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Energy Consumption and Economic Development in Caribbean SIDS

Regan Deonanan and Benjamin Ramkissoon

ABSTRACT

This article examines the direction of causality between energy consumption and economic development in thirteen Caribbean small island developing states, using annual data from 1980 to 2011. We estimate a multivariate model that includes environmental emissions and we utilise the Toda-Yamamoto approach to Granger causality testing to determine causal links in each country. We find evidence of four different types of causal relationships. These results have implications for heterogeneous energy policies in Caribbean economies.

Keywords: Energy conservation, renewable energy, energy dependence, Toda-Yamamoto causality test

One of the major challenges to sustainable development in small island developing states (SIDS) is the high dependence on imported fossil fuels. For Caribbean SIDS, this challenge manifests itself in three ways. Firstly, there is a high monetary cost associated with this dependence. Fuel imports for many Caribbean countries correspond to as much as 15-30 percent of total imports (IRENA 2012), with energy consumption continuing to trend upward (McIntyre et al. 2016). Secondly, the majority of these countries are net oil importers and are heavily reliant on energy imports from Venezuela through the PetroCaribe agreement. Disruptions to PetroCaribe represent downside risks to the region's outlook (Werner 2014) and correspondingly, energy security is a timely issue. Thirdly, higher consumption of fossil fuels is associated with greater environmental emissions. The Caribbean Community (CARICOM) has a regional energy policy that aims to address many of the challenges facing these countries (CARICOM 2013a). It focuses on pillars such as energy security, access to energy, renewable energy, and energy efficiency and conservation. While these measures are likely to affect the long-run energy and environmental challenges facing the region in general, guidance on which measures are most applicable, and therefore warrant priority focus, to individual countries is unclear. This is an important consideration given that the implementation of certain policy initiatives, such as renewable projects and adaptation measures, are constrained by limited financing, low technological capacity, and political constraints (UNEP 2014). Correspondingly, there is a need to determine which of these energy policy measures may be most appropriate for individual countries.

The causal relationship between energy consumption (EC) and economic development (ED) is important in providing insight into the priority focus for energy policy in the Caribbean. Four hypotheses exist: the growth hypothesis posits that an increase in EC causes an increase in ED; the conservation hypothesis asserts that greater ED leads to higher EC; the feedback hypothesis postulates bi-directional causality between EC and ED; and, the neutrality hypothesis suggests that there is no causal link between the two. If a country is energy dependent, in which case the growth or feedback hypotheses hold, policies aimed at promoting energy conservation may come at the expense of economic development. In this case, renewable energy and energy efficiency policies may be more feasible and should come to the forefront of policy discussions. On the other hand, for a non-energy dependent country, for which the neutrality or conservation hypotheses hold, it may be possible to implement energy conservation policies without harming economic growth. If this is the case, then conservation becomes a feasible policy for reducing further environmental damage, in light of the current constraints facing renewable energy projects. However, the evidence regarding this causal relationship is controversial. In addition, empirical evidence in the case of SIDS is limited for several reasons. For one, while studies have examined the causal links between EC and ED, results are mixed in the case of developing countries (Payne 2010). For another, the literature explicitly concerning SIDS is sparse (Ramcharran 1990; Narayan and Singh 2007; Francis, Moseley, and Iyare 2007; Mishra, Smyth, and Sharma 2009; Lorde, Waithe, and Francis 2010) and covers only a few countries.

This article aims to determine which of the four energy hypotheses hold for countries in the Caribbean region, taking into consideration the heterogeneous economic structures among them. In doing so, we extend the energy policy discussion for the region at a more nuanced level. This article differs from the related Caribbean literature in several ways: it is the first to examine the dynamic relationship between energy, growth, and emissions in a multivariate framework for a wide group of Caribbean countries. This is important given the high monetary and environmental costs of energy use within the region compared to other SIDS. Previous studies have focused only on a few countries and this is unlikely to lead to a generalisation for policy discussion, given that country-specific energy structures are likely to differ within the Caribbean region. Additionally, previous studies have provided mixed results. Secondly, the inclusion of environmental emissions (EE) in our study reflects the focus of CARICOM's energy-environmental policies. Indeed, the relationships between energy, economic growth, and the environment are increasingly inter-connected. At an empirical level, the inclusion of EE reduces omitted variable bias that may be present in bivariate models. Among previous studies for the region, there is limited consideration of how EE can affect the EC-ED link. This is surprising as the Environmental Kuznets Curve (EKC) hypothesis suggests a correlation between ED and EE. Similarly, greater EC may be associated with higher EE. Finally, our country-specific analysis contributes to the discussion on energy policy in the Caribbean by assessing whether a one-size-fits-all approach is applicable. By considering each country individually, our results offer more specific guidance on which areas of the regional energy policy may be most appropriate and where further research is required.

In examining the causal link between energy consumption and economic development in thirteen Caribbean SIDS using data over the period 1980 to 2011, we employ the Toda-Yamamoto (TY) approach to Granger causality testing to accommodate variables with different integration and cointegration properties. We estimate a multivariate model in levels of the data, with environmental emissions included as an endogenous variable. Additionally, we adopt a country-specific approach to allow for potential differences in causal relationships. Apart from addressing cross-country heterogeneity, our empirical approach confronts two common sources of bias in causality testing—pre-test bias and omitted variable bias.

We then discuss the background of Caribbean energy trends and policies; provide a review of related literature; describe the data used and empirical approach adopted; and discuss the results obtained. Finally, we summarise and provide policy implications.

BACKGROUND

Cost of Energy

To understand the dependence on fossil fuels in the region and some of its implications, we examine the cost of energy to Caribbean countries. Figure 1 shows the average size of energy consumption and CO_2 (carbon dioxide) emissions per capita for the three groups of SIDS.

