
Original Article

When Water Runs Low: Economic and Geopolitical Effects of Panama Canal Capacity Shocks on Global Trade

Nicole Bernoni

nicolebernoni@gmail.com

Received: 07 September 2025 / Revised: 18 October 2025 / Accepted: 22 Oct. 25, 2025 / Published online: 23 October 2025

© The Author(s) 2025

Abstract: In recent years, the Central American region has been affected by increasingly severe episodes of drought, culminating in the 2023–2024 water crisis that drastically reduced the daily operating capacity of the Panama Canal. In particular, during that year, the Canal handled fewer than 10,000 transits, marking a 29% decline compared to 2023. This and other events have highlighted the vulnerability of this strategic infrastructure, with immediate repercussions on international trade: higher transit fees, rerouting of maritime traffic toward longer and more costly passages, pressure on energy and food markets, as well as slowdowns in global supply chains. This study analyzes, from an economic and geopolitical perspective, the effects of such water-related shocks, and proposes a model to quantify the impact of Canal’s reduced capacity on global trade flows of its main user countries.

Keywords: Panama Canal, Trade dependency, Export simulation, Canal capacity shock, international trade

1. Introduction

The Panama Canal is one of the main arteries of global trade: it stretches for approximately 80 kilometers and, at its widest point, reaches 350 meters. About 5 percent of global maritime traffic passes through it [1], linking the Atlantic and Pacific coasts of the Americas while shortening routes to Asia and Europe. Unlike other maritime chokepoints¹, such as the Suez Canal or the Strait of Malacca, the operation of the Panama Canal directly depends on the availability of freshwater, which is required to fill its locks². Each transit consumes millions of liters of water drawn from Gatún Lake and Alajuela Lake, making the infrastructure particularly vulnerable to climatic shocks.

The relevance of these dynamics is not only economic but also geopolitical. The control and operability of the Canal affect global trade balances, shape strategies for route diversification, and raise new questions of infrastructural

¹ A “choke point” is a strategic passage where the flow of people, goods, or resources can be controlled or blocked, limiting access or transit capacity. In geopolitical and logistical contexts, it often refers to maritime straits or key communication routes essential for global trade.

² Locks are hydraulic structures that enable navigation between water stretches located at different elevations, allowing vessels to be raised or lowered by filling or emptying a chamber enclosed by gates.

security. While the Canal has historically been at the center of dynamics of sovereignty and geopolitical influence, today it is increasingly understood as a strategic water infrastructure, whose climate vulnerability has direct implications for global value chains.

The academic literature on the Panama Canal is extensive from historical and engineering perspectives, yet far less developed in its economic and geopolitical dimensions. Most existing studies focus on the economic effects of infrastructural expansions, particularly in relation to transit costs and the ability to accommodate larger vessels [2]. Far fewer contributions examine the link between water availability and Canal operations. Some technical studies have highlighted the environmental constraints associated with the management of artificial reservoirs, but they have not developed quantitative models of macroeconomic impacts. At the same time, economic and geopolitical literature has thoroughly examined the role of maritime chokepoints such as the Suez Canal or the Strait of Hormuz, showing how the vulnerability of these infrastructures can generate volatility in energy and food markets. However, the case of the Panama Canal is distinctive: its criticality does not stem primarily from political risks or armed conflicts, but rather from climate shocks and water scarcity - factors that have so far received only marginal academic attention

2. The Panama Canal in Historical Perspective: Colonial Competition and U.S. Global Projection

The idea of constructing an artificial passage across the Central American isthmus dates back to the sixteenth century, when Álvaro de Saavedra, only a few years after Balboa's discoveries (1513) and the foundation of Panama by Ávila (1519), recognized the strategic utility of a transoceanic route [3]. The proposal reached Charles V, who initiated the first studies, but rivalries among colonial powers and ongoing political tensions prevented their realization. With the independence of the former Latin American colonies, the idea resurfaced as an instrument of economic and political emancipation. At the Pan-American Conference of 1826, the project of a canal was discussed not as the exclusive asset of a single nation, but rather as an infrastructure of universal interest. This marked the emergence of the principle of canal neutrality, destined to serve the international community, with external - particularly U.S. - financial support.

