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The Panama Canal Expansion: A Failed Game-Changer for Port Throughput of Transshipment Ports

La ampliación del Canal de Panamá: Un cambio de juego fallido para el tráfico portuario de los puertos de transbordo

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Abstract. The Panama Canal has played an important role in the history of the shipping industry. Therefore, it was reasonable to forecast that the Panama Canal expansion would impact port throughput in the six transshipment ports located in Panama. To examine this impact, two periods were analyzed. The first period covered October 2010 to June 2016. The second period covered July 2016 to March 2022. The Wilcoxon signed-rank test and the IBM SPSS Statistics software were used to analyze public data from the Central American Maritime Transport Commission (COCATRAM) measuring port throughput. The research concluded that the Panama Canal expansion has not produced a statistically significant impact on the port throughput of (a) cargo tonnage, (b) cargo TEU and (c) vessel calls.

Keywords: canals; cargo tonnage; containers; Panama Canal; ports; port throughput; transshipment ports.

Resumen. El Canal de Panamá ha jugado un papel importante en la historia de la industria naviera. Por lo tanto, era razonable prever que su expansión repercutiría en el rendimiento portuario en los seis puertos de transbordo ubicados en Panamá. Para examinar este impacto, se analizaron dos períodos. El primero abarcó desde octubre de 2010 hasta junio de 2016. El segundo abarcó desde julio de 2016 hasta marzo de 2022. Se utilizó la prueba de rangos con signo de Wilcoxon y el software SPSS para analizar los datos de la Comisión Centroamericana de Transporte Marítimo (COCATRAM). La investigación concluyó que la ampliación del Canal de Panamá no ha producido un impacto estadísticamente significativo en el rendimiento portuario de (a) tonelaje de carga, (b) carga contenerizada y (c) arribo de buques.

Palabras clave: Canal de Panamá; canales; contenedores; puerto de transbordo; rendimiento portuario; tonelaje de carga

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Introduction

The Panama Canal is a 50-mile system of locks, channels, and lakes that connects the Atlantic and Pacific Oceans and receives more than 14,000 vessels every year (Ramos, 2014). Since its completion in 1914, this waterway worked for nearly a century without important changes. As a result, the Panama Canal Authority (PCA) envisioned the need to expand the canal to in order to adapt to the new demands of the maritime industry.

Therefore, the Panamanian population approved the Panama Canal expansion project through a referendum held on October 22, 2006, which authorized the PCA to start this expansion project (Gonzalez, 2008). This project consisted of three main components: the construction of new locks on both the Pacific and Caribbean sides, the expansion of new channels to connect the new locks, and the augmentation of Operational levels at Gatun Lake (Alarcón et al., 2011).

After nine years of construction, the Panama Canal expansion was officially inaugurated on June 26, 2016, with an investment of USD 5.6 million. However, some scholars wondered whether this project would significantly impact the maritime port sector (Bonney, 2016). With six major transshipment ports on the Pacific and Caribbean sides, Panama's port system has achieved an average of 7 million twenty-foot-equivalent unit (TEU) per year, which makes Panama an important shipping player in the region (Linares & Rovi, 2020). For instance, many Asian container carriers use Panama's port infrastructure as a hub for transshipment to move containers through the Panama Canal toward North and South America and other regional routes (Hui-Huang, 2015)the Panama Canal has reduced both transit time and costs for the container shipping industry in particular. Once canal expansion is completed, container carriers will immediately face emission reduction demands in North America, and will be required to address problems regarding hub port selection for transshipments in the wider Caribbean region (WCR.

The Panama Canal has also experienced a gradual increase in revenue, vessel transit, container ship deployment, and competition from different business operators and commercial routes, which has highlighted the importance of the Panama Canal expansion for the growth of the shipping sector (Wang, 2017). Nonetheless, determining the effect of the Panama Canal expansion has been of interest to different scholars and the business sector. For example, a study on the top 50 U.S. ports in terms of TEU suggested that small ports would increase their import volume depending on how close they were to large ports, which in turn would eventually serve larger ships that were going to cross the expanded Panama Canal (Medina et al., 2021).

As a result, the Panama Canal expansion has been an interesting subject for the business and academic sectors since its announcement. It was reasonable to forecast that the 2016 Panama Canal expansion would significantly impact the container port throughput in the six transshipment ports located in the Republic of Panama, considering their geographical proximity to the Panama Canal. Moreover, the expansion of the Panama Canal was justified because ship capacity restrictions of a channel can significantly affect the performance of transshipment ports (Zheng et al., 2019). While most research has focused on forecasting models for container port throughput, this research contributes a new perspective by testing the claim from business and academic sectors that claimed that the Panama Canal expansion would be a game-changer for the transshipment industry.

Literature Review

The Panama Canal Expansion

From its construction phase to its completion, the Panama Canal expansion has received much academic interest, considering that the PCA envisioned that this project would turn Panama into a major maritime hub (PCA, 2006). However, others remained skeptical of the forecasted impact of this project. For instance, the National Front for the Defense of Economic and Social Rights forecasted that the expanded Panama Canal would neither cause an increase in the international maritime market share nor induce a change in international commercial routes to move more cargo (FRENADESO, 2006).