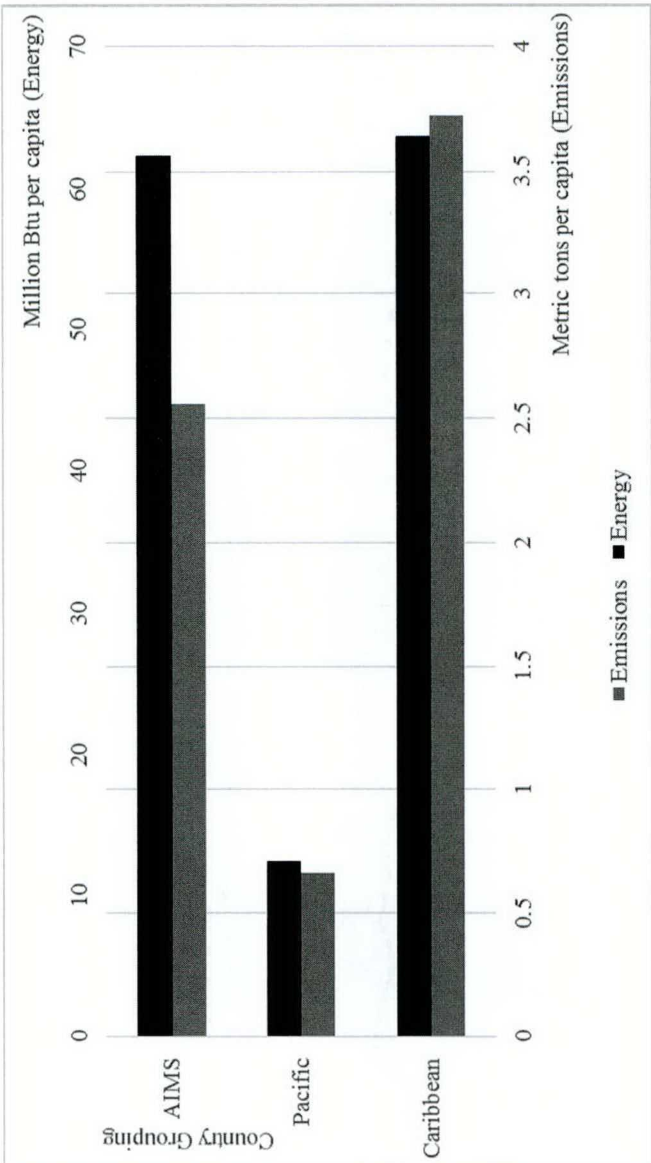
It illustrates, for one, that the amount of energy consumption and emissions in the Caribbean is largest among all SIDS. However, it also shows that while energy consumption in the AIMS (Atlantic, Indian Ocean, Mediterranean and South China Sea) countries is comparable to that of the Caribbean, the latter region has clearly larger emissions per capita. This reflects a greater environmental cost to this region when compared to the other countries. We therefore need to understand how these variables are related. Can the Caribbean reduce its emission levels to that of other SIDS via energy conservation? If so, will this hinder economic development? Figure 2 shows the average amount of CO_2 emissions per capita for the three groups of SIDS over the period 1980-2009.

It augments Figure 1 by showing us that the level of emissions in the Caribbean is higher than in other SIDS. It also shows that since the early 1980s, Caribbean emissions have been on an upward trend, while for the Pacific it has been relatively stable, and for AIMS countries, it has been on a downward trend since the late '90s. This highlights the environmental costs associated with fossil fuel energy consumption and how important an issue it is for the Caribbean region in the context of other small states. Increasing levels of environmental degradation for the region means that investigation into the effects of energy conservation is important, in light of the challenges currently faced in pursuing other strategies such as renewable energies (UNEP 2014).

Finally, Figure 3 shows the average level of fuel imports for Caribbean SIDS, both as a percentage of merchandise imports and in real dollar terms.[1]

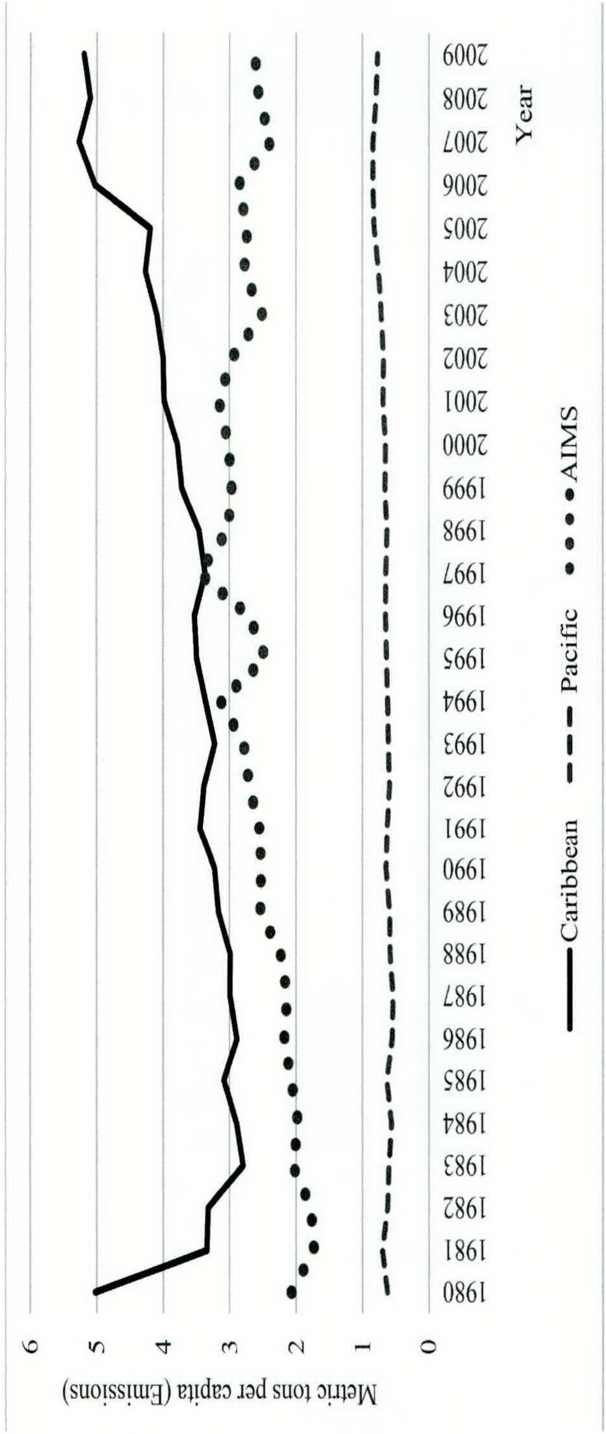
1 Dollar figures were estimated using the percentages of merchandise imports, the current US$ value of merchandise imports and the GDP deflator for the respective years.

