Measuring the causal effect of Panama Canal expansion on Latin America and the Caribbean's economic growth: a Bayesian structural time series approach

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Abstract

Purpose – This study provides empirical evidence on the impact of the Panama Canal expansion (PCE) on the economies of Latin American and Caribbean (LAC) countries, particularly in light of the emergence of larger container ships such as neo-Panamax and post-Panamax vessels.

Design/methodology/approach – This study uses the Bayesian structural time Series (BSTS) model to evaluate the economic effects of the PCE on 21 countries within the LAC region. It utilized the World Bank's gross domestic product (GDP) figures between 2000 and 2019 as the primary variable, alongside the human development index (HDI) (X1), container throughput (TEU) (X2) and unemployment rates (UNEMPL) (X3) covariates. This allowed a precise and robust approach to analyzing time series data while accounting for uncertainties and allowing the inclusion of various components and external factors.

Findings – The findings revealed that the PCE has a positive and statistically significant impact on most countries within the Caribbean Transshipment Triangle, ranging from 9.2% in Belize to 46% in Cuba. This suggests that the causal effect of the PCE on regional economies was not confined to any specific type of economy or geographical location within the LAC region. Where the growth rates were statistically insignificant, primarily in some Latin American countries, it coincided with countries that are primarily driven by exports and service industries, where bulk and oil tanker vessels are likely to be the main carriers for exports rather than container vessels.

Originality/value – The practical implications of this research are crucial for various stakeholders in the maritime industry and economic planning. The factors influencing economic growth resulting from investing in maritime activities are vital for decision-makers to create policies that lead to positive outcomes and sustainable development in regions and countries with flourishing maritime industries. The methodology and findings have significant implications for governments, managers, professionals, policy-makers and investors.

Keywords Panama Canal, LAC, Gross domestic product, Human development index, Unemployment, Maritime traffic, Bayesian structural time series

Paper type Research paper

1. Introduction

The Panama Canal (PC) has had a notable influence on the economies of the North America and Latin America countries. It has influence port infrastructure development and facilitating

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growth for both regional and global trade (Casella *et al.*, 2019). The expansion of the canal in 2016 has created opportunities for enhancing transshipment, trade liberalization and economies of scale (mega-ships) that could hypothetically improve the socio-economic conditions of countries within the Latin America and the Caribbean (LAC) regions (Sabonge, 2014). According to various studies, the transit of Neo-Panamax vessels would further amplified these opportunities (Rodrigue and Ashar, 2016; Singh *et al.*, 2015; Bhadury, 2016; Park *et al.*, 2020).

Irrefutably, the PC has also played a crucial role in supporting the flow of international trade in the western hemisphere (Wang, 2017). Its most significant benefit is the reduction in transportation time between the Atlantic and Pacific Oceans, compared to previous routes via the Suez Canal (SC) or around the Cape of Good Hope (Cho *et al.*, 2019; Gro, 2016). Its importance is further highlighted by the expansion in 2016, which has increased the maximum vessel capacity and overall volume of transported freight therefore, positively influencing the continued growth in world trade, with the World Trade Organization (WTO) projecting a 3.2% increase in global trade for 2024 (WTO, 2023).

Seaborne trade has consistently exhibited a strong correlation with economic growth resulting in poverty reduction, increased employment and improvements in the human development index (HDI) (OECD, 2015; Munim and Schramm, 2018). The correlation between seaborne trade and economic growth has been the primary driver behind the development and improvement of regional ports within LAC region and the USA East and Gulf coasts since the opening of the PC (Pham *et al.*, 2018; Fan and Gu, 2019; Carral *et al.*, 2018; Shibasaki *et al.*, 2018). The PC expansion foresees direct economic benefits for regional ports through port and logistics infrastructural investments that emulate the economic models of port nations such as Singapore and the Netherlands (de Langen *et al.*, 2020). Take, for instance, several ports within the Caribbean "transshipment triangle" (see Figure 1), including Colon, Freeport, Kingston, Mariel, San Juan and Port of Spain, have made significant developments and improvements in port infrastructure to accommodate neo-Panamax and post-Panamax vessels, however, not all port benefited from these development due increase competition among USA East and Gulf Coast ports (ACS, 2017; Bhadury, 2016; Gooley, 2018; Park *et al.*,

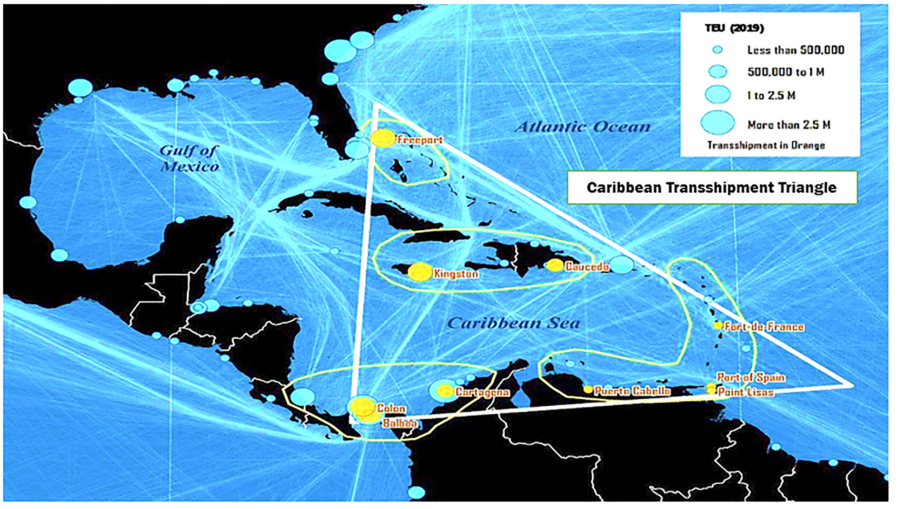

Figure 1.
The Caribbean transhipment triangle

Source(s): Figure courtesy of Rodrigue (2020)

2020; UNCTAD, 2019). The WTO reported in 2023 that the average annual gross domestic product (GDP) growth rate for the Latin America and Caribbean (LAC) region was 3% between 2009 and 2016. This rate was comparatively lower than in other developing regions.

The impact of the Panama Canal Expansion (PCE) on economic growth in the Latin America and Caribbean (LAC) region has been a topic of debate. Prior research has primarily focused on predicting container port throughput. However, this study employs Bayesian Structural Time Series (BSTS) analysis to measure the actual impact of the PCE on the region's economic growth. The research investigates the influence of the PCE on the GDP of 21 countries within the LAC, which represent 85% of the region's container throughput (TEU) volume, before and after the expansion. By identifying unique exogenous and endogenous factors that affect the three sub-regions, the study provides empirical evidence of the economic effects of the PCE in regional countries, particularly since the introduction of neo-Panamax and post-Panamax container vessels. These findings can provide valuable insights and data-driven information to help investors, economists and policy-makers make informed decisions about infrastructural investments, economic policies and other related matters.

2. Global trade within Latin America and the Caribbean

2.1 Latin America and the Caribbean geographical profile

The LAC region comprises thirty-three (33) countries divided into South America, Central America and the Caribbean. The study will examine 21 of these 33, for which data is readily available. The PCE was projected to improve maritime activities, stimulating economic activity through the region's port activities such as transhipment, TEUs and maritime activities. It has, as anticipated, increased marine traffic and cargo tonnage, enabling neo-Panamax and post-Panamax vessels to transit the third lock (Rodrigue and Ashar, 2016; Singh *et al.*, 2015; Bhadury, 2016; Park *et al.*, 2020). The main trade routes with traffic in the PC are:

(1) East Coast of the USA and Asia (Far East);

(2) East Coast of USA and West Coast of South America;

(3) Europe and the West Coast of South America;

(4) East Coast of USA and West Coast of Central America and

(5) Coast to Coast of South America.

