Infrastructure, Water Supply, and Firm Performance*

Nora Pankratz

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Abstract

This paper investigates the potential effects of climate change on firms and supply chains by examining capacity constraints in critical infrastructure. Using granular data on firms' shipping routes, I exploit exogenous variation in water supply to the Panama Canal to analyze the effects of disruption in transportation on the profitability and investment capacity of over 6,000 U.S. firms. I find that a one-standard deviation decrease in precipitation in the watershed decreases revenues by 0.5% and operating income by 3%. In addition, firms face rising costs when precipitation decreases. Highlighting potential liquidity constraints, highly exposed firms experience an increased reliance on trade credit. Less exposed firms face declines in cash holdings consistent with spillover effects. These findings underscore that natural capacity constraints in global supply chains can pose risks to firm performance and economic growth.

Keywords: Production Networks, Firm Performance, Climate Change
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†University of Toronto. Email: n.pankratz@rotman.utoronto.ca.

1 Introduction

Climate change poses growing risks to global trade and supply chains, exposing firms to disruptions beyond their immediate operations. While much attention has been given to direct firm-to-firm vulnerabilities in supply chains (see, e.g., Barrot and Sauvagnat [2016], Carvalho et al. [2021]), a less examined risk could arise from capacity constraints in critical infrastructure. If key trade routes become unreliable due to climate change, firms could face rising costs, unpredictable delivery times, and increased financial uncertainty.

Climate-induced infrastructure constraints are not just hypothetical. In recent years, droughts affected shipping along the Yangtze [European Space Agency, 2022], Rhine [CNBC, 2023], Mississippi [NASA Earth Observatory, 2022] as well as the Panama Canal [U.S. Energy Information Administration, 2024], reducing cargo capacity and increasing transportation costs. The Panama Canal in particular is a key transit point for global shipping with operations highly sensitive to rainfall due to its reliance on freshwater from Gatun Lake powering its lock system. Whereas 6% of global maritime trade pass through the canal, it is of particular importance to the United States (U.S.). Approximately 40% of U.S. container traffic passes the canal per year, and in 2021, more than 73% of ships were heading to or coming from U.S. ports [FreightWaves, 2024]. With large shares of firms relying on individual routes, transportation bottlenecks could have far-reaching effects and create systemic risks. Yet, the effect of such bottlenecks on firm performance and investments remain relatively under-explored.

In this paper, I examine the role of disruptions in infrastructure by studying the effects of reduced water supply to the Panama Canal on the profitability and investment behavior of U.S. firms. Using granular data on local precipitation, supply-chain relationships, shipping routes, and firm financial performance, I analyze how exogenous variation in the capacity of the Panama Canal impacts firms' revenues, operating income, trade credit, and liquidity constraints. Thereby, I find that lower precipitation or an increase of drought days in the Gatun Lake watershed leads to economically significant declines in revenue for firms relying on the canal. In addition, I find that operating expenses and operating income are adversely affected beyond the most exposed firms. This finding is consistent with spillover effects in an economy that is highly dependent on the passage, and underscores the possibility that that climate-induced bottlenecks can have wide-ranging financial consequences.

For the analyses, I combine data on supply-chain relationships from FactSet Revere, financial performance data from Compustat, and granular local information on rainfall in the watershed of the Panama Canal as the primary determinant of water supply to the canal from ERA5 by the European Centre for Medium-Range Weather Forecasts (ECMWF) [Hersbach, 2016]. I focus on precipitation and drought because of their direct impact on capacity. The canal operates through a lock system that relies on freshwater from Gatun Lake to lift and lower ships between the Atlantic and Pacific Ocean. Each vessel passing through requires 200,000 to 300,000 cubic metres of water, which is released from the lake into the locks. During periods of low rainfall, water levels decline, and constrain the number of ships that can pass the canal. When capacity constraints occur, the Panama Canal Authority uses an auction system to determine passage rights. Therefore, capacity constraints coincide with increases in the costs per passage.

To estimate the total precipitation contributing to the canal's water supply, I use watershed shapefiles from the Smithsonian Tropical Research Institute [Smithsonian Tropical Research Institute, 2025]. I then interpolate ERA5 data on total precipitation between grid nodes and aggregate precipitation across the watershed area. This approach allows for a precise measurement of the water available for canal operations to study how abnormally low rainfall conditional on season affects global trade and firm performance. I use two measures of water-related capacity constraints. First, I study the effects of changes in overall precipitation combined with season fixed effects. Second, I generate an alternative measure of drought as the number of days per financial quarter with rainfall below the $10^t h$ percentile of the historical distribution for the same calendar quarter.