Figure 1. Energy consumption and CO_2 emissions per capita for different groups of SIDS,



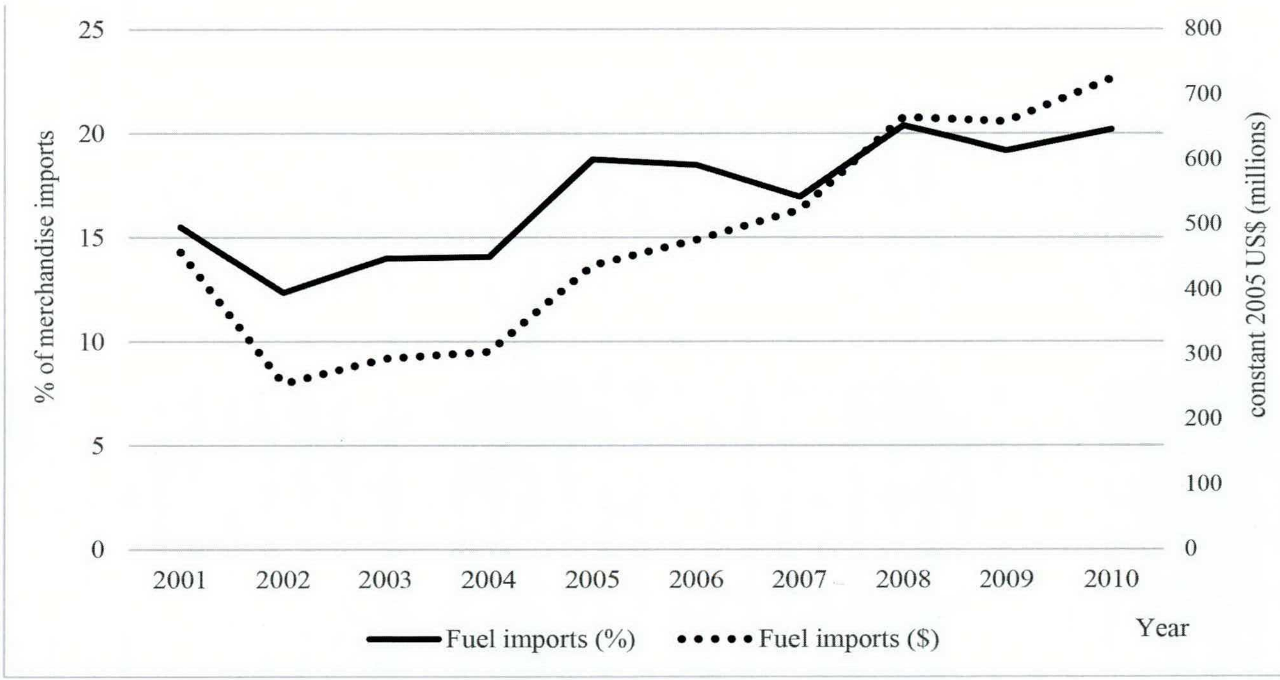
Source: Data from World Bank (2017) and US Energy Information Administration (2014)

Figure 2. CO^2 emissions per capita for different groups of SIDS, average per country [31 countries, 1980-2009].



Source: Data from World Bank (2017)

Figure 3. Fuel imports as a percentage of merchandise imports and in constant 2005 US$ for Caribbean SIDS,



Source: Author's calculation using data from World Bank (2017) and United Nations (2017)

In dollar terms, it illustrates a strong upward trend that tells us that, on average, the amount spent on fuel imports by these countries has been increasing. As a percentage of merchandise imports, fuel imports have also been increasing over the years, which tells us that they are commanding a larger share of merchandise imports for these countries. Energy consumption in the Caribbean, then, also has a large economic cost, given the amount of imported fossil fuels used and the rising expenditure of foreign exchange on these imports. Most countries in this region are heavily reliant on energy imports from Venezuela through the PetroCaribe agreement. Disruptions to this agreement represent a certain level of risk for these countries. Re-examining current energy policy may therefore be important to energy security issues in the region.

This discussion highlights the monetary and environmental costs associated with energy consumption in the Caribbean. While energy consumption in the region may be comparable to some other SIDS, their emissions are clearly greater, and increasing over time. The dependence on imported fuels also has a monetary cost, as the real dollar value, as well as its percentage of merchandise imports, have increased over the years. Given the high cost of energy to the region, it is important to investigate the effects associated with energy conservation by examining the EC-ED relationship empirically.

Energy Arrangements in the Caribbean

PetroCaribe is an agreement that began in 2005 for the government of Venezuela to provide petroleum products to Caribbean and Latin American countries with preferential payment structures. All CARICOM members except Barbados, Trinidad & Tobago, and Montserrat signed this agreement (CARICOM 2013b). In practice, however, the Bahamas and St. Lucia have not applied the agreement (SELA 2015). The agreement allows for the purchase of petroleum products at current market prices, with only part of the payment made in the short term and the remainder financed over a long-term period at preferential interest. This is generally a period of 17–25 years, with an interest rate of 1% if oil is greater than US$40 a barrel, and 2% if higher (CARICOM 2013b). Financing can range from 5%-70% depending on current oil prices. This agreement was set up to provide a level of energy security to Caribbean countries, given the trend of rising oil prices in the 2000s and growing energy demand. In addition, the agreement has since been extended to include social and economic programmes and the upgrading of energy infrastructures (SELA 2015).

According to a recent report (SELA 2015), the PetroCaribe agreement has provided, on average, 32% of member countries' oil demand. In addition, over the period 2005–2014, Jamaica and Haiti were among the CARICOM countries with the highest supply received in barrels of oil. Due to high oil prices, however, Caribbean countries' PetroCaribe financing averaged over two percent of GDP in 2014. Haiti's financing accounted for over four percent of GDP and Jamaica's was around 2.5 percent. The Eastern Caribbean countries' financing was generally below 2 percent (Cheasty 2015). Lower oil prices will reduce the amount of financing, though the support of PetroCaribe may now be in jeopardy. Countries such as Haiti, without alternative financing, may face significant adjustment costs. Haiti's stock of debt to Venezuela is approximately 15 percent of its GDP. Several countries, such as Antigua & Barbuda, Guyana, and St. Kitts & Nevis have saved from PetroCaribe financing as a buffer in the event of a disruption (International Monetary Fund 2014). In recent years, oil exports declined and interest rates to some countries have increased (IMF 2014). It has been argued that this agreement only increases dependence on petroleum products, given the availability of financed oil (Goldwyn and Gill 2016; McIntyre et al. 2016).