Panama is the anchor point of the Caribbean transhipment triangle – a configuration of hub ports within the Caribbean basin. It is geographically located at the narrowest point of the Central American isthmus, which connects the countries with commercial activities in the Atlantic and Pacific oceans. It provides accessibility which competitively binds the major global markets, i.e. Asia, Europe, North and South America (Panama Canal Authority, 2019). The Caribbean Sea facilitates transhipment activities that include ports that form corners of the triangle, namely, Freeport, ColonKingston, and Port of Spain, benefits from the strategic position near USA East, while Port of Spain (Trinidad and Tobago (TT)) service has a transhipment port for the Lesser Antilles of the Caribbean (Rodrigue, 2020; McCalla *et al.*, 2005). Most of the countries within the transhipment triangle are well-positioned to benefit economically from the increase in TEU volumes (Notteboom *et al.*, 2021; Rodrigue and Ashar, 2016; Marle, 2016).

2.2 Port development, trade and economic growth

The LAC and Caribbean region comprises Mexico, Central America, South America and the Caribbean. In 2020, the International Monetary Fund reported sluggish 2019 growth of 0.9%

for the region, compared with 2.3% in 2018. Despite growth in 2019 being less than expected, economic activity in the region was actually on an upward trajectory, moving from −0.4% in 2017 to +0.9% in 2019. Figure 2 shows the GDP growth for the LAC region for pre- and post-PCE period. GDP growth in 2014 was US$ 6.4tn, sharply declined to US$ 5.4tn in 2016, increased to US$ 6.0tn in 2017, then gradually decreased to US$ 5.7tn in 2019.

Shan *et al.* (2014) suggests that a 1% increase in port cargo can increase GDP per capita growth by 7.6% and port throughput positively impacts neighboring economies. Similarly, analyzing the impact of the PCE on the economic development within the LAC region since the advent of neo-Panamax vessels is essential for determining the PCE causal effect. Therefore, the PCE may serve as an economic intervention since maritime transport is the backbone of international trade and global economic growth (UNCTAD, 2019).

The PCE has increased cargo tonnage and vessel traffic throughout the LAC region, stimulating maritime growth in TEUs and transhipment activities (Rodrigue, 2020). The advent of the Neo-Panamax vessels through the expanded canal's third lock has influenced regional governments to politically evaluate the feasibility of economic growth through seaport activities (Nicholson and Boxill, 2017). This has motivated requests for public funds and foreign direct investment (FDI) to develop existing regional infrastructure or the construction of new facilities to accommodate mega-ships (neo-Panamax and post-Panamax). For example, the expansion of the Kingston Container Terminal (KCT) involved an investment of approximately $510mn. Additionally, the development of the port facilities at Montego Bay, known as the Montego Freeport, has seen investments of over US$350mn.

Shan *et al.* (2014) used econometric analysis to study the effect of the seaport economy on major ports in China from 2001 to 2010. The result showed a positive relationship between port cargo and the host city's economic growth. A similar result was noted in Tunisia's economic growth between 1987 and 2014. Jouili (2016) used an econometric model based on the Cobb-Douglas production function and identified a positive relationship between investments in seaports and the country's GDP. Similarly, Michail (2020) used the vector error correction model (VECM) to investigate the relationship between seaborne transport demand (as measured by the price of oil) and the global economic environment and concluded that trade volumes (as measured by crude oil, petroleum products and dry cargo transported) are affected by the global economic environment. The positive correlation between trade and economic development was further examined by Lane and Pretes (2020), who explored the five factors in maritime dependency correlation to economic prosperity. Their findings reveal a significant relationship between maritime dependency and economic prosperity. Furthermore, Osadume and Blessing (2020) used the Granger causality and Bound test

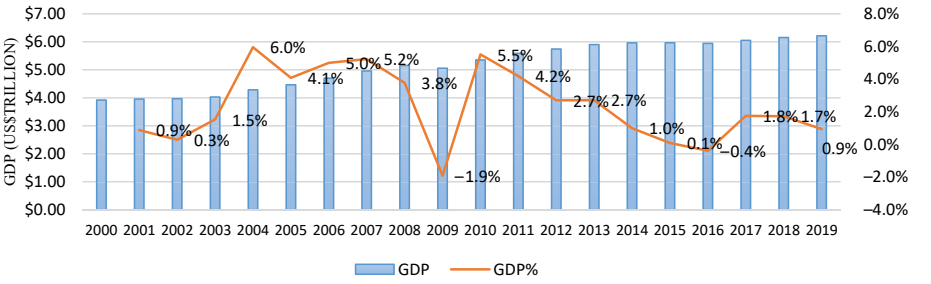

Figure 2.
LAC's GDP growth 2000–2019

Source(s): Created by authors

approach to examine this relationship between maritime trade and economic development and arrived at a similar conclusion – there exists a positive correlation between maritime trade and economic growth. This is possible with active integration into the global supply chain through coordination and coordination (Jung, 2012) and the supporting port infrastructure and logistics performance (Munim and Schramm, 2018). Failure to do so will result in the failure of the port; this can be seen in Korea in the 1980s (Jung, 2012). Therefore, as ports continue to play a significant role in a country and a region's economic development and economies diversify into newer economic sectors (Grossmann, 2008), it is essential that there is a clear understanding of the interlinkages needed to maximize the impact of a port expansion on the nation's economy. With the relationship between economic growth and seaborne trade established, we can conclude that the development of infrastructure to support global trade can result in increased rates of economic growth as in the case of Singapore, Holland and China (Grossmann, 2008; Munim and Schramm, 2018).

2.3 LAC container throughput growth by region

Container throughput (TEU) in the LAC port system grew from 15.9mn TEUs in 2000 to 53mn TEUs in 2019 (World Bank, 2020), which is 6.7% of all global port movement. The three (3) sub-regions, namely South America, Central America and the Caribbean saw increases ranging between 10 and 18%. The Caribbean was the lowest at 10%, followed by South America with an increase of 12%, with Central America at 18% (See Table 1). This is post-PCE and in 2019, before the onset of the coronavirus disease 2019 (COVID-19) pandemic which significantly affected global trade, ten (10) Latin America and the Caribbean countries accounted for 85% of all cargo shipped in the region.

2.4 Economies of scale

Doubling the maximum container ship size has reduced total vessel cost per shipped container by roughly 35% over the last decade (Merk, 2018; Helmy and Shrabia, 2016) and containerization has undoubtedly contributed to decreased transportation costs (OECD, 2015). On the other hand, although the economy of scale may benefit liner shipping, as the ship's size increases, the diseconomies are more apparent within a port infrastructure and operations (Rodrigue, 2020). Lim (1998) and Kapoor (2016) study the impact of mega-ship on ports and economies of scale. Their studies revealed the diseconomies increases for vessels over 18,000 TEUs. Ports within the LAC region have made substantial investments in port development to acquire ship-to-shore (STS) gantry for Neo-Panamax vessels, deepening channel and hinterland expansion. The regional countries invested in port development and

Rank	Country	Throughput
1	Brazil	10,396,182
2	Panama	7,347,000
3	Mexico	7,100,644
4	Chile	4,496,578
5	Colombia	4,402,574
6	Peru	2,678,258
7	Ecuador	2,127,042
8	Dominican Republic	1,894,225
9	Argentina	1,771,628
10	Jamaica	1,647,609

Source(s): Created by authors

Table 1. Latin America and the Caribbean top 10 ports (TEU)

logistics infrastructure to gain economic benefits from the PCE. Although container shipping has benefited from economies of scale in maritime shipping, an overview of the authors revealed. However, as ships increase in the TEUs, the benefits of lower cost per TEUs increase, thus, there is a powerful trend towards increasing ships' size, but this may lead to "diseconomies of scales" of mega-ships that may not necessarily benefit some regional ports (Rodrigue, 2020).