On the contrary, Alvarez et al. (2009) predicted that the expanded Panama Canal would experience a massive increase in cargo because of the transit of Post-Panamax vessels, which would produce a positive economic effect in the first 10 years of operation. Likewise, several U.S. government officials endorsed the expansion project because of the impact on transnational commercial sectors and the promotion of worldwide trade and international shipping (Mann, 2011).

On the other hand, Bussolo et al. (2012) claimed that the expanded Panama Canal would produce economic disparities and exacerbate the gap between the poor and the rich. However, Hricko (2012) believed that the Panama Canal expansion would have an outsized impact because it would change the market share distribution among U.S. ports between the West Coast and the Gulf Coast as well as increasing the export and import of agrarian products. Similarly, Corbett et al. (2012)oxides of sulfur and particulate matter estimated that the expanded Panama Canal would produce a potentially small shift in Asia–U.S. container volumes from the West Coast toward major ports on the East Coast due to the transit of larger vessels.

Additionally, the U.S. Department of Transportation and Maritime Administration (2013) expected that this project would increase the preference for Caribbean or Panamanian container transshipment ports over American due to increased vessel size and impact on container cargo flows. Not surprisingly, Muirhead et al. (2015)scheduled for completion in 2015, is expected to have major effects on commercial shipping and port operations throughout the world, with potential consequences for the transfer and establishment of non-indigenous species that remain largely unexplored. We developed a series of scenario-based models to examine how shipping traffic patterns may change after expansion and consider possible implications for species transfers and invasion dynamics in the USA. Location: Coastal USA, excluding Alaska and Hawaii Methods: Using a Monte Carlo simulation approach, we predicted changes in discharged ballast water, wetted surface area of ship hulls and frequency of ship arrivals modelled under scenarios that are based on (1 predicted that the Panama Canal expansion would double the number of ships arriving at the Gulf Coast in only five years after its completion because it would be able to potentially divert incoming ships from the West Coast to the East Coast of the United States. However, just like the National Front for the Defense of Economic and Social Rights, Rodrigue (2015) warned about the exaggeration of expected benefits from the Panama Canal expansion because this new project would not change current trends in the global market.

Later, Park and Park (2016) forecasted a change in export and import shipping routes for the U.S. West Coast because the Panama Canal expansion would allow more cargo to move by larger seagoing vessels instead of by smaller land transport, such as trucks and trains in the American transportation system. As a result, Serebrisky et al. (2016) claimed that while the Panama Canal had transformed Central American and Caribbean ports into specialized transshipment ports, the expanded Panama Canal had added extra pressure on those ports to prepare themselves to receive a higher demand and larger vessels.

Moreover, Bhadury (2016) argued that Gulf Coast ports have been experiencing massive investment in order to prepare their infrastructure in terms of channel depth, channel width, and the capacity to handle Post-Panamax or Super Post-Panamax vessels. Also, Martinez et al. (2016) claimed that the Panama Canal expansion would cause a gradual change in cargo carriers coming from Asia because they would use the new channel for saving time to reach the East Coast instead of using the congested West Coast, which would have more implications for different actors in the American shipping industry. For instance, Vorotnikova and Devadoss (2016) explained that the Panama Canal expansion would increase the trade flow of dairy products such as dry milk and butter coming from the West Coast and the East Coast toward other international markets in Asia, Africa, and Oceania.

In general, scholars expected that the expanded Panama Canal would reduce congestion, lower the costs of transportation, and reduce contamination (Mulligan & Lombardo, 2016). Additionally, Tai and Lin (2016)the departure points of which are all in East Asia. Design/methodology/approach-The operating conditions of various shipping practices were used to simulate trunk route deployment after canal expansion. Subsequently, a clean-line strategy featuring liquefied natural gas (LNG argued that the Panama Canal would influence container carriers to choose this route due to the increasing cargo capacity of ships. Of note, it was expected that the Panama Canal would increase its container ship capacity for being able to handle the transit of vessels of 5,320 TEUs to a capacity of 13,500 TEUs (Liu et al., 2016).

Likewise, the Panama Canal expansion would enhance the competitiveness of its maritime cluster, which is located in a strategic geographical position, given the increase in vessel transit and port interconnections (Pagano et al., 2016). For instance, Rodrigue and Ashar (2016) claimed that the Panama Canal expansion would eventually increase transshipment activity in Caribbean ports, which led some global terminal operators to consider those ports as potential areas to expand capacity and depth.

As a result, Knatz (2017) explained that the U.S. government had improved funding, its management interactions with ports, its legal framework, and the harbor maintenance tax regulations in order to reduce port congestion, retain American competitiveness, and improve general economic development. Notably, the Panama Canal has an advantage over other options, such as the Suez Canal and the U.S. intermodal system, for vessels of 8,600 TEU to 13,000 TEU in terms of reducing transportation costs and reliability for liner shipping companies (Pham et al., 2018). In other words, this expansion project would produce many benefits in the traffic of vessels in terms of speed, efficiency, and capacity (Zielinski, 2018).

