{***}	3.457^{**}
TOUR	-0.382^{***}	-0.435^{**}
	Long-run asymmetry	**Short-run asymmetry**
A	6.708^{**}	20.68^{***}
P	2.587	2.605
ENER	24.84^{***}	0.04509
URB	16.69^{***}	0.4167
TOUR	31.25^{***}	50.61^{***}

A = Affluence/economic growth; *P* = Population; *ENER*= Energy consumption; *URB* =Urbanisation; *TOUR* = Tourism demand. $\chi^2 SC$; $\chi^2 HET$; $\chi^2 FF$ represent LM test for serial correlation, heteroscedasticity and Ramsay Reset test (functional form) respectively. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

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