The PCE is an intervention that seeks to increase maritime activities within the USA and Latin American regions. The project's sole purpose is to allow the PC to accommodate mega-ships (Neo-Panamax and some Post-Panamax vessels) to reduce the bottleneck effect and remain a competitive route to the SC. Several authors' studies agreed that PCE increases maritime traffic within the region (Lim, 1998; Rodrigue and Notteboom, 2021; Grossmann, 2008; Munim and Schramm, 2018). However, recent studies have revealed that PCE may not impact port throughput with in the LAC region. Chavez-Rodriguez (2023), studied the impact of the expansion on regional transhipment ports throughput during the period of 2010–2022. The findings indicated that the PCE did not result in a statistically significant impact on the cargo tonnage, cargo TEU and vessel calls at the port. Therefore, if port throughput is low, it will have a negative impact on the economic outlook for certain transshipment ports in the region.

The strong correlation between seaborne trade and economic growth has influenced regional governments' initiatives to promote port development (Nicholson and Boxill, 2017; Rodrigue, 2020; Jouili, 2016; Zhang and Zhang, 2005; Shan *et al.*, 2014). Several authors, using econometrics (Rodrigue and Notteboom, 2021; Lim, 1998), the structural equation model (Munim and Schramm, 2018) and the Bayesian model (Zhang and Zhang, 2005; Shan *et al.*, 2014) agreed that economy of scale had impacted port development, port infrastructure and operation, freight rate and maritime traffic.

However, there is no study done on the PCE impact on the economy of LAC since the advent of Neo-Panamax vessels. Therefore, this research stands to fill this research gap. It will focus on the PCE effects on LAC's economic growth in conjunction with socio-economic co-variables such as HDI and unemployment using the BSTS model. Maritime transport is the backbone of international trade and the economy (IMO, 2019). Therefore, maritime transport is essential to a country's socio-economic development.

3. Methodology

3.1 Sampling and data collection

For the BSTS analysis of 21 countries in the Latin American and Caribbean (LAC) region, primary data on gross domestic product (GDP), human development index (HDI), container throughput (TEUs) and unemployment rates (UNEMPL) will be used. Due to limited data availability, some countries have been excluded from the analysis, including Puerto Rico (USA), Bolivia, French Guinea, Guyana, Paraguay, Suriname, Venezuela and some small Caribbean states. Please refer to Table 2 for a list of the LAC countries that are included in the model, along with their GDP, HDI, TEUs and UNEMPL data from 2000 to 2019, covering both pre and post eras.

The study aims to assess the economic impact of the PCE on countries in the LAC region. In the BSTS model, GDP will be the primary variable, while HDI (X1), TEUs (X2) and UNEMPL (X3) will serve as covariates. The data for this analysis were sourced from the World Bank for the period 2000 to 2019. GDP is the total value of goods and services produced within a country's borders, while gross national income (GNI) measures a country's wealth based on the money earned by people and businesses.The HDI is a composite index used to rank countries into four tiers of human development based on life expectancy, education and per capita income. Container throughput (TEUs) measures container handling activity, which includes import and export as well as transshipment (World Bank, 2020).

LAC	Region	Growth rate GDP ($US) billion (%) (Y)		Growth rate HDI (%) (X_1)		Growth rate throughput (TEUs), (%) (X_2)		Growth rate UNEMPL (%) (X_3)	
		Pre-PCE	*Post-PCE*	*Pre-PCE*	*Post-PCE*	*Pre-PCE*	*Post-PCE*	*Pre-PCE*	*Post-PCE*
Argentina	South America	9	−20	1	1	−13	25	0.39	1.87
Bahamas	Caribbean	9	14	0.1	0.5	9.5	22.8	−2.02	−2.59
Brazil	South America	−27.1	2.2	2.9	0.9	13.9	18.2	1.24	0.33
Belize	Central America	13.2	5.9	1.3	−0.1	16.3	−3.3	−0.54	0.76
Chile	South America	−8.9	12.8	0.6	0.7	12.7	12.5	−0.15	0.78
Cuba	Caribbean	19.1	9.4	0.4	1.3	8.3	15.1	−0.73	−0.33
Colombia	South America	−21	14.5	−6.5	17.1	6.4	23.3	−1.44	1.27
Costa Rica	Central America	17.9	8.1	1.8	1.1	9.3	14.3	−0.78	2.89
Dominican Republic	Caribbean	17.3	17.5	3.4	1.7	−21.7	1.5	0.89	0.92
Ecuador	South America	12.9	7.1	1.7	0.1	14.7	9.9	−0.26	−2.43
Honduras	Central America	13.2	15.6	1.0	1.3	11.5	4.4	2.4	1.16
Guatemala	Central America	23.4	16.1	23.4	16.1	19.0	4.0	−0.15	−0.38
Haiti	Caribbean	8.4	4.4	2.9	2.0	8.5	−4.0	−0.15	−0.47
Jamaica	Caribbean	−4.2	16.9	0.0	0.4	−10.9	13.3	−0.42	−5.47
Mexico	Central America	−2.50	17.6	0.92	1.4	12.9	25.3	−0.58	0.38
Panama	Central America	33.79	15.4	1.65	1.2	15.1	17.4	0.61	1.42
Peru	South America	−1.55	18.2	2.29	1.6	6.57	0.5	0.02	−0.35
El Salvador	Central America	9.60	11.7	−0.15	0.3	6.32	23.4	0.16	−0.46
Trinidad and Tobago	Caribbean	−2.72	8.9	1.54	0.5	−3.97	−13.9	−1.29	0.25
Uruguay	South America	4.01	4.7	1.64	0.9	7.61	−15.5	1.04	1.51
Paraguay	South America	15.2	−2.6	2.85	0.8	12.9	−0.1	0.47	1.34
LAC	Region	3.91	4.6	1.49	0.8	6.07	14.0	−0.2	0.00

Note(s): This data presents the Gross Domestic Product (GDP) of L.A.C. along with the human development index (HDI) and unemployment rate (%) from the years 2000–2019. It is divided into two periods: Pre-PCE (2012–2015/16) and Post-PCE (2016–2019)
Source(s): Created by authors

Table 2.
LAC's GDP, HDI and unemployment rate from 2000–2019

3.2 Models

3.2.1 Structural time series models. Structural time series (STS) models are statistical models used to decompose a time series into various underlying components, which can provide insights into the underlying patterns and structures present in the data. There are two

equations that define a structural time series model. First, the observation equation relates the observed data y_t to a vector of latent variables α_t known as the "state."

$$y_t = Z_t^T \alpha_t + \epsilon_t \, (Observation\ equation) \tag{3-1}$$

The *transition equation* describes how the latent state evolves through time.

$$\alpha_{t+1} = T_t \alpha_t + R_t \eta_t \, (Transition\ or\ state\ equation) \tag{3-2}$$

The error terms ϵ_t and η_t are Gaussian and independent of everything else. The arrays Z_t, T_t, R_t are structural parameters. They may contain parameters in the statistical sense, but often they simply contain strategically placed 0's and 1's indicating which bits of α_t are relevant for a particular computation.

The term $R_t \eta_t$ allows us to incorporate state components of less than full ranks. The simplest useful model is the "local level model," in which the vector α_t is just a scalar μ_t. The local level model is a random walk observed in noise.

$$\begin{aligned} y_t &= \mu_t + \epsilon_t \\ \mu_{t+1} &= \mu_t + \eta_t \end{aligned} \tag{3-3}$$

Here $\alpha_t = \mu_t$ and z_t, T_t and R_t all collapse to the scalar value 1. Like Bayesian hierarchical models for nested data, the local level model comprises two extremes.

3.2.2 State components. Scott and Varian model for the data using three state components; a trend μ, a seasonal pattern τ_t and a regression component of $Z_t^T \alpha_t$ *which is removed based on the objective of the model. The extra term of* δ_t when t and t+1, where $\eta_t = (u_t, v_t, w_t)$ contains independent components of Gaussian random noise. The current level of trend is μ_t and the current slope of the trend is δ_t. The seasonal component τ_t can be thought of as a set of S dummy variables with dynamic coefficients constrained to have zero expectation over a full cycle of S seasons.