Later, Changkeun et al. (2020) claimed that it was expected that West Coast ports in Oregon, California and Washington would lose importance because shipping lines would prefer to use the new Panama Canal given its larger capacity, which would benefit the East Coast and the Gulf Coast. Moreover, Medina et al. (2020) argued that the Panama Canal expansion had significantly increased the import volume of U.S. ports located on the Atlantic and Gulf Coasts over those located on the Pacific Coast.

Likewise, a study concluded that the expanded Panama Canal would produce a smaller impact on the cargo competition for ports located in Europe than those located in the United States given their longer geographical distance from the canal (Hassel et al., 2020). Additionally, Miller and Hyodo (2021) conducted a study on 100 ports on the Latin American and Caribbean sides of the canal and concluded that the Panama Canal expansion had significantly increased cargo volume in Latin American ports, except for some ports in the Caribbean region.

Transshipment Ports

Transshipment ports play an important role in global shipping. According to Medda and Carbonaro (2007), transshipment ports focus on interactive connections working as hubs to feed and relay cargo from one port to another region. As a result of their importance, transshipment ports have been subject to different studies. For instance, McCalla (2008) conducted research on the transshipment port in Kingston, Jamaica which highlighted that this port has the centrality to minimize distance at regional and hemispheric levels as well as intermediacy to main routes because of its proximity to the Panama Canal.

Likewise, McCalla (2008) analyzed the effect that geographical proximity to main shipping lanes and the Panama Canal had on transshipment ports in Colon, Kingston, Freeport, Rio Haina/Caucedo, Port of Spain/Point Lisas, and Cartagena. The results of this study demonstrated the primary importance of proximity, infrastructure, management, and productivity on transshipment cargo volumes.

Chou (2009) studied transshipment ports in Hong Kong and Kaohsiung and concluded that shipping companies chose competitive transshipment ports that reduced the costs to tranship cargo as well as those with increased efficiency of loading and discharging. Similarly, Sohn and Jung (2009) examined 16 major Asian transshipment ports from 1995 to 2005 and concluded that the port size has a positive effect on container handling efficiency and container transshipment volume.

Yabin (2010) conducted research on the Gaolan transshipment port in China and determined that when it comes to transshipment seaports, coal power industries consider key factors such as train transportation, handling capacity, and costs. On the other hand, based on an analysis of 50 carriers and 30 port operators in Asia, Min and Park (2011) argued that although volume discounts and monetary incentives can be desirable for transshipment ports, several other influential factors such as port proximity to export/import businesses, port service quality, and port security are often ignored by port operators.

Similarly, by studying the transshipment port in Singapore, Kwan and Hilmola (2012) highlighted different problems stemming from high operational costs, incentives from port competitors, limited manpower, customs processes, and increasing relocation of firms away from Singapore. Also, Bae et al. (2013) proposed a model to analyze container port competition in China, where the model underscored the influence of port capacity, price difference, transshipment level, and port congestion.

Slack and Gouvernal (2016) studied transshipment ports located in Gioia Tauro, Kingston, Marsaxlokk, Panama, Singapore and Tangiers-Med to accentuate the weakness of transshipment ports to develop large logistics industries because of changing shipping strategies, costs, limited volume of goods, and distance from major markets. On the other hand, Chen et al. (2017) argued that port selection is influenced by route cost, government policies, customs regulations, and connectivity.

Additionally, Kavirathna et al. (2018) researched Southeast Asian transshipment ports to evaluate their competitiveness in terms of cost, time, location, operation, and other liner-related factors. Kadaifci et al. (2018) also studied 14 transshipment ports to demonstrate that port preference is affected by transshipment costs, location, infrastructure, equipment, and technologies.

Likewise, Petrlić and Pavletić (2019) studied the transshipment port of Rijeka in the North Adriatic Sea to demonstrate the importance of considering different factors such as equipment, liner services, transport network, cost, infrastructure, and quality systems. Also, Koza et al. (2020) examined the data of 277 ports around the world to conclude that transshipment ports require synchronization among liner services in terms of cargo and time to improve reliability and competitiveness. Finally, Corey et al. (2022) performed research on Caribbean transshipment ports given their connections to the Panama Canal and the Atlantic Ocean and determined that the ports in Jamaica and the Bahamas have the best geographical position in the region.

Port Throughput

Port throughput represents the amount of cargo or the number of vessels that ports manage during a certain period of time, which can be measured in cargo tonnage, TEU container, and vessel calls (U.S. Department of Transportation, 2017). Port throughput is the most important driver of decision-making processes in port terminals.