Trinidad & Tobago, the region's sole net exporter of energy products, also supplies CARICOM countries with petroleum products. No preferential agreement exists as this occurs under the unified trade policy. Trinidad's total intra-regional exports of mineral fuels accounted for approximately 13% of its total exports in 2013, while for many CARICOM countries, imports of mineral fuels account for over 40% of total intra-regional imports (CARICOM 2015).

CARICOM's Energy Policy

In 2003 CARICOM agreed to develop an energy policy, which initially included Barbados, Grenada, Guyana, Jamaica, Suriname, and Trinidad & Tobago, to address energy security, energy pricing, and purchasing arrangements. This eventually expanded to include renewable energy, the environment, and energy efficiency (CARICOM 2013a). The energy policy was approved in 2013 and the policy objectives include increasing energy security, securing least-cost hydrocarbon resources, increasing the use of renewable energy, encouraging energy saving, ensuring fair pricing and encouraging greater investment in the energy sector and eliminating energy poverty, among other issues (CARICOM 2013a). The aim of the policy is to address the region's dependence on fossil fuels, rising vulnerability to climate change and growing energy demand. It is the view of the Community that weak energy security, energy poverty, and the high cost of imported fuels affect the regional energy sector. Though the energy policy addresses, in a large way, climate change concerns, energy security, market pricing, and improving energy access, a portion is devoted to energy conservation and efficiency as renewable energy remains low in the region.

Caribbean countries also have individual energy policies with many geared toward the use of renewables and energy efficiency. Energy policy in Barbados focuses on reducing imported oil while promoting energy-saving-related investments. Grenada, Guyana, Haiti, and Jamaica have already engaged in a similar policy, with a large effort already underway in Jamaica (Carpio et al. 2010). As at 2010, however, no energy efficiency policies were in effect in Trinidad & Tobago. Renewable energy continues to remain a challenge in the region. Barbados continues to rely on imported oil though it targets 29% of electricity consumption from renewable sources by 2029. Belize, Guyana, and Haiti are also able to generate certain amounts of clean energy. Trinidad & Tobago generates very little clean energy and has a limited renewable energy policy in place (MIF et al. 2015). Potential for renewable energy is also high for many countries, especially with solar, wind, or geothermal energy sources. According to a recent report (IRENA 2012), Belize, Guyana, Haiti, Jamaica, St. Kitts & Nevis, and St. Lucia have renewable energy programmes in place.

LITERATURE REVIEW

Theory

Four hypotheses exist for the causal relationship between energy consumption (EC) and economic development (ED): the growth hypothesis, the conservation hypothesis, the feedback hypothesis, and the neutrality hypothesis. The growth hypothesis implies that EC causes ED. One reasoning behind the existence of such a causal link is that the typical inputs of production all require energy and thus reducing energy consumption may be detrimental to a country's growth prospects. The view is that energy is required for technological progress and therefore growth (Wolde-Rufael 2006). In theory, this may also be contingent on the level of development. There is an argument that given stricter energy efficiency policies, energy-intensive production is likely to lead to growth (Mahadevan and Asafu-Adjaye 2007) since there is little wastage.

The conservation hypothesis implies that ED causes EC. Economic growth means increased income. If spending and production persist in energy-intensive sectors as an economy grows, then it is likely that energy consumption must grow to meet its demands. This point applies particularly to energy-exporting countries. As economic activity expands, energy use increases to boost the export sector (Mahadevan and Asafu-Adjaye 2007). This effect is possible if access to energy is high. Countries with lower access or technical constraints may not be able to increase energy use in response to greater incomes.

The feedback hypothesis implies that ED causes EC and vice versa. A continuous cycle emerges where growth fuels increases in energy consumption, which then provide the necessary inputs for the growth process. A situation such as this is likely where production takes place in energy-intensive sectors, which may also be the key sectors for growth in the economy. For example, if a particular industry that drives growth is energy intensive, then growth will lead to an increase in energy consumption, which then feeds into this industry that drives growth.

The neutrality hypothesis implies that there is no discernible link in any direction between energy and growth. A number of explanations may exist. On the one hand, energy may not cause growth if the cost of it is relatively low when compared to GDP (Ghali and El-Sakka 2004). A second line of reasoning might imply that wastage and mismanagement occur. This effect may likely be more prevalent in oil-producing countries (Squalli 2007), though poor energy efficiency in any country might imply that its consumption has little growth effects. Energy infrastructure relates to this point. Some countries may face constraints, for example distribution losses, and therefore may have a difficult time increasing energy consumption in any consistent manner if income increases. Additionally, production might be energy-intensive but not lead to growth if power losses are a significant problem. Thirdly, if key sectors are not energy-intensive then neutrality is possible. For example, the service sector may be less energy intensive than manufacturing. The structure of an economy is important for this reasoning. A growing economy might shift production to less energy-intensive industries and energy use may not be greatly affected. A fourth line of reasoning is that energy efficiency or conservation policies already in place may restrict EC despite growth. Stronger regulations may cause a decoupling effect between energy and growth, as there is a more efficient use of energy.

Caribbean Literature

The empirical literature on the relationship between energy consumption, economic development, and environmental pollution in the Caribbean is limited. Ramcharran (1990) did one of the earliest studies, which examined the relationship between electricity consumption and growth in Jamaica. Using a bivariate framework and least squares regression, the author found that electricity had a positive impact on real GDP and vice versa. The results also suggested increasing energy intensity, suggesting that the electricity-output ratio is growing over time.