The Bayesian Structural time series (BSTS) model was used to determine the economic impact of the PCE within the LAC regions. The structural time-series models are state-space models for time-series data supported by Takyi and Bentum-Ennin (2021), Chipman (2010), Scott and Varian (2015), Feroze (2020), Scott and Varian (2014) and Brodersen *et al.* (2015). For simplification purposes, the BSTS model was defined according to Takyi and Bentum-Ennin (2021) into seasonality to evaluate the PCE's impact on LAC GDP performance:

$$\begin{aligned} y_t &= \mu_t + \tau_t + \varepsilon_t, \varepsilon_t N\left(0, \sigma_t^2\right) \\ \mu_{t+1} &= \mu_t + w_t \,, w_t N\left(0, \sigma_w^2\right) \\ \tau_{t+1} &= \sum_{s=0}^{s-2} \tau_{t+1} + V_t, V_t \sim N\left(0, \sigma_V^2\right) \end{aligned} \tag{3-4}$$

where y_t is the GDP for each LAC country within three (3) sub-regions (South America, Central America and the Caribbean) at a time (year) t, $\varepsilon_t N(0, \sigma_t^2)$, $w_t N(0, \sigma_w^2)$ and $V_t \sim N(0, \sigma_V^2)$ or iid standard errors (Takyi and Bentum-Ennin, 2021). The μ_t is the value of the trend at time t. w_t is the predictable increase in μ between times t and t + 1 and also be referred to as the slope at time t (Scott and Varian, 2015). And τ_t is referred to as the cyclical element, with S being the number of seasons.

3.3 Data analysis

Data was imported from the World Bank using RStudio, which is an integrated development environment for a programming language for statistical computing and graphics. The BSTS

package found in R was used to run the Bayesian structural time series (BSTS) model. This package uses spike and slab prior for the regression component of the model and Kalman filter for the time-series component (Kitamura, 2018). The PCE impact on the economy of 33 LAC countries using the intervention evaluation under this model, which is the focus of this research.

4. Results

In this section, we will discuss the results of both the Bayesian posterior estimates for the causal effect of the PCE on the GDP for each of the 21 countries within the LAC region. The absolute effects from posterior estimates for each country within the three (3) sub-regions will also be discussed in this section.

4.1 LAC

According to Table 3, the impact of PCE (relative effect) on economic growth (GDP) in the LAC region was −1% [95% credible interval: −9.2%; 7.4%]. This calculation was based on TEUs, HDI and UNEMPL covariates. The *P* value for the covariate of TEUs was 0.389, while the *P*-value for HDI was 0.080 and it was 0.001 for UNEMPL.

4.2 Central America

The analysis of Central American countries included seven: Panama, El Salvador, Mexico, Honduras, Guatemala, Belize and Costa Rica. Out of these, only four showed statistically significant results (Panama, Honduras, Guatemala and Belize), while the other three (El Salvador, Mexico and Costa Rica) yielded insignificant results (refer to Table 4).

4.2.1 Of statistical significance. The four (4) neighboring countries of Panama, Honduras, Guatemala and Belize had results that were not only statistically significant, but also had positive growth post-PCE (See Table 4).

(1) On average, the economic performance (GDP) in Panama was around US$64.7bn. However, if there had been no expansion, it was predicted to be US$57.10bn [95% credible interval: US$ 47.15bn, US$ 67.32bn]. As a result of the expansion, the GDP performance increased by approximately US$7.51bn [95% credible interval: 2.70B, 18.57B], which is a statistically significant increase of around 13% [95% credible interval: 18%; 50%].

		GDP			
Region	Actual	Prediction (s.d)	Absolute effect (s.d.)	Relative effect (s.d.)	Posterior tail-area probability
LAC	6.10E+12	6.2e+12 (2.3e+11) [5.8e+12, 6.7e+12]	−6.8e+10 (2.3e+11) [−5.1e+11, 3.6e+11]	−1% (3.9%) [−8.4%, 6.6%]	0.383
Covariates (TEUs, HDI,UNEMPL)					
p-values		*TEUs (0.389) HDI (0.004)*** UEMPL (0.008)****			

Note(s): The values in the brackets show a 95% confidence interval, while those in the parentheses are standard deviations. ****p* < 0.01, ***p* < 0.05, **p* < 0.1 significance level and p stands for Posterior tail-area probability

Source(s): Created by authors

Table 3. Results of posterior estimates (inference) of the PCE on LAC's GDP

Central America	Actual	Average Prediction (s.d)	Average Absolute effect (s.d.)	Average Relative effect (s.d.)	Posterior tail-area probability
Panama	6.50E+10	5.7e+10 (5.2e+09) [4.7e+10, 6.7e+10]	7.5e+09 (5.2e+09) [−2.7e+09, 1.8e+10]	13% (9.1%) [18%, 50%]	0.059*
El Salvador	2.60E+10	2.6e+10 (1.4e+09) [2.4e+10, 3.0e+10]	−4.3e+08 (1.4e+09) [−3.3e+09, 2.3e+09]	−1.6% (5.5%) [−12%, 8.7%]	0.376
Mexico	1.20E+12	1.2e+12 (6.7e+10) [1.1e+12, 1.4e+12]	−7.4e+10 (6.5e+10) [−1.9e+11, 6.4e+10]	−5.7% (5.1%) [−15%, 4.9%]	0.125
Honduras	2.40E+10	2.2e+10 (1.2e+09) [2.0e+10, 2.4e+10]	2.4e+09 (1.2e+09) [1.6e+08, 4.5e+09]	11% (5.3%) [−6.4%, 10%]	0.019**
Guatemala	7.40E+10	6.4e+10 (4.1e+09) [5.7e+10, 7.3e+10]	9.8e+09 (4.1e+09) [6.8e+08, 1.7e+10]	15% (6.4%) [1.1%, 26%]	0.024**
Costa Rica	6.00E+10	6.4e+10 (3.3e+09) [5.8e+10, 7.0e+10]	−3.7e+09 (3.6e+09) [−3.4e+10, 1.0e+10]	6.3% (6.2%) [−6%, 18%]	0.158
Belize	1.90E+09	1.7e+09 (4.8e+07) [1.6e+09, 1.8e+09]	1.6e+08 (7.5 +07) [1.4e+07, 3.1e+08]	9.2% (2.8%) [2.8%, 14%]	0.015**

Table 4.
Results of posterior estimates (Inference) of the PCE on Central America's GDP

Note(s): The values in the brackets show a 95% confidence interval, while those in the parentheses are standard deviations. ***$p < 0.01$, **$p < 0.05$ and *$p < 0.1$ significance level and p stands for Posterior tail-area probability
Source(s): Created by authors

(2) In the case of Honduras, the country's economic performance averaged approximately US$24.09bn. In relative terms, GDP performance increased by approximately 11% with a 95% interval [−6.4%, 10%]. The probability of obtaining this effect by chance is minuscule (Bayesian one-sided tail-area probability $p = 0.018$). Nevertheless, this causal effect can be considered statistically significant.

(3) Similarly, Guatemala had an average GDP of US$74bn with a predicted value of US$64.01bn with a 95% confidence interval [5.7e+10, 7.3e+10]. In comparative terms, the economic performance was 15% better than it would have been without the PCE, with a 95% confidence interval [1.1%, 26%]. Therefore, the causal effect was statistically significant, with a posterior tail-area probability of 0.024 or 2.4%.

(4) Finally, in Belize, GDP averaged approximately US$1.8b during the post-PCE-era. The relative effect for GDP was 9.2% [2.8%, 14%]. With the posterior tail-area probability of 0.015 or 1.5%, the causal effect was also statistically significant at a 5% level.

4.2.2 Of statistical insignificance. The insignificant results imply that the economy of these countries may be influenced by other factors besides the PCE, such as exogenous and endogenous factors.

(1) The economy of Costa Rica was evaluated at around US$60.3bn, indicating an impact of 6.3% [95% credible interval: −6.0%, 18%]. Nevertheless, this impact does not hold statistical significance.