According to Chou (2007), there are numerous criteria for port selection, such as port location, the volume of the hinterland economy, facilities, efficiency, free trade zones, and future development plans. However, port throughput is one of the most common criteria taken into account for transshipment port selection and one of the most commonly studied aspects as well (Lirn et al., 2003). For instance, Fung (2002) conducted research on port throughput in Singapore and Hong Kong port terminals to develop a forecasting model, which highlighted the Hong Kong port's potential to replace Singapore´s regarding future demands for more cargo.

Similarly, after studying the port throughput of Rotterdam Port in the Netherlands, Langen (2003) proposed a model to forecast port throughput, which considered different factors such as the rate of containerization, competitive position, the direction of trade, openness, and gross domestic product. Additionally, Veldman and Buckmann, (2003) examined data from Western European ports to propose a forecasting model that considered other factors such as transport costs, transit time, and the frequency and quality of service. Also, Talley (2006) studied the port throughput of two Spanish ports to demonstrate that different factors, such as port prices, port service diversification, and port congestion can affect port throughput.

From a different direction, Schulze and Prinzb (2009) analyzed port throughput data from 1985 to 2005 and predicted a continuous growth of port throughput in Germany until 2008. Also, Gosasang et al. (2011) examined port throughput in the port of Bangkok from 1999 to 2010 and demonstrated the significant impact of factors such as exchange rates, fuel prices, gross domestic product, inflation rate, and population on container port throughput.

Likewise, Zhang and Cui (2011) analyzed port throughput in Shanghai Port from 1995 to 2010 to propose a model capable of predicting important variables. Notably, Liu and Park (2011) found that ports should improve their transshipment and service levels, reduce tariffs, speed up customs clearance, improve government support, and take advantage of the economic development of the surrounding hinterland if they want to improve port throughput.

However, an economic crisis can negatively affect port throughput because of decreased shipping rates, reduced chartering of shipping services, the closing of secondary commercial routes, reduced logistic and port costs, and increased strategic shipping alliances (Mădălin, 2012). Furthermore, port throughput can fluctuate as a result of the weather, political factors, management, and other competing ports (Tian et al., 2013).

It is important to highlight that port throughput can incentivize port managers to embark on massive investments to expand port infrastructure without a guarantee of economic return; however, ports should develop strategies to accommodate higher traffic volumes during peak seasons to reduce costs and delays given the volatility of port throughput (Xiao et al., 2016). Nonetheless, the improvement of port throughput can positively affect the economic growth in a country (Park & Seo, 2016).

Moreover, port throughput can be considered as the result of the development of different sectors in terms of imports and exports that work in tandem (Paflioti et al., 2017). Thus, port throughput can be positively affected by different factors. For instance, the growth and development of connectivity between ports and their surrounding hinterlands by train and the efficiency of the rail-served port's operations exert a significant influence on port throughput (Woodburn, 2017).

Port throughput can be also influential. For instance, after studying 11 ports in the Yangtze River, Yang et al. (2017) concluded that port throughput has a negative effect on the bulk traffic of transshipment seaports. However, other factors can also affect port throughput. For instance, changing regional transshipment markets can affect the forecast of port throughput (Grifoll, 2019). Likewise, container freight rates can negatively affect port throughput, although this effect is not consistently significant (Açik, 2019). Of note, transshipment ports can experience a significant instability in terms of port throughput given the interaction of different actors and factors (Notteboom et al., 2019).

Subsequent research has focused on port throughput in the Asian continent. For instance, Tang et al. (2019) analyzed the port throughput data of the Shanghai Port and Lianyungang Port from 1990 to 2017 to propose a model capable of predicting port throughput for both ports. Likewise, Rumaji (2019) examined the high-cost logistics and price disparities of transshipment ports in Indonesia, which aimed to enhance connectivity and reduce total shipping costs.

Additionally, Feng et al. (2020) examined port throughput data of the Yangtze River Delta ports to propose a model able to analyze the evolution, concentration, inequality, and competition of different ports in that region. Finally, after analyzing the port throughput data of Shanghai Port from 2012 to 2020, Huang et al. (2022) underscored the negative effect of COVID-19 on those ports.

Consequently, while most research has focused on forecasting models for port throughput, this research focuses on analyzing the effect of the Panama Canal expansion on the port throughput of transshipment ports in the Republic of Panama given their geographical proximity to the expanded Panama Canal.

Research Question

What is the effect of the Panama Canal expansion on the port throughput of Panama transshipment ports?

Hypotheses

H_0: The Panama Canal expansion has not produced a significant change in the port throughput of Panama transshipment ports.

H_A: The Panama Canal expansion has produced a significant change in the port throughput of Panama transshipment ports.

Methods

To test the hypotheses regarding the Panama Canal expansion's effect on the port cargo throughput of transshipment ports, this research used the Wilcoxon signed-rank test. This test, developed by Frank Wilcoxon in 1945, is a non-parametric statistical method to analyze whether there is a significant difference between two or more sets of pairs (Hayes, 2021). In other words, this test can compare several subjects under two different conditions (Scheff, 2016).