Francis, Moseley, and Iyare (2007) examined this relationship for three Caribbean countries, namely Haiti, Jamaica, and Trinidad & Tobago. The authors used the Engle-Granger two-step procedure to test for long-run relationships in a bivariate framework. The empirical evidence suggested that there was bi-directional long causality between energy consumption and real GDP for Trinidad & Tobago and no causality elsewhere, while Hsiao's Granger causality technique showed short-run bi-directional causality for all countries. Their forecasts also suggested growing energy consumption in all countries.

Lorde, Waithe, and Francis (2010) investigated electricity consumption and economic growth in Barbados. In addressing the omitted variable bias of a bivariate framework, they included these variables in a neoclassical production model with labour, capital, and technology. Using the Johansen test for cointegration Granger causality tests within the vector error correction (VEC) framework, the authors found a long-run relationship between the variables where electricity had a positive relationship with growth. Making use of disaggregate energy series, they found that non-residential consumption was likely the key driver of growth. Long-run causality suggested a bi-directional relationship between electricity and growth, while the short-run results suggested causality from electricity to growth.

Zilio and Recalde (2011) and Pablo-Romero and De Jesús (2016) investigated the relationship between energy and growth in Latin America and the Caribbean in the context of the Energy-Environmental Kuznets Curve (EEKC) hypothesis. They sought to determine whether economic growth affected environmental pressure, using energy as a measure for this pressure. Both studies included five Caribbean countries in their panel estimations. Zilio and Recalde (2011) found no long-run relationship between the variables while Pablo-Romero and De Jesús (2016) found that economic growth led to increased energy consumption but no evidence for the EKC hypothesis.

Chang and Carballo (2011) examined the link between energy and growth in LAC, using a country-specific approach. Their sample of countries included the Dominican Republic, Jamaica, and Trinidad & Tobago. Their framework was multivariate and included carbon dioxide emissions. The authors use the Johansen test and Granger causality in a VEC/VAR framework. The authors find no evidence of cointegration for the Caribbean countries, but short-run results suggest growth leading energy in Jamaica. Al-mulali et al. (2013) followed a similar approach but included fifteen Caribbean countries in their sample. While the authors included carbon emissions in their framework, estimation involved three separate models, using the Canonical Cointegrating Regression approach with the aim of examining the bidirectional links. The authors found various links, including positive and negative relationships. They found a bi-directional relationship between energy and growth for all but three Caribbean countries—

Barbados, Belize, and Dominica. However, this relationship is negative for Antigua & Barbuda and the Bahamas. The results for Belize and Dominica suggest a one-way relationship from growth to energy while no relationship exists for Barbados.

The literature for Caribbean countries remains sparse and inconclusive. Results for countries such as Jamaica, Barbados, and Trinidad & Tobago are not consistent across the relevant studies. This is likely due to a range of factors, from the estimation method and span of data to the model and form of variable used.

International Literature

There are many studies on the relationship between energy and growth but there is no strong consensus on the direction of causality involved. The existing empirical evidence points to possibilities for each of the hypotheses discussed.[2] In a review of some country-specific studies, Omri (2014) found that 29 percent of the results supported growth, 23 percent conservation, 27 percent feedback and 21 percent neutrality. The differences in the empirical evidence relate to a number of factors, not limited to the datasets used, the methodology and theoretical framework involved, as well as country-specific characteristics.

For example, early literature on this relationship varies by data and methods alone. Kraft and Kraft (1978) found causality from growth to energy in the US, applying Sims' causality method. Akarca and Long (1980) used a more homogeneous period and the same method to show that the causality found was spurious. In recent literature, Lee (2006) found bidirectional causality for the US with the TY causality test, while Chontanawat, Hunt, and Pierse (2008) found no evidence of causality for the US using Hsiao's procedure. Both studies employed a bivariate framework but ended up with different conclusions. This extended to developing countries as well. Chen, Kuo, and Chen (2007) found evidence of causality from energy to GDP in Indonesia using Yoo's causality test, while Squalli (2007) confirmed this result with the TY test, but the ARDL result revealed a relationship in the opposite direction.

Causality results also differed based on the theoretical framework used. Soytas and Sari (2003) found no evidence of

2 Payne (2010), Ozturk (2010) and Omri (2014) provide detailed reviews of the literature.

causality for the US using the Johansen procedure and the VEC framework in a bivariate setting, while Soytas and Sari (2006) found causality from energy to growth with the same method, but in a multivariate framework with capital and labour. Further, Soytas, Sari, and Ewing (2007) included carbon emissions in their multivariate framework to test for the EKC and the causality tests revealed no link between energy and income. For developing countries, Masih and Masih (1996) used a bivariate framework and found no evidence of causality in Malaysia, while Ang (2008) added carbon emissions to the model and found evidence of growth to energy. Both studies used similar methods. Omitted variable bias can mask the true causal relationship between energy and growth.

The empirical literature also varies based on the type of data used. This is likely due to the respective energy structures within economies. For example, according to Mahadevan and Asfu-Adjaye (2007), aggregate energy consumption may not be the best measure to employ if a country is heavily reliant on electricity in their total energy consumption. The literature reflects these differences. For example, Alam et al. (2012) found causality from energy to growth in Bangladesh with total energy consumption, but bidirectional causality when electricity was used. Lorde, Waite, and Francis (2010) found evidence of electricity leading to growth in Barbados with total and non-residential electricity consumption, but not with residential consumption. The energy consumption patterns in an economy therefore have a strong bearing on the relationship between energy and growth that exists.

Finally, empirical results largely differ by country. Lee (2005) suggested that energy leads to growth in developing countries, though Chontanawat, Hunt, and Pierse (2008) suggested that this was more likely in the developed world and neutrality may be the case for developing countries. Huang, Hwang, and Yang (2008) found that neutrality was the case for low-income countries but growth leads energy otherwise. However, this relationship was only positive for middle-income countries. Belke, Dobnik, and Dreger (2011), however, found bidirectional causality in developed countries. Al-Iriani (2006) found that in the resource-rich countries of the Gulf Cooperation Council (GCC) growth led energy, while Squalli (2007) found an array of results for OPEC (Organization of the Petroleum Exporting Countries) members. On the other hand, Mahadevan and Asafu-Adjaye (2007) found that bidirectional causality was likely among both energy exporters and importers, using a sample of countries. One reasoning for the differences in results obtained is the use of panel data methods versus country-specific methods. Lee, Chang, and Chen (2008) found bidirectional causality between energy and growth for a panel of OECD (Organisation for Economic Co-operation and Development) countries, while many studies have shown that causality can differ among developed countries (Lee 2006; Soytas and Sari 2006). Similarly, a vast number of studies show differing results for developing countries, so that panel studies that state specific conclusions for the group of developing countries (e.g. Lee 2005; Huang, Hwang, and Yang 2008) cannot give relevant policy recommendations for each of these countries. While panel methods improve certain aspects for the methodological approach such as a larger number of observations, a country-specific approach is important when we require specific policy relevance (Smyth and Narayan 2015).