(2) On the contrary, El Salvador's economy averaged around US$26bn, but experienced a slight decrease of 1.6% [95% credible interval: 12%; 8.7%]. The predicted value for

GDP is around US$22bn [95% credible interval: 24.1B, 30.3B], but the negative effect was not statistically significant.

(3) Similarly, Mexico's GDP has averaged around US$1.22tn. The projected value is US$1.20tn with a 95% range of [1.1e+12, 1.4e+12]. This represents a decrease in GDP performance of roughly 5.7% at a 95% confidence interval of [-15%, 4.9%]. However, the outcome was statistically insignificant.

4.3 South America

Table 5 shows that during the post-PCE era, South America saw mixed economic results. Among the countries in the region, only Brazil experienced a positive impact on its economy, with a statistically significant increase of 27% in GDP [95% credible interval: −1.45%; 3.8%]. In contrast, Colombia saw a statistically significant decrease in economic growth of −16.3% [95% credible interval: 30%; −2.6%]. The results were statistically insignificant in Argentina, Chile, Ecuador, Peru, Paraguay and Uruguay.

4.3.1 Of statistical significance. In 2019, Brazil's economy was valued at about US$1.93tn following the PCE (see Table 5). This resulted in a positive effect of US$410bn, with a 95% interval ranging from −2.2e+10 to 9.0e+11. The GDP performance increased by approximately 27% in relative terms, with a 95% interval of −1.45%–3.8%, which was statistically significant. There was only a 3.4% chance that the PCE would negatively affect Brazil's GDP performance, as indicated by the posterior tail-area probability value of 0.034.

On the other hand, during the post-PCE-era, the economic performance of Colombia averaged around US$323.33bn. This resulted in an effect of −16.3%, with a 95% credible interval of −30% to −2.6%. In relative terms, the GDP performance decreased by about 16.3%, with a 95% interval of −30% to −1.7%. The effect was statistically significant when considering the entire post-intervention period.

South America	Actual	*Average* Prediction (s.d)	Absolute effect (s.d.)	Relative effect (s.d.)	Posterior tail-area probability
Argentina	5.4e+11	5.2e+11 (2e+10)	−1.8e+10 (3.7e+10)	−3.3% (6.8%)	0.287
		[4.9e+11, 5.6e+11]	[−9.1e+10, 4.7e+10]	[−16%, 8.5%]	
Brazil	1.9e+12	1.5e+12 (2.3e+11)	4.2e+11 (2.3e+11)	27% (13%)	0.034**
		[1.0e+12, 2.0e+12]	[−2.2e+10, 9.0e+10]	[−1.45%, 3.8%]	
Chile	2.9e+11	2.7e+11 (1.1e+10)	6.8e+09 (1.5e+10)	2.5% (5.2%)	0.323
		[2.5e+11, 3.0e+11]	[−2.3e+10, 3.5e+10]	[−8.7%, 13%]	
Colombia	3.2e+11	3.2e+11 (3.1e+10)	−6.3e+10 (2.7e+10)	−16.3% (8.7%)	0.007***
		[3.9e+11, 4.1e+11]	[−1.1e+11, 8.7e+09]	[−30%, −2.6%]	
Ecuador	1.1e+11	1.1e+11 (5.6e+09)	6.4e+09 (6.7e+09)	6.4% (6.9%)	0.189
		[8.6e+10, 1.1e+11]	[−7.9e+10, 2.0e+09]	[−7.2%, 20%]	
Peru	2.2e+11	2.2e+11 (9.1e+09)	3.1e+09 (10.1e+10)	1.2% (6.2%)	0.412
		[1.9e+11, 2.4e+11]	[−1.6e+10, 2.0e+10]	[−12.3%, 14%]	
Paraguay	1.2e+10	1.2e+10 (5.2e+08)	5.5e+08 (5.2e+08)	4.4% (4.6%)	0.169
		[1.1e+10, 1.3e+10]	[−6.8e+08, 1.5e+09]	[−4.34%, 13%]	
Uruguay	6.1e+12	5.9e+12 (2.2e+11)	2.3e+11 (2.2e+11)	−1.6% (5.3%)	0.350
		[5.4e+12, 6.4e+12]	[−1.9e+07, 7.8e+07]	[−10.6%, 9.7%]	

Note(s): The values in the brackets show a 95% confidence interval, while those in the parentheses are standard deviations. ***$p < 0.01$, **$p < 0.05$ and *$p < 0.1$ significance level and p stands for Posterior tail-area probability

Source(s): Created by authors

Table 5. Results of posterior estimates (inference) of the PCE on South America economic (GDP)

4.3.2 Of statistical insignificance. Out of the remaining five (5) South American countries, their statistical insignificance was not enough to draw conclusive results (See Table 5).

(1) Argentina's post-PCE-era average economic performance was around US$ 535.67bn, resulting in a 5.1% decrease in relative GDP performance. The negative impact was approximately US$-29.60bn, with a 95% interval of [−1.1e+11, 5.1e+10]. However, the intervention's positive effect was not statistically significant throughout the post-intervention period.

(2) During the post-PCE-era, Ecuador had an average economic performance of around US$110.33bn, with a positive effect of US$6.50bn and an 8.8% increase in GDP performance. However, this effect is not statistically significant when considering the entire post-intervention period, with a 6.6% chance that the PCE had a negative effect on GDP performance in Ecuador.

(3) Peru had an average economic performance of about US$220.00bn during the post-PCE-era, with a non-statistically significant effect of US$310mn and a 1.4% increase in GDP performance. There was also a 41.9% chance that the PCE would negatively affect GDP performance in Peru.

(4) Paraguay had an average economic performance of US$12.07bn, with a non-statistically significant effect of US$950mn and a 4.3% increase in GDP performance.

(5) Uruguay had an average economic performance of about US$6141.40bn, with a non-statistically significant effect of US$41bn and a −1.8% increase in GDP performance.

(6) Chile had an average economic performance of US$285.67bn, with a non-statistically significant effect of US$6.81bn and a 2.5% increase in GDP performance, with a range of −8.7%–13%.

4.4 The Caribbean

Table 6 indicates that all Caribbean countries within the BSTS model, except for TT, exhibited statistical significance for GDP. Cuba, the Dominican Republic, Jamaica and the Bahamas all showed a positive impact on GDP, with statistical significance at a 5% level. The positive results were 46%, 9.3%, 12% and 7.9%, respectively. However, Haiti showed a negative impact, resulting in a decrease of 5.5% in GDP.

4.4.1 Of statistical significance.

(1) Table 6 shows Cuba's economy had a value of approximately US$98.95bn. This effect is US$31.10bn with a 95% interval of [−1.6B, 4.71B]. Thus, GDP performance increased approximately by 46% in relative terms with a 95% interval of [24%, 69%]. This positive effect observed during the PCE is statistically significant at a 5% significance level. Also, the posterior tail-area probability value of 0.001 indicates a 0.1% chance that the PCE would have a negative effect on the GDP performance in Cuba.

(2) The Bahamas' economic performance recorded an average of approximately US$ 13.03bn. This effect is US$950mn with a 95% interval [1.6e+08, 1.73e+09]. In relative terms, GDP performance increased by approximately 7.9% percent. The 95% interval of this percentage is [0%, 11%]. This positive effect was statistically significant at the 5% level, with a posterior tail-area probability value of 0.012, indicating a 0.12% chance that the PCE would negatively affect the GDP performance in the Bahamas.