The Wilcoxon test has been used to compare simulation models and predicted values for the port of Alexandria, Egypt (Ragheb et al., 2010). Similarly, this test has been used to analyze the efficiency of port performance and the optimal size of investment in 20 Korean ports from 1997 to 2007 (Ro, 2010).

Also, it has been used to analyze forecasting models for container traffic in Turkish seaports (Gökkuş et al., 2017). Similarly, it has been used to analyze services in Brazilian seaports in terms of economy, reliability, and quality (Longaray et al., 2019). Additionally, this research uses the IBM SPSS Statistics software (version 27) for analysis.

Population

The population for this research was the six transshipment ports located in the Republic of Panama as the main beneficiaries of the Panama Canal expansion: (1) the Panama Port

Company-Balboa and (2) the PSA Panama International Terminal, located on the Pacific Ocean, (3) the Colon Container Terminal, (4) the Manzanillo International Terminal, (5) the Panama Port Company-Cristobal, and (6) the Bocas Fruit Company Port located on the Caribbean Sea.

Data Collection and Analysis

This research used public data from the Central America Maritime and Port Statistical Information System to measure port throughput (COCATRAM, 2022a). To determine the effect of the Panama Canal expansion, completed in June 2016, on the port throughput of transshipment ports, two periods were analyzed. The first period covered the fourth quarter of 2010 to the second quarter of 2016. The second period covered the third quarter of 2016 to the first quarter of 2022.

In this research, the first quarter includes January, February, and March; the second quarter covers April, May, and June; the third quarter includes July, August, and September; and the fourth quarter encompasses October, November, and December. To have a more precise analysis of the effect of the Panama Canal expansion on port throughput, this research considered cargo tonnage, cargo TEU, and vessel calls.

Cargo Tonnage

Cargo tonnage represents the total amount that a ship can carry, which excludes the weight of fuel, supplies, equipment, and crew (ProConnect, 2022). Cargo tonnage is a conventional measure that can be very influential for decision-making, allocation of public resources, and attracting private investments (Simkins & Stewart, 2015).

This variable is the most comprehensive measure because it can include the weight of shipping containers, roll-on/roll-on cargo, solid bulk cargo, liquid bulk cargo, and general cargo (U.S. Department of Transportation, 2017). In other words, cargo tonnage is a better measure than cargo TEU because it includes all forms of cargo (Valentine et al., 2013). For cargo tonnage, the data is expressed in metric tons. A metric ton is equivalent to 1,000 kilograms or approximately 2,200 pounds (COCATRAM, 2022b).

Cargo TEU

Cargo TEU are intrinsically related to containers, which are reusable steel boxes for transporting different types of cargo by container ships (Witters & Ivy, 2002). Those container ships have been gradually expanding their cargo capacity because of international corporate alliances, which aim to save costs and time as well as increase the frequency of calls (Kelly & Arai, 2009).

Container ships have been key to worldwide interconnections because the containerization of goods and products can save time in port operations as well as enhance import and export activities (ICC, 2022). Ports use cranes to load and unload massive amounts of containers onto and off container ships (Jha, 2022). Consequently, when a container ship arrives in a port, it will first unload its container cargo; afterward, it will load laden containers to satisfy demands as well as empty containers according to port management (Song & Dong, 2008). For this research, the data is expressed in Twenty-Foot-Equivalent Unit (TEU). A TEU is a conventional measure where a 20-foot-long container is expressed as 1 TEU and a 40-foot-long container is expressed as 2 TEU (Vis & Koster, 2003).

Vessel Calls

Although vessel calls can be affected by location, trade routes, and weather conditions, vessel calls are one of the most important considerations for port planning and construction because it is expected that a certain number of vessels arrive during a period of time (Jagerman & Altiok, 2003). Vessel calls refer to ship arrivals in any port (U.S. Department of Transportation, 2017). Nevertheless, vessel calls are primarily dependent on the shipping schedule (Bellsola et al., 2018).

Due to vessel calls, ports can experience periods of high activity during arrivals of expected and unexpected vessels as well as times of idleness when ports are not used (Jiménez et al., 2021). For this research, vessel calls are defined as the vessel arrivals in the six transshipment ports to load and unload cargo or to avoid any danger (COCATRAM, 2022c). The data is expressed in units.

Results

First, the results indicate that after the Panama Canal expansion, there was a 13% growth in cargo tonnage. Prior to this project, the mean from 2010 to 2016 was 38,995 metric tons, while the mean from 2016 to 2022 increased to 43,915 metric tons (Table 1).

Table 1. Cargo tonnage in metric tons

Before Panama Canal expansion		After Panama Canal expansion	
Year	Cargo Tonnage	Year	Cargo Tonnage
2010 (4Q)	10,871	2016 (3Q–4Q)	23,488
2011	48,508	2017	48,104
2012	48,955	2018	49,048
2013	47,608	2019	51,064
2014	48,579	2020	57,021
2015	47,690	2021	64,119
2016 (1Q–2Q)	20,751	2022 (1Q)	14,562
Mean	**38,995**	**Mean**	**43,915**

Source: own elaboration

Nonetheless, the Wilcoxon signed-rank test shows that the increase in cargo tonnage after the Panama Canal expansion is statistically insignificant, with Z = -1.352, p = 0.176 (Table 2).