The United States, having concluded its phase of internal expansion and lacking a frontier to conquer, sought new markets. Industrial growth between 1898 and 1900 had already saturated domestic demand, pushing toward global commercial integration. In this context, the Panama Canal became a strategic objective: a means to project American power beyond continental borders and to secure simultaneous access to both the Atlantic and Pacific. It is no coincidence that as early as 1825 the Central American republics sent an official note to Washington requesting U.S. involvement in the project. Henry Clay, Secretary of State, confirmed the American government's interest, while Simón Bolívar emphasized Panama's centrality in geopolitics. At the Pan-American Congress it was established that the canal should have a universal character, a principle ratified by the U.S. Senate in 1835 with the recognition of the free and equal right of use by all nations.

The nineteenth century, however, saw rising rivalries between the United States and Great Britain, both interested in controlling the future canal. To avert conflict, the Clayton-Bulwer Treaty was signed in 1850, which established the neutralization of the project: neither power could claim exclusive control, build fortifications, or assert

dominion over surrounding territories such as Nicaragua or Costa Rica. This agreement reflected the fragile geopolitical balance between Atlantic powers but did not eliminate long-term tensions. While the United States temporarily turned inward to confront the Civil War and Britain focused on consolidating its empire in India, France obtained in 1881 a concession from Colombia to build the canal. Ferdinand de Lesseps, renowned for his success with the Suez Canal, founded the French Panama Canal Company. Yet unlike Suez, the enterprise proved to be an unprecedented engineering and environmental challenge: it required cutting through the Culebra Mountain, dealing with landslides, torrential rains, and tropical diseases. Climatic and sanitary conditions caused the death of some 20,000 workers, and the French company, burdened with a \$207 million deficit, declared bankruptcy [4]. It was in this vacuum that the United States, under President Theodore Roosevelt, reasserted its geopolitical supremacy. Determined to secure control of the isthmus, Washington supported the Panamanian independence movement against Colombia. In 1903, with the proclamation of Panama's independence, the U.S. obtained a perpetual concession over the canal, transforming it into a cornerstone of its global maritime strategy. The work was not only an engineering triumph but above all a symbol of American power projection and of the principle that strategic transcontinental infrastructures are decisive instruments for controlling trade routes and redefining global geopolitical equilibria [5].

3. Locks, Lakes, and Limits: Understanding the Hydrological Constraints of the Panama Canal

Engineers understood from the outset that excavating the entire Isthmus of Panama down to sea level would have required a disproportionate investment in labor, time, and financial resources. The adopted solution was a revolutionary innovation: the creation of a vast artificial lake - Gatún Lake - designed to transport ships for approximately 33 kilometers through the heart of the isthmus. To achieve this, the Gatún Dam was constructed, one of the most imposing engineering works of its time, though it entailed the flooding of thousands of hectares of forest and the displacement of numerous settlements [6].

The lake serves not only as a navigational link but also as the main freshwater reservoir of the system: its waters feed the locks, enabling the raising and lowering of ships along the interoceanic passage. The Panama Canal is not, in fact, a sea-level canal: vessels must be lifted about 26 meters above ocean level to cross Gatún Lake, before being lowered again toward the opposite ocean. Each passage requires, on average, more than 100,000 cubic meters of freshwater, which flows by gravity from the lakes into the locks. This is an ingenious yet costly mechanism: the water used for each transit is discharged into the sea and cannot be recovered.