DATA

Following the literature, we use gross domestic product (constant 2005 US$) in logarithms as our economic development variable (EDt) and carbon dioxide emissions in logarithms to capture environmental emissions (EEt). Both variables are taken from the World Bank's World Development Indicators database (2017).[3] For our energy consumption variable (ECt), we use total primary energy consumption in logarithms, taken from the US Energy Information Administration's International Energy Statistics (2014). Our dataset contains annual data for thirteen Caribbean countries over the period 1980 to 2011.[4]

To examine the time series properties of the data, we employ two commonly used unit root tests, the Phillips-Perron test (PP) and Augmented Dickey Fuller test (ADF). These results are reported in Table 1 and indicate that the data for most countries is comprised of a mixture of I(0), I(1) or I(2) variables.

3 For Haiti and Jamaica, GDP (constant 2005 US$) is taken from United Nations' National Accounts Main Aggregates database (2017).

4 For Guyana, we use data from 1980 to 2009 due to data availability.

Table 1. PP and ADF unit root tests

Country	ED_t	EC_t	EE_t
Antigua & Barbuda	I(1)/I(1)	I(0)/I(0)	I(0)/I(0)
Belize	I(2)/I(2)	I(1)/I(1)	I(1)/I(1)
Barbados	I(1)/I(0)	I(1)/I(0)	I(1)/I(1)
Dominica	I(1)/I(1)	I(1)/I(0)	I(1)/I(0)
Grenada	I(1)/I(1)	I(1)/I(1)	I(1)/I(1)
Guyana	I(1)/I(0)	I(1)/I(1)	I(1)/I(1)
Haiti	I(1)/I(1)	I(1)/I(1)	I(1)/I(1)
Jamaica	I(1)/I(1)	I(1)/I(1)	I(1)/I(1)
St. Kitts & Nevis	I(1)/I(1)	I(1)/I(1)	I(1)/I(1)
St. Lucia	I(1)/I(1)	I(1)/I(0)	I(1)/I(1)
St. Vincent & Grenadines	I(1)/I(1)	I(1)/I(1)	I(1)/I(1)
Suriname	I(1)/I(1)	I(1)/I(1)	I(0)/I(0)
Trinidad & Tobago	I(2)/I(2)	I(1)/I(1)	I(1)/I(1)

Note: First and second entries correspond to results of the PP and ADF tests respectively. For level variables, a trend and intercept is included. For first differenced variables, an intercept is included.

METHODOLOGY

We use the Toda and Yamamoto (1995) approach to Granger causality testing (hereafter referred to as TY) to examine the ED-EC relationship in each country. The TY method has several advantages. For one, it allows testing causal links regardless of the integration or cointegration properties of the data. This is relevant given the different orders of integration among the variables in our dataset. Secondly, the TY procedure does not require testing for cointegration prior to causality testing. It therefore avoids the pre-test bias. Thirdly, as the variables enter the empirical model in levels, there is no loss of long-run information from differencing.

Testing proceeds in three steps for each country. We first construct a vector autoregressive model (VAR) with the series in levels. We determine the optimal lag length, *k*, using the Schwarz Bayesian criterion, and perform a battery of diagnostic tests to ensure the VAR(k) is well-specified.[5] Secondly, we determine the maximum order of integration among the group of variables, *d*, using the results of the unit root tests reported in Table 1. In the third step, we augment the optimal VAR(k) with d additional lags.

5 Available upon request

We therefore estimate a VAR(k+d) with normally distributed error terms, ε, as specified below:

$$ED_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} ED_{t-i} + \sum_{i=1}^{k} \alpha_{2i} EC_{t-i} + \sum_{i=1}^{k} \alpha_{3i} EE_{t-i} + \sum_{i=k+1}^{k+d} \alpha_{4i} ED_{t-i} + \sum_{i=k+1}^{k+d} \alpha_{5i} EC_{t-i} + \sum_{i=k+1}^{k+d} \alpha_{6i} EE_{t-i} + \varepsilon_{1t} \quad (1)$$

$$EC_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} ED_{t-i} + \sum_{i=1}^{k} \beta_{2i} EC_{t-i} + \sum_{i=1}^{k} \beta_{3i} EE_{t-i} + \sum_{i=k+1}^{k+d} \beta_{4i} ED_{t-i} + \sum_{i=k+1}^{k+d} \beta_{5i} EC_{t-i} + \sum_{i=k+1}^{k+d} \beta_{6i} EE_{t-i} + \varepsilon_{2t} \quad (2)$$

$$EE_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} ED_{t-i} + \sum_{i=1}^{k} \gamma_{2i} EC_{t-i} + \sum_{i=1}^{k} \gamma_{3i} EE_{t-i} + \sum_{i=k+1}^{k+d} \gamma_{4i} ED_{t-i} + \sum_{i=k+1}^{k+d} \gamma_{5i} EC_{t-i} + \sum_{i=k+1}^{k+d} \gamma_{6i} EE_{t-i} + \varepsilon_{3t} \quad (3)$$

To assess Granger causality, we use a standard block exogenous Wald test to determine whether the coefficients of the k lagged values of the independent variable of interest are jointly equal to zero, ignoring the d additional lags. More specifically, to determine whether EC Granger causes ED, we test the null hypothesis of Granger non-causality, H_0: $\alpha_{21} = \alpha_{22} = \ldots = \alpha_{2k} = 0$. Rejection of the null indicates causality running from EC to ED. In the case of causality from ED to EC, we test the null hypothesis, H_0: $\beta_{11} = \beta_{12} = \ldots = \beta_{1k} = 0$. According to TY, the modified Wald statistic has an asymptotic χ^2 distribution with k degrees of freedom.