Table 2. Wilcoxon signed-rank test for laden container port throughput.

Wilcoxon signed-rank test		N	Mean Rank	Sum of Ranks
After expansion – Before expansion	Negative Ranks	2[a]	3.00	6.00
	Positive Ranks	5[b]	4.40	22.00
	Ties	0[c]		
	Total	7		
a. After expansion < Before expansion				
b. After expansion > Before expansion				
c. After expansion = Before expansion				
Test Statistics[a]		**After expansion – Before expansion**		
Z		-1.352[b]		
Asymp. Sig. (2-tailed)		0.176		
a. Wilcoxon Signed Ranks Test // b. Based on negative ranks				

Source: own elaboration

Second, the results indicate that after the Panama Canal expansion, there was a 13% growth in laden container port throughput. Prior to this project, the mean throughput from 2010 to 2016 was 3,912,567 TEU, while the mean from 2016 to 2022 grew to 4,431,504 TEU (Table 3).

Table 3. Laden container port throughput in TEU

Before Panama Canal expansion		After Panama Canal expansion	
Year	Laden Containers	Year	Laden Containers
2010 (4Q)	1,061,983	2016 (3Q–4Q)	2,327,316
2011	4,808,632	2017	4,818,013
2012	5,041,623	2018	4,925,087
2013	4,716,632	2019	5,167,629
2014	4,864,373	2020	5,796,577
2015	4,847,385	2021	6,499,016
2016 (1Q–2Q)	2,047,338	2022 (1Q)	1,486,890
Mean	**3,912,567**	**Mean**	**4,431,504**

Source: own elaboration

Nevertheless, the Wilcoxon signed-rank test shows that the increase in laden container port throughput is also statistically insignificant, with Z = -1.352, p = 0.176 (Table 4).

Table 4. Wilcoxon signed-rank test for laden container port throughput

Wilcoxon signed-rank test		N	Mean Rank	Sum of Ranks
After expansion – Before expansion	Negative Ranks	2[a]	3.00	6.00
	Positive Ranks	5[b]	4.40	22.00
	Ties	0[c]		
	Total	7		
a. After expansion < Before expansion				
b. After expansion > Before expansion				
c. After expansion = Before expansion				

Test Statistics[a]	After expansion – Before expansion
Z	-1.352[b]
Asymp. Sig. (2-tailed)	0.176
a. Wilcoxon Signed Ranks Test // b. Based on negative ranks	

Source: own elaboration

Third, the results indicate that after the Panama Canal expansion, there was 7% growth in empty container port throughput. Before this project, the mean throughput from 2010 to 2016 was 1,585,318 TEU while the mean from 2016 to 2022 increased to 1,695,652 TEU (Table 5).

Table 5. Empty container port throughput in TEU

Before Panama Canal expansion		After Panama Canal expansion	
Year	Empty Containers	Year	Empty Containers
2010 (4Q)	467,559	2016 (3Q–4Q)	924,141
2011	1,821,287	2017	2,081,241
2012	1,942,824	2018	2,090,221
2013	1,821,443	2019	2,187,361
2014	1,905,858	2020	1,956,755
2015	2,165,364	2021	2,122,910
2016 (1Q–2Q)	972,890	2022 (1Q)	506,934
Mean	**1,585,318**	**Mean**	**1,695,652**

Source: own elaboration

However, the Wilcoxon signed-rank test shows that the observed difference between both measurements for empty container port throughput is statistically insignificant, with Z = -1.014, p = 0.310 (Table 6).

Table 6. Wilcoxon signed-rank test for empty container port throughput

Wilcoxon signed-rank test		**N**	**Mean Rank**	**Sum of Ranks**
After expansion – Before expansion	Negative Ranks	2[a]	4.00	8.00
	Positive Ranks	5[b]	4.00	20.00
	Ties	0[c]		
	Total	7		

a. After expansion < Before expansion
b. After expansion > Before expansion
c. After expansion = Before expansion

Test Statistics[a]	**After expansion – Before expansion**
Z	-1.014[b]
Asymp. Sig. (2-tailed)	0.310

a. Wilcoxon Signed Ranks Test // b. Based on negative ranks

Source: own elaboration

It should be also noted that, from 2010 to 2022, laden container volume represents 72% of the total container port throughput in Panama. On the other hand, empty container volume accounts for 28% of the total container port throughput.

Fourth, there was a 12% decrease in vessel calls. Before the Panama Canal expansion, the mean from 2010 to 2016 was 5,741 vessels while the mean from 2016 to 2022 decreased to 5,079 vessels (Table 7).