The "battery" of the system is therefore the tropical hydrological cycle, which replenishes Gatún and Alajuela Lakes through the Chagres River. These lakes have a multifunctional role: in addition to sustaining canal traffic, they supply drinking water to the Panama metropolitan area and support agricultural, industrial, and ecological uses. Maintaining a freshwater-based system is thus vital. Any infiltration of saltwater into the reservoirs would disrupt the ecological balance, compromise potable water quality, and accelerate infrastructure corrosion, with severe economic consequences. The operability of the canal therefore depends on an extremely delicate hydrological balance: in years of abundant rainfall, the lakes maintain sufficient levels to ensure the full functionality of the locks, whereas in periods of drought - becoming increasingly frequent due to climate variability - the reservoirs drop rap-

idly. This necessitates immediate restrictions: reductions in maximum allowable draft (forcing vessels to carry lighter loads) and a decrease in the number of daily transits.

To meet growing global traffic demand, in 2006 the Panama Canal Authority launched the construction of two new series of locks, known as the New Panamax, one on the Atlantic side and one on the Pacific side, capable of accommodating larger ships that can carry up to twice the cargo of traditional Panamax vessels. However, this expansion raised a critical concern: the increased consumption of freshwater from the artificial lakes. To mitigate this, the new locks were equipped with an innovative system of side basins that recycle part of the water during each cycle, significantly reducing consumption and improving the canal's sustainability. The economic and geopolitical consequences of water restrictions are immediate and global. Transit delays generate long queues at the canal's entrances; costs rise due to auction mechanisms that favor those willing to pay more; and part of the traffic is diverted toward alternative routes such as the Suez Canal or the circumnavigation of the Cape of Good Hope. Yet these deviations imply longer navigation times, higher energy consumption, and increased costs along the entire supply chain [7].

The case of the Panama Canal thus demonstrates how an apparently local natural phenomenon - tropical rainfall variability - can become a structural constraint on global trade. The hydrological cycle itself becomes a true "bottleneck" of globalization: less rainfall means less water in the lakes, reduced lock operability, and diminished canal capacity, with direct effects on international logistics and the organization of global maritime routes. The Panama Canal therefore represents a genuine global chokepoint. Its reduced capacity generates significant economic and geopolitical repercussions worldwide. Alongside these global effects, critical local issues also emerge it is estimated that the passage of a single ship requires an amount of water equivalent to the daily needs of roughly 500,000 Panamanians. The use of water for the canal thus conflicts with the needs of the population, more than half of whom rely on the same lakes. Moreover, reduced transits lead to a significant loss of revenue for the state: canal tolls account for approximately 6 percent of Panama's GDP, with direct impacts on the national economy and citizens' welfare.

The primary cause of this water crisis is linked to climatic factors. Although Panama enjoys an equatorial climate with generally abundant rainfall, in 2023 precipitation decreased by about 40 percent, largely due to the cyclical El Niño³ phenomenon, which increases average temperatures and reduces rainfall. This implies that drought periods will become increasingly prolonged and intense, leading to a progressive decline in water availability in the reservoirs that sustain both the canal and Panama's broader hydraulic infrastructure [8].

4. Proposed Methodology

To estimate the effect of a reduction in goods transit, the five countries with the highest traffic through the Panama Canal in 2024 were selected, based on official data from the Panama Canal Authority. For each country, two key elements were collected: the tonnage of goods transiting the Canal, expressed in long tons, and the total value of exports to the rest of the world, expressed in euros.

³ El Niño is a climatic phenomenon characterized by the abnormal warming of surface waters in the eastern tropical Pacific Ocean, which alters global atmospheric patterns, affecting precipitation, droughts, floods, and economic activities in various regions worldwide.