Information on firms' usage of the canal comes from shipping routes and is inferred at this stage based on the start and end locations of customers and suppliers [Halili, 2022]. In the next iteration, this paper will use confirmed data on routing from customs reports, which is processed and provided by S&P Panjiva. The data offers granular insight into the specific routes used, and will help with a more definitive understanding of direct effects due to the exposure of firms to the canal and spillovers in the economy. In the meantime, the approach appears feasible as differences in duration between the first-best and second-best shipping routes tend to be substantial and mean that few firms deviate from the most efficient route [Heiland et al., 2019]. Firms' average exposures line up with broader estimates of firms' exposures. Based on the current data set, the mean (median) share of supply-chain per firm relationships involving passages of the Panama Canal per customer firm in Compustat is 20% (30%), with similar levels of exposure across industries.

Before analyzing the effects of capacity constraints of the Panama Canal on U.S. firm performance, I estimate the effect of precipitation and drought days on minimum water levels in the Panama Canal. Minimum water level are crucial, since they determine the number of passages but affect permitted freight. The Panama Canal Authority closely monitors rainfall and adjusts the number of transiting ships in response. Yet, net of managerial responses, I find that minimum water levels remain highly sensitive to rainfall. This result is consistent with operator and press reports that limited precipitation noticeably strains canal operations. To estimate causal effects, I focus on the precipitation-based measures of constraints going forward which are not driven by the decision making of the canal authority or the demand for passages in terms of trade volumes over time.

Based on this approach, there are two key results. First, I find that drought conditions, measured as below-average precipitation conditional on the time of year, affect firms' operations and corporate financial performance. Limited water supply decreases revenues and operating income for firms highly reliant on the Panama Canal, while less exposed firms' revenues are not affected. In contrast, firm profitability decreases across a wider range of firms with high and low levels of exposure to the canal. The effects are economically meaningful: a one standard deviation decrease in precipitation reduces revenues relative to assets by 0.53% and operating income relative to assets by 3.0%. In percentage terms, the results are consistent when I measure constraints in terms of drought days: For a one standard deviation increase equivalent to 5.8 days, revenues (operating income) over assets decreases by 0.86% (3.88%). In dollar amounts, the effects correspond to a decrease in firm revenue (operating income) by approximately $4.69 million ($770,000) at the mean as well as a decrease in revenue (operating income) by $330,000 ($55,000) at the median firm size.

As a possible explanation for the effects at high and low levels of exposure to the canal, I find that costs also increase across firms with both high and low levels of exposure to the canal, potentially driven spillover effects. For instance, spillovers could occur if disruptions affect the customers of a relatively less exposed firm and slow down their demand for inputs [Barrot and Sauvagnat, 2016], or if prices increase in equilibrium in input markets. In particular, I find that the cost of goods sold (COGS) increases when precipitation declines. In contrast, SG&A expenses remain largely unchanged across all firms. This result is in line with the intuition that the costs of trade disruptions, i.e., in terms of delayed deliveries or higher fees for passing the canal affect the costs related to production and are less likely reflected in sales, general, and administrative expenses. These patterns are consistent with a standard model of firm production and the idea that reduced water supply coincides with logistical bottlenecks. If firms produce goods or services using capital, labor, and inputs, a constraint of the quantity of desired inputs or increase in prices due to rising costs of shipping would be projected to decrease profits.

Second, I examine the effects on firm financing and investments. Analyzing trade credit and liquidity responses, I find that decreases in water supply increase accounts payable and accounts receivable for highly exposed firms. This result could indicate that firms increasingly draw upon trade credit but also have to extend customer credit when deliveries are held up. Less exposed firms do not exhibit any changes in trade credit. However, less exposed firms see negative effects on cash holdings and short-term investments during drought periods, in line with the documented adverse effects on expenses and income despite their lower levels of exposure. Again, this result could indicate that spillovers in the economy create financing pressures beyond the firms with the highest direct exposure. Finally, I include tests on adjustments in firms' investment behavior. In a world with financial constraints, the decreases in cash holdings of less exposed firms could be expected to lead to reduced investment. In contrast, in the absence of financial constraints, the costs of capacity constraints in shipping could make long-term investments in capital intensive projects more attractive to relieve the reliance on suppliers and exposure to the canal. For instance, such investments could involve acquisitions or large-scale investments in plant, property, and equipment. In line with the first hypothesis, less exposed firms experience negatively affected cash reserves together with decreases in short-term investments. For firms highly reliant on canal, however, there are no changes in capital expenditures, and long-term investments decrease with precipitation as well. Future analyses will examine dynamic responses to trends in constraints over time.

Taken together, the results point towards the relevance of infrastructure vulnerabilities in the context of climate change, firms, and supply chains. The estimates suggest that natural constraints to shipping affect firm profitability and potentially also firm financing and investments. Thereby, the findings connect to the literature on climate change and finance as well as the literature on the propagation of shocks in firm networks.