Table 7. Vessel calls measured in units

Before Panama Canal expansion		**After Panama Canal expansion**	
Year	Vessel Calls	Year	Vessel Calls
2010 (4Q)	1,723	2016 (3Q–4Q)	3,205
2011	7,345	2017	6,153
2012	7,179	2018	6,082
2013	7,001	2019	6,351
2014	6,691	2020	6,261
2015	6,921	2021	6,035
2016 (1Q–2Q)	3,329	2022 (1Q)	1,463
Mean	**5,741**	**Mean**	**5,079**

Source: own elaboration

Nevertheless, the Wilcoxon signed-rank test shows that the observed difference between both measurements for vessel calls is also statistically insignificant, with Z = -1.352, p = 0.176 (Table 8).

Table 8. Wilcoxon signed-rank test for vessel calls

Wilcoxon signed-rank test		N	Mean Rank	Sum of Ranks
After expansion – Before expansion	Negative Ranks	6[a]	3.67	22.00
	Positive Ranks	1[b]	6.00	6.00
	Ties	0[c]		
	Total	7		

a. After expansion < Before expansion
b. After expansion > Before expansion
c. After expansion = Before expansion

Test Statistics[a]	After expansion – Before expansion
Z	-1.352[b]
Asymp. Sig. (2-tailed)	0.176

a. Wilcoxon Signed Ranks Test // b. Based on negative ranks

Source: own elaboration

Therefore, the null hypothesis (H_0) is totally supported. Consequently, the Panama Canal expansion has not produced a statistically significant change in the port throughput of Panama transshipment ports (a) cargo tonnage, (b) cargo TEU, and (c) vessel calls.

Discussion

The research confirms that the Panama Canal expansion has not elicited a statistically significant impact on container port throughput in the six transshipment ports located in the Republic of Panama. Plainly said, the Panama Canal expansion has not been a game-changer for the cargo volume of transshipment ports.

This result agrees with FRENADESO (2006), which predicted the expanded Panama Canal would neither cause an increase in the international maritime market share nor provoke a change in international commercial routes to move more cargo. Similarly, Rodrigue (2015) warned about the exaggeration of expected benefits from the Panama Canal expansion because this new project would not change current trends in the global market. Moreover, this research agrees with Herrera et al. (2017), who argued that although transshipment represents an important percentage of container movement in ports, the Panama Canal expansion would not exert a significant effect on the percentage of transshipment movement.

Although this research only studied six transshipment ports located in the Republic of Panama, the result partially validated similar predictions in different regions. For instance, Edmonds (2012) predicted that it was not possible to precisely measure how the Panama Canal expansion would change trade routes and port cargo volumes in the Gulf and Southeast regions of the United States because the situation was going to remain static for quite some time.

On the contrary, the results of this research contradict the estimates by the U.S. Department of Transportation and Maritime Administration (2013), Serebrisky et al. (2016), and Pagano et al. (2016), who forecasted that the Panama Canal expansion would increase port preference, boost challenges, and enhance the competitiveness of its maritime cluster, respectively. Additionally, the results partially contradict estimates that the Panama Canal expansion would increase port container throughput in the Central America region (Miller & Hyodo, 2021).

Managerial Implications

Because of the magnitude and importance of the Panama Canal expansion for the international shipping industry, it was reasonable to believe that this project would produce massive increases in container port throughput in the six transshipment ports in the Republic of Panama. The prediction logically considered those transshipment ports as the primary beneficiaries because of their geographical proximity to the Atlantic and Caribbean entries of the Panama Canal.

The insignificant improvement in cargo tonnage and cargo TEU as well as the decrease in vessel calls to Panama transshipment ports will eventually make port managers more cautious when it comes to massive economic investments, acquisitions of more equipment, and recruitment of new manpower. It is also possible that the lack of significant improvement in port throughput will lead to losing more competitiveness to other ports in the Caribbean basin.

The managerial implications for the future are heterogeneous. On the one hand, although the effect of the Panama Canal expansion has not been significant, the slow increase in cargo tonnage and cargo TEU may indicate that the significant benefits for transshipment ports will remain the same for quite a long time. For example, in 2013, the Manzanillo International Port in Panama enthusiastically announced a $270 million investment to receive more cargo and remain competitive due to the Panama Canal expansion (Panamá América, 2013). Later, in 2014, Panama Ports Company-Balboa announced a $110 million investment in preparation for the Panama Canal expansion (CDS, 2014). On the other hand, the gradual decrease in vessel calls can be worrisome for the whole industrial maritime cluster of Panama transshipment ports.

Nevertheless, it should be observed that Gourdin (2019) argued that since economic benefits take too long to become tangible, they are commonly inflated to justify the construction of new waterways, ports, and bridges; however, those economic investments are eventually discovered to be avoidable. Notably, container ports can experience uncertainty because of the unsecured returns of economic investments, the reality of local institutions, the legal framework, the fragmented interdependency of various international logistical actors, the state of the relationship with port workers, and the political and community support for infrastructure projects (Danyluk, 2019).