Table 1. Panama Canal Cargo Traffic: Leading 5 Countries, 2024 (Long Tons)

Top 5 countries by cargo traffic through the Panama Canal 2024 (longtons)			
Country	Total	Total in kg	%
United States	160.121.069	162.683.006.104	58,6
China	45.042.754	45.763.438.064	16,5
Japan	30.730.138	31.221.820.208	11,2
Republic of Korea	19.668.991	19.983.694.856	7,2
Mexico	17.725.942	18.009.557.072	6,5
Total	273.288.894,00		100,0
* The participation percentage for each country is calculated from both the origin and destination perspective of the cargo: each ton of cargo is assigned an origin and a destination for each country.			
ABAQUA calculations based on data from the Panama Canal Authority			

In line with approaches found in the literature, canal dependency was estimated using indicators based on the share of trade flows transiting through major maritime chokepoints. As in [9], dependency is measured as the proportion of national trade crossing the Suez Canal, both in terms of value and volume. Similarly, the [10] study calculates, for Germany, the share of imports and exports that depends on passage through specific chokepoints. Following these methodological frameworks, a canal dependence index was constructed, calculated as the ratio between the tonnage transited and the total exports of the countries using the Canal. Although this indicator compares physical units with monetary values, it provides a relative measure of countries' commercial vulnerability to the Canal's operation, highlighting those for which Panama transits represent a significant share of total trade.

$$\text{Canal dependency} = \frac{\text{Total exports (in euros)}}{\text{Quantity exported via canal}} \quad (1)$$

The analysis then focused on the three main countries - United States, China, and Japan - as they collectively represent approximately 86% of the total tonnage transited. The dependence index values calculated for 2024 are 13.6 for the United States, 12.08 for China, and 12.75 for Japan, confirming the strategic importance of the Canal for these primary exporters.

Table 2. Panama Canal Dependency Index

Dependency Index of the Top 3		
Country	Export in euros	Dependency
United States	1.196.129.520.120	13,60
China	378.929.884.106	12,08
Japan	244.858.839.152	12,75

The dependence index was subsequently used to simulate the effect of hypothetical reductions in Canal capacity, under scenarios of 5%, 10%, and 15%. The simulation applied the formula whereby simulated exports are equal to actual exports multiplied by the product of the capacity reduction and the dependence index, properly normalized.

$$\text{Simulated export} = \text{Actual export} * (1 - \text{Canal Reduction (\%)} * \text{Canal dependency}) \quad (2)$$

Normalization represents the share of exports remaining available after the shock: without reduction, the subtractive term is zero, and simulated exports coincide with actual exports; in the presence of a reduction, the subtracted share corresponds to the portion of exports theoretically lost due to the limited Canal capacity. Although simplified, this approach allows a straightforward estimate of how the trade flows of major countries are potentially sensitive to operational shocks of the Canal. The analysis provides initial quantitative evidence of the strategic relevance of the Panama Canal for international trade and enables a comparison of the relative impact of different capacity reduction scenarios on the export flows of the main user countries.

A related approach is provided by [11], who combine a maritime logistics model with a Computable General Equilibrium (CGE) framework to simulate the systemic effects of chokepoint disruptions. Their study introduces hypothetical shocks - such as increases in “iceberg” trade costs and tariff-like barriers - applied to three major chokepoints (the Panama Canal, the Suez Canal, and the Bosphorus Strait).

Table. 3 Assumptions on Panama Canal Traffic Reduction

Country	Reduction in traffic (%)		
	5%	10%	15%
United States	159.032.183	157.943.297	156.854.411
China	44.770.763	44.498.772	44.226.781
Japan	30.534.219	30.338.300	30.142.380

The results obtained for the United States, China, and Japan show a consistent pattern: as Canal capacity decreases, simulated export values decline proportionally to each country’s level of exposure. The simulation indicates that capacity reductions produce similar effects for all three countries: in each case, exports contract by a roughly proportional amount. These common dynamics highlight that Canal dependence acts as a shared vulnerability factor. Japan experiences a relatively stronger impact due to a slightly higher dependence index, even though its total exported value is smaller, making its foreign trade more sensitive to modest changes in transit capacity. Overall, the three economies considered are particularly exposed to infrastructural shocks affecting interoceanic traffic. The simulation, despite its simplified nature, underscores a crucial point: disruptions at the Canal are not marginal events but propagate with intensity directly proportional to the degree of dependence, transforming a hydrological and logistical constraint into a major macroeconomic issue for the trade partners involved.