Caribbean	Actual	Average Prediction (s.d)	Absolute effect (s.d.)	Relative effect (s.d.)	*p*-value
Cuba	9.90E+10	6.8e+10 (7.4e+09) [5.2e+10, 8.3e+10]	3.1e+10 (8.1e+09) [1.6e+11, 4.7e+10]	46% (12%) [24%, 69%]	0.001***
Dominican Republic	8.50E+10	7.8e+10 (4.4e+09) [6.9e+10, 8.6e+10]	7.2e+10 (4.4e+09) [−1.2e+10, 1.6e+10]	9.3% (5.7%) [17%, 33%]	0.048**
Haiti	1.50E+10	1.6e+10 (6.6e+08) [1.4e+10, 1.7e+10]	8.9e+08 (6.2e+08) [−2.1e+09, 3.0e+08]	−5.5% (4.2%) [−13%, 1.9%]	0.084*
Jamaica	1.60E+10	1.4e+10 (1.8e+08) [1.4e+10, 1.4e+10]	1.5e+09 (1.8e+08) [1.2e+09, 1.9e+09]	12%*** (1.3%) [8.3%, 13%]	0.001***
Trinidad and Tobago	2.40E+10	2.4e+10 (3.2e+09) [1.6e+10, 2.9e+10]	[−8.4e+08, 3.3e+09] [−5.3e+09, 7.9e+09]	−3.4% (14%) [−22%, 30%]	0.292
Bahamas	1.30E+10	1.1e+10 (3.9e+08)	9.3e+08 (3.9e+08)	7.7% (3.1%)	0.012***

Note(s): The values in the brackets show a 95% confidence interval, while those in the parentheses are standard deviations. ***$p < 0.01$, **$p < 0.05$ and *$p < 0.1$ significance level and p stands for Posterior tail-area probability

Source(s): Created by authors

Table 6. Results of posterior estimates (inference) of the PCE on Caribbean economic (GDP)

(3) The Dominican Republic's economic performance had an average of approximately US$ 84.83bn. This effect is US$7.2bn with a 95% interval of [−1.2e+10, 1.6e+10]. In relative terms, GDP performance increased by approximately 9.3% percent. The 95% interval of this percentage is [17%, 33%]. The intervention appeared to have caused a positive effect and was statistically significant at a 5% level with a posterior tail-area probability value of 0.050.

(4) Jamaica's economic performance had an average of approximately US$ 16.24bn. This effect is US$1.52bn with a 95% interval of [1.2e+09, 1.9e+09]. In relative terms, GDP performance increased by approximately 12% percent. The 95% interval of this percentage is [8.3%, 13%]. This positive effect observed during the PCE was statistically significant at a 5% significance level. Also, the posterior tail-area probability value of 0.001 indicates a 0.1% chance that the PCE would have a negative effect on the GDP performance in Jamaica.

(5) Unlike Cuba, the Bahamas, Dominican Republic and Jamaica, TT's economic performance which was valued at approximately US$29.1bn decreased by approximately 3.9% with a 95% confidence interval [−20%, 0.23%]. This effect is negative US$2.7bn with a 95% interval [−5.4e+09, 6.0e+07]. However, this effect was not statistically significant when considering the entire post-intervention period. This could be a result of the market segment that predominately Oil tanker vessels and it the economic slowdown in China (World Bank, 2020).

(6) In the period following the PCE, Haiti's economy had an average performance of around US$14.60bn. The negative causal effect was US$1.1bn with a 95% interval of [−2.5e+09, 2.3e+08]. This means that GDP performance decreased by approximately 6.6%, with a 95% interval of [−15%, 1.4%]. Despite this, the intervention had a negative effect that was statistically significant throughout the whole post-intervention period.

4.4.2 Of statistical insignificance.

(1) TT's economy averaged $23.52bn after PCE, but suffered a negative impact of $2.7bn. GDP performance decreased by about 10% during PCE and the introduction of Neo-Panamax, with a 0.1% chance of positive effects on GDP performance.

The result revealed that several countries in Central America, such as Panama, Honduras, Guatemala and Belize, experienced significant GDP growth ranging from 9.2% to 15% since the PCE. Brazil was the only country in South America with a statistically significant positive economic growth of 27%. Meanwhile, Cuba, Bahamas, Dominican Republic and Jamaica in the Caribbean region experienced GDP growth ranging from 7.7% to 15%, which was statistically significant. However, Colombia and Haiti had negative growth during the PCE. Table 3 showed that the PCE impact on GDP growth for the overall LAC economy was −1% and not statistically significant.

5. Discussion

The findings of the BSTS model revealed that the PCE had a positive and statistical significant impact on a number of countries in the LAC region; Panama, Honduras, Guatemala, Belize, Cuba, Brazil, Colombia, Haiti, Jamaica, Bahamas and the Dominican Republic. The other countries within the model were not statistically significant, as shown in Tables 4–6 during the period 2000 to 2019. Furthermore, Table 3 shows that the economic growth (GDP) for LAC region declined during the Post-PCE era, using covariates of TEUs, HDI and UNEMPL, whereby all covariates were statistical significant except for TEUs.

The introduction of New Panamax vessels has increased the capacity and efficiency of trade routes (Table 2). This has resulted in the boosting of international trade and economic activity in the region with positive impacts for Panama, Honduras, Guatemala, Belize, Cuba, Brazil, Jamaica, Bahamas and the Dominican Republic. Consequently, these countries stand to benefit from the strong correlation between seaborne trade and economic growth, which is fueled by economies of scale, as evidenced by the impact of Neo-Panamax and some Post-Panamax vessels on port development, port infrastructure and operation, freight rates and maritime traffic. Therefore, countries that have positive and statistical significant growth since the PCE show strong correlation between seaborne trade and economic growth, which can inherently reducing unemployment and improving the HDI. This correlation is supported by regional integration, port and logistics infrastructural development.

Countries within the Caribbean Transshipment Triangle and some major regional ports such as Santos, Brazil depicted positive and statistical significant GDP growth since the PCE. However, for non-transshipment port countries, the impact of the PCE on economic growth for container volume (TEUs) were statistically insignificant, except for Honduras, Belize and Guatemala with positive GDP growth since PCE (Table 4). It is noteworthy to mention that the BSTS model has demonstrated that the container shipping volume (TEUs), does not significantly impact the GDP of most South American countries, with the exception of Brazil, due to their dominant use of Bulk Carriers and Tanker carriers for exports, global economic conditions, commodity prices, geopolitical developments and domestic policies. This suggests that other factors, such as global recession, trade policies, port proximity and variations in port investment and ship classification in trading routes, were more influential towards their GDP growth.

Economic growth since the PCE has been influenced by a myriad of factors such as ship classification, infrastructural development, shifting shipping routes, regional competition, trade agreements, commodity prices, geopolitical developments and domestic policies (Chavez-Rodriguez, 2023; Jung, 2012; UNCTAD, 2019; Lane and Pretes, 2020). However, the trade diversity of the three (3) sub-regions; Caribbean, Central and South America also depict unique economic model that varies per region. Therefore, trade segments determine ship classification. This means that large export driven economies in the Central and South America that trade using predominately bulk and tanker vessels, would expectedly have positive growth since the PCE but statistical insignificance using the covariate of TEUs. This is evident for countries such as, Chile, Peru, Ecuador, Paraguay and Costa Rica (Tables 4–6).

The export portfolio, economic model, global value chains and trade policies in the LAC region are in a constant state of flux and vary depending on the sub-regions. These internal and external factors create a highly dynamic trade and economic environment that demands meticulous attention and careful consideration. This research presents empirical evidence regarding the impact of the expansion of the PC on economic growth (GDP) in the LAC region, which is of great significance for academic purposes. Notably, the effect of PCE on economic growth is contingent on the trading practices of each country. Ship categorization also plays a pivotal role in the forecasting models utilized to evaluate the impact of interventions in the maritime sector. The study suggests that future research should consider export volumes across different ship classifications, as well as other social and economic factors such as infrastructure, logistics, government policies, trade regulations, political stability, security, environmental regulations and sustainability, to assess the impact of PCE on the region comprehensively. The findings of this study could have practical implications for policy-makers, investors and economists.