It could be argued that the Panama Canal expansion was only conceived and financed by the PCA to increase the transit of larger vessels through the Panama Canal. In other words, the Panama Canal expansion was completed to specifically solve the Panama Canal's needs and not those of the transshipment ports. For example, since its expansion, the Panama Canal has notably expanded the transit of container ships through its Neopanamax locks. Considering that transshipment ports did not finance the Panama Canal expansion, the former argument seems valid. However, the present result contradicts the PCA's (2006) claim that this project would transform Panama into a great maritime hub.

Moreover, the 12% decrease in vessel calls to the six transshipment ports could indicate that the Panama Canal expansion is gradually affecting transshipment port preference, which is causing container ships to transit more easily transshipment hubs in the Caribbean basin. In other words, container ships are reducing their transshipment activities in ports located in the Republic of Panama, considering the expanded capacity of the Panama Canal. A case in point was the straightforward crossing through the expanded Panama Canal by the container ship CMA CGM ZEPHYR with its 16,285 TEU, which was a milestone in container ship capacity for the expanded Panama Canal (PCA, 2022). Notably, Rodrigue and Ashar (2016) argued that the expanded Panama Canal would exert a negative impact on Panamanian transshipment ports on the Pacific side because post-Panamax ships would not have ship size constraints.

On the other hand, it should be noted that from 2010 to 2022, while the laden containers represented 72% of the total container port throughput of transshipment ports in Panama, empty containers accounted for 28% of the total. According to Christoph et al. (2022), the median of empty container port throughput for seaports is around 20% of the total volume. This should be a matter of consideration for port managers because of the higher percentage of empty container port throughput in the Panama Canal compared to elsewhere in the world.

This consideration about empty containers should not be taken lightly because of its repercussions in the shipping industry. For instance, the relocation of an empty container to another port thousands of kilometers away can cost significantly more than buying a new container (Lam & Iskounen, 2010). Likewise, increasing empty containers is commonly related to trade imbalance (Song & Dong, 2011). As a result, when it comes to cargo TEU, liner shipping companies face challenges to relocate empty containers from America to other regions to satisfy the worldwide demand for exports (Chao & Yu, 2012). Consequently, shipping liners will prioritize and conduct scheduled operations based on laden containers instead of empty containers (K. Wang et al., 2017).

Suggestions for Further Studies

Further studies should analyze whether the Panama Canal expansion has significantly affected port throughput in Caribbean and Central American transshipment ports due to their geographical proximity as well as others located on the Pacific Ocean side of South America. Similarly, further studies should consider other factors regarding transshipment ports on the West and East Coasts of the United States and their relationship with the Panama Canal expansion.

It is also recommended that future research should study other related factors such as ship waiting time, berthing time, international trade, human talent management, port congestion, strategic leadership, and other port performance indicators. Moreover, while considering port cargo volume as a measure of accomplishment, several influential factors can also help transshipment ports succeed, such as their proximity to shipping lanes, terminal facilities, management, and productivity, which can help them understand but not accurately predict their causes of success (McCalla, 2008). Similarly, Ng (2006) highlighted that when it comes to transshipment ports, there are other important variables such as monetary cost, time efficiency, geographical proximity, and quality of service.

It is also suitable to study the influence of the Panama Canal expansion by using more inclusive indicators. For instance, the Liner Shipping Connectivity Index measures the maritime connectivity for container shipping by taking into account other aspects such as the number of shipping lines, size of vessels, number of services, and capacity (Niérat & Guerrero, 2019).

Likewise, further studies should research the return on investment for transshipment ports in the Caribbean Sea and Pacific Ocean that embarked on projects to enhance infrastructure, equipment, and logistics facilities related to the Panama Canal expansion. In that regard, transshipment ports in Panama have been making multimillion-dollars investments in new cranes and container yards to accommodate bigger vessels coming to the Panama Canal (Alvarez et al., 2009). A final suggestion for further studies would be the analysis of the Panama Canal expansion's effect on its surrounding maritime cluster, such as the Colon Free Trade Zone, the Panama Pacifico Special Economic Zone, tourism industries, Panama's International Banking Center, the Panama Canal Railway Company, the maritime supply chain, and shipyard industries.

Conclusion

This research examined the effect of the Panama Canal expansion, completed in June 2016, on the port throughput of transshipment ports. These transshipment ports include the Panama Port Company-Balboa and the PSA Panama International Terminal in the Pacific Ocean in addition to the Colon Container Terminal, the Manzanillo International Terminal, the Panama Port Company-Cristobal, and the Bocas Fruit Company Port in the Caribbean Sea.

To test its effect, the Wilcoxon signed-rank test was used to analyze two periods. The first period covered the third quarter of 2010 to the second quarter of 2016. The second period covered the third quarter of 2016 to the second quarter of 2022. As a result, the research concluded that the Panama Canal expansion has not elicited a statistically significant impact on port throughput in the six transshipment ports located in the Republic of Panama despite their geographical proximity to the Panama Canal. In other words, the Panama Canal expansion has failed to be a game-changer for the six transshipment ports located in Panama. These findings could have substantial implications for managers, investors, and maritime clusters related to Panama transshipment ports.

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