5. Conclusion

The analysis highlights that the United States, China, and Japan, together accounting for the majority of goods traffic through the Panama Canal, exhibit a high degree of dependence on the Canal, with the value of their exports

closely tied to the operational functionality of this critical infrastructure. Simulation results confirm that the impact of capacity reductions on exports is broadly uniform across these major trading nations: although quantitative differences exist, the contraction dynamics are largely consistent, indicating that operational shocks to the Canal propagate transversally across international trade flows. These findings are particularly salient in light of the structural challenges currently confronting the Canal.

This study demonstrates that water-related crises warrant attention and proactive management even in contexts where water scarcity does not appear to be an immediate concern but requires long-term strategic oversight. For instance, prolonged periods of low or absent rainfall are atypical for Panama, which ranks fifth globally in terms of annual precipitation according to World Bank data.

The Government of Panama is currently evaluating the construction of a new artificial reservoir along the Chagres River, aimed at increasing daily transit capacity by approximately 12–15 additional vessels. Such an undertaking, however, would necessitate an investment of at least USD 900 million and entail significant social and environmental impacts, including the displacement of local communities and the loss of protected natural areas.

Moreover, addressing water scarcity through infrastructure alone is insufficient. Droughts induced by climate change represent an escalating risk to Canal's long-term sustainability, potentially undermining its capacity to maintain stable transit levels in the future. In this context, international trade must increasingly account for alternative routes, each associated with distinct costs and trade-offs. From this perspective, current dependence on the Panama Canal constitutes not only a measure of vulnerability but also a strategic factor necessitating the reassessment of the global geography of maritime trade routes.

References

- [1] Mariottini, L. (2016). Entre océanos. La geopolítica dei canali in America Latina. *GNOSIS*, 1, 81-89.
- [2] Rodrigue, J. P., & Notteboom, T. (2012). The Panama Canal expansion: business as usual or game-changer. *Port Technology International*, 51, 10-12.
- [3] Iannettone, G. (1978). Sul Canale di Panama. *Rivista di Studi Politici Internazionali*, 45(2 (178), 209-228.
- [4] Waltham, T. (2023). Difficult ground conditions at the Panama Canal. *MERCIAN GEOLOGIST*, 20(4).
- [5] Mills, P. (2022). Teddy Roosevelt and the Panama Canal. *Legacy*, 22(1), 7.
- [6] Carse, A. (2012). Nature as infrastructure: Making and managing the Panama Canal watershed. *Social Studies of Science*, 42(4), 539-563.
- [7] Carse, A. (2014). *Beyond the big ditch: Politics, ecology, and infrastructure at the Panama Canal*. Mit Press.
- [8] Aguilar, G., & Naranjo, L. (2022). The Panama Canal: The 2015–2016 El Niño. In *El Niño Ready Nations and Disaster Risk Reduction: 19 Countries in Perspective* (pp. 347-360). Cham: Springer International Publishing.
- [9] UNCTAD. (2024, February). Navigating troubled waters: Impact to global trade of disruption of shipping routes in the Red Sea, Black Sea and Panama Canal (UNCTAD Rapid Assessment, No. UNCTAD/OSG/INF/2024/2). Geneva: United Nations Conference on Trade and Development.

- [10] Bodenschatz, P., Erhardt, K., Flach, L., & Eberth, L. (2025). The Role of Maritime Chokepoints for German International Trade (No. 56). ifo Institute-Leibniz Institute for Economic Research at the University of Munich.
- [11] Key, R., Parrado, R., Delpiazzo, E., King, R., & Bosello, F. (2024). Potential climate-induced impacts on trade: the case of agricultural commodities and maritime chokepoints. *Journal of Shipping and Trade*, 9(1), 11.