RESULTS

We present the results of the TY test in Table 2. Columns 2 and 3 show the Wald statistics and p-values for the test of the null hypothesis of Granger non-causality from energy consumption to economic development for each country. Columns 4 and 5 correspond to the test of the null hypothesis of Granger non-causality from economic development to energy consumption. In all cases, the estimated VAR models on which TY Granger non-causality tests are performed meet the modified lag length requirement that $k \geq d$.[6]

6 Available upon request.

Table 2. TY Granger non-causality tests

Country	EC → ED		ED → EC		Hypothesis
	Wald statistic	p-value	Wald statistic	p-value	
Antigua & Barbuda	14.726***	0.005	7.549	0.110	Growth
Belize	0.898	0.638	0.130	0.937	Neutrality
Barbados	0.001	0.982	0.353	0.553	Neutrality
Dominica	0.502	0.479	0.399	0.528	Neutrality
Grenada	1.272	0.259	0.140	0.708	Neutrality
Guyana	0.056	0.813	0.372	0.542	Neutrality
Haiti	5.222**	0.022	1.405	0.236	Growth
Jamaica	0.845	0.358	0.131	0.717	Neutrality
St. Kitts & Nevis	0.233	0.629	3.476*	0.062	Conservation
St. Lucia	0.208	0.648	0.327	0.567	Neutrality
St. Vincent & Grenadines	0.023	0.880	0.347	0.556	Neutrality
Suriname	1.241	0.265	0.278	0.598	Neutrality
Trinidad & Tobago	7.078*	0.069	17.240***	0.001	Feedback

Note: ***, ** and * denote 1%, 5%, and 10% level of significance respectively.

The results indicate unidirectional causality from EC to ED in two countries (Antigua & Barbuda and Haiti), while there is causality from ED to EC in one country (St. Kitts & Nevis). We find a bidirectional link for one country (Trinidad & Tobago), while the remaining nine countries show neutrality. The result for Trinidad & Tobago suggests that reductions in EC or ED are likely to have a negative effect on each other. This is consistent with the results of Francis, Moseley, and Iyare (2007) and Al-mulali et al. (2013). The result is also consistent with the multi-country study by Chontanawat, Hunt, and Pierse (2008). Our finding seems intuitive for a country such as Trinidad & Tobago that has largely been dependent on the energy sector. On one hand, ED can promote EC given that energy is an important input in their key sector, for example in the extraction and refining of oil and natural gas, and in related heavy industries. This effect is also plausible given the country's high access to energy resources, low transmission and distribution losses (World Bank 2017) and low retail prices for electricity (MIF et al. 2015). Consumers and producers can readily increase energy use as incomes rise. Causality from EC to ED is also intuitive given that energy exports are likely to drive growth, as evidenced by the country's performance in relation to commodity price fluctuations. Given the energy-intensive nature of production, it implies that energy is an important input in the current growth path. Similar bi-directional relationships exist in the literature for other oil exporters such as Iran and Qatar (Squalli 2007).

For Jamaica, we find no evidence of causal links. This contradicts the findings by Ramcharran (1990) and Al-mulali et al. (2013), which both revealed a bidirectional relationship, but was consistent with Chontanawat, Hunt, and Pierse (2008) and with Francis, Moseley, and Iyare (2007) and Chang and Carballo (2011), who detected no long-run causality. It is important to note, however, that Ramcharran (1990) found a link between electricity and growth in a bivariate framework. On the other hand, Al-mulali et al. (2013) included emissions in their model but their bidirectional relationships came from three separate regressions. Our multivariate model allows for simultaneous interaction between the variables. Thus, our causality results are not *a priori* restricted.

Our results for Barbados also indicate neutrality, which suggests that changes in EC or ED are not likely to affect each other. This is in line with the findings of Al-mulali et al. (2013) but it does not agree with the bidirectional result found by Lorde, Waithe, and Francis (2010). In the latter study, the authors accounted for omitted variables by including capital and labour in a production framework, in addition to using electricity consumption in their analysis. This accounted for other control variables in the growth process, but did not consider the important environmental linkages. Our approach considers that link by including carbon dioxide emissions.

Neutrality in Barbados and Jamaica may occur for different reasons. Barbados appears to be the most energy-efficient country in the region (McIntyre et al. 2016). Despite their dependence on fossil fuels, they have been pursuing efficiency policies and giving incentives for renewable energy participation for many years. This may reflect the decoupling of energy and growth in the economy. In Jamaica, though attempts are ongoing to diversify their energy mix, energy intensity is still high (McIntyre et al. 2016). Jamaica's economy, however, has become less reliant on commodity exports in recent years as tourism receipts and financial services continue to grow. This sectoral shifting may reflect a potential decoupling of energy and growth for the economy.

In the case of Haiti, we find evidence of causality from EC to ED. Existing results for Haiti (Francis, Moseley, and Iyare 2007; Chontanawat, Hunt, and Pierse 2008) suggest no evidence of causality. However, these studies only used a bivariate framework. Our results for Haiti may highlight a missing link that does not appear without the environmental consideration. We note, however, that Francis, Moseley, and Iyare (2007) did find bidirectional causality for Haiti, but only in the short run. Haiti's energy sector faces several issues. Low usage of energy by the industrial sector coupled with the high level of energy intensity (Haiti Ministry of Public Works, Transport and Communications 2006) may imply that energy is required for contribution to growth at this stage of development. Haiti's energy intensity is among the highest in the region (behind Trinidad & Tobago), which suggests that larger amounts of energy are required for productive activity in the country.

In the remaining cases, we find causality from EC to ED in Antigua & Barbuda, from ED to EC in St. Kitts & Nevis, and neutrality in Belize, Dominica, Grenada, Guyana, St. Lucia, St. Vincent & the Grenadines, and Suriname. To our knowledge, only Al-mulali et al. (2013) have obtained results for these countries and they differ from ours. The authors found causality from ED to EC in Belize and Dominica and in both directions for the remaining countries. As mentioned previously, this article also takes into account carbon emissions but we investigate causality in a simultaneous framework.