5.1 Limitation

This study has certain limitations, as it focused only on a small sample size of 21 of 33 Latin American countries from the World Bank database. The exclusion of twelve (12) countries due to a lack of data may have further impacted the study's scope. Additionally, the study did not analyze China's economic slowdown, which undeniably impacted Latin American countries. While the data displayed a slow recovery from the recession, as illustrated in Figure 2, the economic growth observed from BSTS results could be attributed to regional recovery rather than PCE influence. Notably, the absence of regional tonnage data from bulk and oil tanker vessels is a significant limitation that requires remedying. Excluding such data could adversely affect the overall accuracy and comprehensiveness of the study's findings, especially when assessing the economic impact of maritime activities in a specific region or country. Unfortunately, the model did not incorporate COVID-19 pandemic data from 2020 to 2022, which may limit its relevance and overlook the pandemic's crucial impacts.

5.2 Robust checks

Note that the definitions of all the variables and the parameters in Equations (3)-(5) are the same as those in Equations (3)-(4) with the introduction of an additional explanatory variable (GNI) and parameter β.

$$\begin{aligned} y_t &= \mu_t + \tau_t + \beta^T(GNI) + \varepsilon_t, && \varepsilon_t\, N\left(0, \sigma_t^2\right) \\ \mu_t &= \mu_{t-1} + \delta_{t-1} + u_t\,, && u_t\, N\left(0, \sigma_u^2\right) \\ \tau_t &= -\sum_{s=1}^{s-1} \tau_{t-s} + w_t\,, && w_t \sim N\left(0, \sigma_w^2\right) \end{aligned} \tag{3-5}$$

Tables 1 and 7–9 displays the results of the above equations. There were statistical significances for the PCE impact for explanatory variables of GDP and GNI using covariates of HDI and UNEMPL for all countries within the three sub-regions except for Honduras, Chile, Colombia, Paraguay and Uruguay results showed that PCE impact for economic growth was statistically insignificant. However, the robustness of the results was confirmed based on the similar statistical significance (Posterior tail-area probability) of the impact for each country for the GNI and GDP.

Table 7.
Robustness checks results of posterior estimates of the PCE on Central America's gross national income (GNI) comparison to GDP

Central America	Actual		Predicted (s.d.)		Absolute effect (s.d.)		Absolute effect (s.d.)		Posterior tail-area probability	
	GNI	GDP	GNI	GDP	GNI	GDP	GNI	GDP	GNI	GDP
Panama	2.9e+11	6.5e+10	2.8e+11 (3.5e+10)	5.7e+10 (5.2e+09)	3.8e+9 (−4.5e+10)	7.5e+09 (−2.7e+09)	1.3% (9.3%)	13% (9.1%)	0.351	0.059*
			[2.1e+11, 3.5e+11]	[4.7e+10, 6.7e+10]	[−5.4e+10, 8.2e+10]	[−2.4e+09, 1.8e+10]				
El Salvador	2.5e+10	2.6e+10	2.4e+10 (2.1e+10)	2.2e+10 (8.5e+08)	1.9e+08 (1.1e+09)	4.1e+09 (8.5e+08)	15% (5.4%)	−1.6% (5.5%)	0.495	0.376
			[1.9e+10, 2.3e+10]	[2.0e+10, 2.4e+10]	[2.2e+09, 5.6e+09]	[2.3e+09, 5.7e+09]	[5.3%, 26%]	[11%, 27%]		
Mexico	1.2e+12	1.2e+12	1.2e+12 (9.3e+10)	1.2e+12 (1.1e+12)	−5.2e+10 (9.3e+10)	−7.5e+10 (−1.9e+11)	−8.2% (−22.6%)	−5.71% (5.6%)	0.083	0.125
			[1.1e+12, 1.4e+12]	[1.1e+12, 1.3e+12]	[−2.3e+11, 1.3e+11]	[−9.9e+10, 1.5e+11]	[−18%, 11%]	[−8.3%, 13%]		
Honduras	2.2e+10	2.4e+10	2.1e+10 (1.4e+09)	2.2e+10 (1.1e+09)	1.3e+09 (1.4e+09)	2.4e+09 (1.1e+09)	6.2% (6.8%)	11% (5.2%)	0.168	0.018**
			[1.8e+10, 2.4e+10]	[2.0e+10, 2.4e+10]	[−1.4e+09, 4.4e+09]	[2.1e+08, 4.6e+09]	[−6.4%, 21%]	[0.95%, 21%		
Guatemala	7.2e+10	7.4e+10	6.5e+10 (5.5e+09)	6.6e+10 (4.2e+09)	7.9e+09 (5.5e+09)	7.4e+09 (4.2e+09)	12% (7.5%)	15% (6.4%)	0.05**	0.024**
			[5.4e+10, 7.6e+10]	[5.8e+10, 7.4e+10]	[−2.7e+09, 1.9e+10]	[−5.7e+08, 1.6e+10]	[−5.7%, 28%]	[1.1%, 26%]		
Costa Rica	5.9e+10	6.0e+10	5.8e+10 (4.9e+09)	5.6e+10 (3.4e+09)	9.4e+08 (4.7e+09)	−3.7e+09 (−3.4e+09)	0.47% (−17%)	6.4% (−6%)	0.483	0.158
			[4.9e+10, 6.7e+10]	[4.9e+10, 6.3e+10]	[−8.1e+09, 1.0e+10]	[−2.4e+09, 1.1e+10]	[0.47%, 8.4%]	[−4.3%, 20%]		
Belize	1.8e+09	1.9e+09	1.6e+09 (9.7e+07)	1.7e+09 (8.6e+07)	1.5e+08 (9.7e+07)	1.6e+08 (8.6e+07)	9.6% (−5.6%)	9.2% (2.8%)	0.047**	0.015**
			[1.4e+09, 1.8e+09]	[1.5e+09, 1.9e+09]	[−6.8e+07, 3.2e+08]	[−3078306, .4e+08]	[−4.2%, 20%]	[2.8%, 14%]		

Note(s): The values in the brackets show 95% confidence interval, while those in the parentheses are standard deviations. ** represent 5% significance level and p stands for Posterior tail-area probability
Source(s): Created by authors

Table 8. Robustness checks results of posterior estimates of the PCE on South America's gross national income (GNI) comparison to GDP

South America	Actual		Predicted (s.d.)		Absolute effect (s.d.)		Absolute effect (s.d.)		Posterior tail-area probability	
	GNI	GDP	GNI	GDP	GNI	GDP	GNI	GDP	GNI	GDP
Argentina	5.2e+11	5.40E+11	5.8e+11 (6.4e+10) [4.5e+11, 7.1e+11]	5.6e+11 (4.2e+10) [4.9e+11, 6.5e+11]	−1.8e+10 (3.7e+10) [−9.1e+10, 4.9e+10]	−2.9e+10 (4.2e+10) [−1.1e+11, 5.1e+10]	−5.9% (−27%) [−5.9%, −27%]	−3.3% (6.8%) [−20%, 9%]	0.267	0.287
Brazil	1.9e+12	1.9e+12	1.4e+12 (3.9e+11) [6.2e+11, 2.2e+12]	1.5e+12 (1.9e+11) [1.2e+12, 1.9e+12]	5.3e+11 (3.9e+11) [−2.6e+11, 1.3e+12]	4.1e+11 (1.9e+11) [3.9e+10, 7.7e+11]	39% (28%) [−19%, 93%]	27% (13%) [2.6%, 51%]	0.083**	0.034**
Chile	2.7e+11	2.9e+11	2.6e+11 (2.3e+10) [2.2e+11, 3.1e+11]	2.7e+11 (1.3e+10) [2.4e+11, 2.9e+11]	9.3e+09 (2.3e+10) [−3.3e+10, 5.2e+10]	1.9e+10 (1.3e+10) [−8.0e+09, 4.3e+10]	3.5% (8.8%) [−13%, 20%]	2.5% (5%) [−8.7%, 13%]	0.364	0.323
Colombia	3.2e+11	3.2e+11	3.7e+11 (3.6e+10) [3.0e+11, 4.4e+11]	3.2e+11 (2.8e+10) [2.7e+11, 3.7e+11]	−5.7e+10 (3.6e+10) [−1.3e+11, 1.2e+10]	5.5e+09 (2.8e+10) [−4.8e+10, 5.7e+10]	−22% (10%) [−34%, 3.3%]	−8.3% (8.7%) [−26%, 9.1%]	0.019*	0.007***
Ecuador	1.0e+11	1.1e+11	1e+11 (8.4e+09) [8.3e+10, 1.2e+11]	9.8e+10 (5.6e+09) [8.7e+10, 1.1e+11]	4.3e+09 (8.4e+09) [−1.2e+10, 2.1e+10]	8.6e+09 (5.6e+09) [−2.3e+09, 1.9e+10]	4.4% (8.4%) [−12%, 21%]	6.7% (5.7%) [−2.3%, 20%]	0.326	0.166
Peru	2.1e+11	2.2e+11	2.1e+11 (2e+10) [1.7e+11, 2.4e+11]	2.1e+11 (1.6e+10) [1.1e+10, 1.3e+10]	4.5e+09 (2e+10) [−3.4e+10, 4.3e+10]	3.8e+08 (6.1e+08) [−7.7e+08, 1.6e+09]	2.2% (9.7%)	1.24% (6.2%) [−12.3%, 9.1%]	0.402	0.419
Paraguay	3.8e+10	1.2e+10	4.1e+10 (4.4e+09) [3.3e+10, 5.0e+10]	1.2e+10 (5.9e+08) [1.1e+10, 1.3e+10]	−3.5e+09 (4.4e+09) [−1.3e+10, 5.1e+09]	3.8e+08 (5.9e+08) [−7.3e+08, 1.5e+09]	−8.4% (11%) [−−31%, 12%]	4.3% (4.6%) [−6.3%, 13%]	0.199	0.190
Uruguay	6.0e+10	6.1e+12	5.7e+10 (6.3e+09) [4.5e+10, 7.0e+10]	6.1e+12 (3.0e+11) [5.5e+12, 6.7e+12]	2.8e+09 (6.3e+09) [−1e+10, 1.4e+10]	4.1e+10 (3.0e+11) [−5.5e+11, 6.1e+11]	4.9% (11%) [−17%, 25%]	−1.8% (5.3%) [−10.6%, 9.7%]	0.337	0.369

Note(s): The values in the brackets show 95% confidence interval, while those in the parentheses are standard deviations. ** represent 5% significance level and p stands for Posterior tail-area probability

Source(s): Created by authors

Table 9.
Robustness checks results of posterior estimates of the PCE on Caribbean's gross national income (GNI) comparison to GDP

Caribbean	Actual		Predicted(s.d.)		Absolute effect(s.d.)		Absolute effect (s.d.)		Posterior tail-area probability	
	GNI	GDP	GNI	GDP	GNI	GDP	GNI	GDP	GNI	GDP
Cuba	9.0e+10	9.9e+10	7.0e+10 (6.4e+09) [5.8e+10, 8.3e+10]	7.1e+10 (5.5e+09) [6.1e+10, 8.2e+10	2e+10 (6.4e+09) [7.4e+09, 3.2e+10]	2.7e+10 (5.5e+09) [1.7e+10, 3.8e+10]	29% (9.1%) [11%, 45%]	38% (7.7%) [23%, 53%]	0.003**	0.001**
Dominican Republic	8.1e+10	8.5e+10	8.0e+10 (6.2e+09) [6.7e+10, 9.2e+10]	7.7e+10 (4.5e+09) [6.9e+10, 8.7e+10]	1.2e+09 (6.2e+09) [−1.1e+10, 1.4e+10]	7.7e+09 (4.5e+09) [−2e+09, 1.6e+10]	3.0% (7.7%) [−14%, 17%]	9.3% (5.9%) [−2.6%, 21%]	0.422	0.048**
Haiti	1.5e+10	1.5e+10	1.7e+10 (1.3e+09) [1.5e+10, 2e+10]	1.6e+10 (6.9e+08) [1.5e+10, 1.7e+10]	−2.5e+09 (1.3e+09) [−5.0e+09, 1.4e+07]	−1.1e+09 (6.9e+08) [−2.5e+09, 2.3e+08]	−14.0% (7.3%) [−14%, 7.4%]	−15%.(7.5%)	0.034**	0.092*
Jamaica	1.5e+10	1.6e+10	1.3e+10 (7.1e+08) [1.2e+10, 1.4e+10]	1.4e+10 (2.7e+08) [1.4e+10, 1.5e+10]	2.1e+09 (7.1e+08) [6.8e+08, 3.5e+09]	1.4e+09 (2.7e+08) [8.8e+08, 1.9e+09]	16% (5.5%) [5.3%, 27%]	9.8% (1.9%) [6.1%, 13%]	0.003**	0.001**
Trinidad andTobago	2.3e+10	2.4e+10	2.6e+10 (2.0e+09) [2.2e+10, 3.0e+10]	2.6e+10 (1.4e+09) [2.3e+10, 2.9e+10]	−3.0e+09 (2.0e+09) [−6.8e+09, 8.2e+08]	−2.7e+09 (1.4e+09) [−5.4e+09, 6.0e+07]	−9.3% (11%) [−26%, 3.2%]	−10% (5.5%) [−20%, 0.23%]	0.158	0.289
Bahamas	1.3e+10	1.3e+10	1.3e+10 (4.8e+08) [1.2e+10, 1.4e+10]	1.2e+10 (2.9e+08) [1.1e+10, 1.2e+10]	−7.9e+07 (4.8e+08) [−1.0e+09, 8.8e+08]	1.1e+09 (2.9e+08) [5.6e+08, 1.7e+09]	2.4% (3.8%) [−5.1%, 11%]	7.9% (3.1%) [1.3%, 13%]	0.279	0.012**

Note(s): The values in the brackets show 95% confidence interval, while those in the parentheses are standard deviations. ** represent 5% significance level and p stands for Posterior tail-area probability
Source(s): Created by authors

6. Conclusion

The research indicates that the PCE has statistically significant impact on most countries within the Caribbean Transshipment Triangle. The results from BSTS revealed that PCE had positive and statistically significant relative effects for all regions ranging from 9.2% in Belize to 46% in Cuba. This suggests that the causal effect of the PCE on regional economies was not confined to any specific type of economy or geographical location within LAC region. However, the impact on Cuba's economy is notably 3 times the results of the next highest impact in Guatemala, which could be as a result of the newly constructed Mariel port, which would require further investigation.

Further findings also revealed that other countries in South and Central America also experienced positive growth during the PCE period, except for Argentina, Colombia, El Salvador, Mexico and Uruguay. However, these growth rates were statistically insignificant. This suggests that the Latin American region is primarily driven by exports and service industries, meaning that bulk and oil tanker vessels are likely to be the main carriers for exports rather than container vessels. As a result, further research may be necessary to explore this potential trend in the South and Central American regions. It is worth noting that the PCE was not the only factor influencing GDP growth before and after the PCE era. Policy changes in fiscal balance, General government final consumption expenditure (GFCE) and trade agreements also contributed to economic growth. Additionally, external factors such as port liner connectivity, market segment, proximity and trade routes may impact port throughput and overall economic performance in ways that are not directly related to the PCE or its associated policies. Overall, it is crucial that key stakeholders thoroughly evaluate the success of the intervention and take immediate and necessary measures to enhance the economic outlook. The dynamic maritime industry, like the PCE, is perpetually evolving, with exports and services that significantly contribute to economic growth varying by region. These findings can aid in developing precise policies for regional and local socio-economic progress.

The practical implications of this research are crucial for various stakeholders in the maritime industry and economic planning. The factors influencing economic growth resulting from investing in maritime activities are vital for decision-makers to create policies that lead to positive outcomes and sustainable development in regions and countries with flourishing maritime industries. The findings have significant implications for governments, managers, professionals, policymakers and investors. In summary, the BSTS model is an efficient tool for evaluating the impact of the PCE on LAC.

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