POLICY IMPLICATIONS

This article looked at the direction of causality between energy consumption and economic development in thirteen Caribbean countries. We tried to determine which of four energy hypotheses hold for each country—growth, feedback, conservation, or neutrality. This is important for two main reasons: the majority of the Caribbean is dependent on imported fossil fuels, which entails large economic costs; and carbon emissions in the region are the highest among SIDS groups and growing over time. Energy conservation, suggested at the regional policy level, is one possible way to address these issues. Whether it is a feasible or effective policy focus for each country, or whether priority on other measures is warranted, depends on the energy-economic development relationship. We examine this relationship in a multivariate framework that takes into consideration environmental emissions. We use the Toda-Yamamoto approach to assessing Granger causality for each country over the period 1980 to 2011.

We find evidence of unidirectional causality from EC to ED in two countries (Antigua & Barbuda and Haiti), unidirectional causality from ED to EC in one country (St. Kitts & Nevis), bidirectional causality between EC and ED in one country (Trinidad & Tobago), and no evidence of causality between EC and ED in the remaining nine countries. Our results both contradict and support previous findings for the region, with differences likely arising from our consideration of EE in assessing the ED-EC link. The inclusion of EE in our study reflects the focus of CARICOM's energy-environmental policies and may be more relevant than previous studies that used a bivariate framework to assess the ED-EC link.

Our results indicate that for the majority of the region, no causal link exists between EC and ED, and as such, energy conservation policies may not be harmful to economic development. However, we also emphasise that more research is required to determine why there is no causal link. If energy conservation policies are undertaken or continued, countries can reduce reliance on imported fossil fuels without harming economic development. Less reliance on imported energy reduces energy security risks. In addition, energy conservation is a viable policy option for reducing the environmental impact of energy use from fossil fuels. Despite the increase in focus on renewable energy projects, several challenges remain a concern. Conservation may therefore provide a more accessible remedy for and environmental concerns while the region aims to overcome financing, and political and technical capacity challenges to renewable energy implementation. However, this is not to say that the Caribbean should implement energy savings policies without restraint. For instance, while there is no link between energy and aggregate incomes for several countries, energy consumption is likely to be important for certain sectors. In addition, the quantity of environmental emissions resulting from energy use is also likely to be different across sectors.

Identifying the relationship between these variables within each sector may help to determine more precisely where countries can target their conservation policies. This is one avenue for further research. Another point of consideration is the relationship between energy use and other aspects of economic development. Energy may not contribute to economic growth directly but access to energy can be important in other areas, such as reducing poverty, improving rural infrastructure, or increasing technological capacity. Future research on assessing these linkages is therefore important prior to implementing conservation policies.

On a more country-specific level, however, our results highlight that the EC-ED relationship differs within the region, which has important implications for the regional energy policy outlined by CARICOM. In particular, this policy stands on a few main pillars such as energy security, energy access, renewable energy development, and energy conservation. However, the policy is not clear on which areas may need more focus for specific countries. Our results extend this discussion on regional energy policy. More specifically, we highlight which measures are more likely to be feasible or warrant greater attention in each country, and where more research is needed.

In the case of Antigua & Barbuda, Haiti, and Trinidad & Tobago, where there is causality from EC to ED, conservation is likely to be detrimental to growth. Alternatively, this suggests that policies in these countries should prioritise energy efficiency and renewable energy given the need to address environmental concerns and energy security issues. This is particularly the case for Trinidad & Tobago where we find bi-directional linkages, suggesting energy plays an integral part of that economy. In addition, increasing the ratio of output to energy use is important. There is scope for this among these countries, given production and distribution problems (Haiti), the lack of sufficient energy-efficiency programmes (Trinidad & Tobago), and the lack of significant clean energy generation (Antigua & Barbuda, Trinidad & Tobago). This may require overcoming certain constraints such as financing, or the unwillingness to engage in these programmes due to cheap electricity generation from traditional sources (Trinidad & Tobago). An avenue for future research among these countries may be determining what causes the coupling between EC and ED.

While it may be intuitive for the case of Trinidad & Tobago, competing theories may explain why this is the case for the other countries (low substitutability between energy and factors of production or different stages of development). Finally, given that energy is integral to economic growth in these countries, policies aimed at increasing energy access may be important to consider along with renewable energy and efficiency measures.

In the case of St. Kitts & Nevis, where we find unidirectional causality from ED to EC, while conservation may be feasible, it may not necessarily be effective. Although reducing energy consumption may not be detrimental to economic growth within the current economic structure, growth leads to greater energy use and emissions. Importantly, such economic growth may give rise to future economic expansion if energy consumption occurs in key industries and sectors. The recommendations here are twofold. First, efficiency policy and renewables are imperative if the increase in energy consumption is taking place in key economic sectors that are likely to contribute to future growth. However, these policies can be more direct. Future research aimed at identifying sectors and industries where energy consumption is most responsive may allow for more aggressive efficiency policies and more targeted renewable initiatives. Secondly, an energy access policy may have an important role in tandem with the above. Although growth leads to greater energy consumption, building technical capacity and infrastructure in energy distribution may be important for equitable and efficient energy access for all, and particularly the expansion of key industries and sectors.

Finally, in the remaining nine countries where we find no evidence of causality, conservation may be feasible, but will require more research to determine why there are no causal linkages prior to implementation. Going back to the theoretical discussion, if neutrality is the result of inefficiency and wastage, then conservation alone may be ineffective or even counter-productive, and therefore cannot constitute the majority of the policy discussion. In this case, policies promoting efficiency and access are more important. This deviates from the traditional recommendation of conservation in non-energy dependent countries, but does take into consideration the Caribbean context (adequate and reliable energy access is still an impediment in several countries). This would open the door then for determining energy efficiency and monitoring usage in these countries. If neutrality arises due to sectoral shifts then conservation becomes more feasible. Disaggregating energy consumption by sector becomes an important point for further research to more precisely determine where conservation may be more effective. If neutrality is the result of better energy and environmental regulations, the necessary steps are already in place to reduce environmental damage and conservation policies may further support these measures. The need for caution arises, however, with the composition of energy use. If households are the main users of energy, then conservation may be a more immediate policy goal for reducing emissions as renewable energy involves significant costs. If firms and industry are the main users, a conservation policy requires more care, and renewable energy projects may need greater priority.

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