First, previous research in finance has studied the direct effects of weather shocks on firm profitability [Addoum et al., 2020, Pankratz et al., 2023, Ponticelli et al., 2023, Zhang et al., 2018]; stock returns [Addoum et al., 2020, Kumar et al., 2019] and financial markets [Acharya et al., 2022, Bansal et al., 2016, Sautner et al., 2023, Schlenker and Taylor, 2019]. The results in this paper align with these studies in indicating that firm performance is sensitive to a variety of climate-related hazards, and that not all of them are particularly salient. The most closely related paper might be Hong et al. [2019], who find that drought trends affect profit growth and produce predictable returns as a possible sign of under-reaction of the market to climate risk. Instead of the direct effects of drought on firm profitability, I study disruptions caused by droughts elsewhere through bottlenecks in transportation channels.

Second, the preliminary findings on the effects on cash reserves and investments fit with the previous literature on climate change and firms' financing decisions. For instance, previous research has linked increased risk related to climate change with adjustments of capital structure [Dang et al., 2023, Ginglinger and Moreau, 2023] and corporate investment behavior [Li et al., 2024]. In line with this literature, the results suggests that risks materializing in the real economic activity affect financing decisions.

Third, the paper relates to the literature on production networks. Previous research examines the propagation of shocks through firm-to-firm connections, and documents that firms can be indirectly exposed to natural hazards due to their global supplier network [Barrot and Sauvagnat, 2016, Boehm et al., 2019, Carvalho et al., 2021, Custodio et al., 2022]. Instead of the propagation of shocks between firms, this paper focuses on vulnerabilities in transportation infrastructure. These shocks could potentially pose larger and systematic risks due to correlations across firms when economies rely on a few prominent shipping routes.

Future versions of this paper will explore firms' and stock market responses in more detail. For instance, data extensions will make it possible to study firms' responses to uncertainty in shipping, and add to the growing literature on endogenous production networks, growth, and productivity [e.g., Acemoglu and Azar, 2020, Antràs et al., 2017, Lim, 2018, Oberfield, 2018]. However, the findings on the effects of constraints in water supply to the Panama Canal alone have potentially important implications. Bottlenecks causing vulnerabilities in shipping infrastructure exists in many regions of the world and cannot be directly managed by firms.

2 Data

For the analyses, I combine data on supply-chains, firm financial performance, and precipitation over the watershed of the Panama Canal from four main sources. The following sections describe the data, and explain how individual datasets are linked. Table 1 summarizes the key variables. Throughout the paper, I discuss relevant summary statistics in the context of the respective empirical tests.

2.1 Global Supply Chains

To determine firms' exposure to shipping through the Panama Canal, I use data on supply-chain relationships from FactSet Revere. The data is hand-collected by FactSet analysts based on a range of sources, e.g., annual reports, SEC filings, investor presentations, websites, press releases, supply contracts, and purchase obligations. Previous research (e.g., Banerjee et al., 2008, Cohen and Frazzini, 2008, Hertzel et al., 2008) has primarily relied on SEC regulation S-K, which requires U.S. firms to disclose customers representing at least 10% of their total sales. In contrast, the Revere data does not require sales to exceed 10%, and covers both U.S. and foreign firms. From the data, I obtain customer and supplier identifiers to match with locations and determine routing.

2.2 Accounting Data and Firm Characteristics

Further, I obtain financial data for over 6,000 U.S. firms from 2016 to 2024 from Compustat. A major structural change to the canal occurred with the Panama Canal Expansion Project, completed in June 2016. The expansion introduced a new set of larger locks (the Neopanamax locks) and increased capacity by allowing wider and heavier ships to transit. This expansion fundamentally altered operations. To avoid confounding the results with changes stemming from the capacity expansion, I focus on the time period after the completion. The main measures of sales turnover and profitability are quarterly operating income scaled by lagged total assets. I use information on firms' financial reporting schedules to ensure correct temporal matches between weather records and firm performance when financial quarters deviate from calendar quarters. I also collect data on employees, asset tangibility, operating margins, inventories, accounts receivables and accounts payable, cost of goods sold (COGS), sales, general, and administrative expenses, and short and long-term investments. For firm locations, I use addresses of headquarters from FactSet and geocode city, zip code, and street names using the Bing Maps API. For both customers and suppliers, I obtain six digit NAICS industry codes from Factset.

2.3 Routes

To infer data on shipping routes including departure and arrival ports, I use the sea route package for Python [Halili, 2022]. In the next iteration, this data will be replace with confirmed information on routing based on U.S. Customs data processed by S&P Panjiva.[1] Based on supplier-customer relations in Factset Revere, I calculate the share of supplier relationships that require goods to be shipped through major maritime passages per U.S. customer firm. Figure 1a shows the share of passages traversed across all supply-chain relationships. The Panama Canal has the largest share above 35%, followed by Gibraltar and the Suez Canal. Figure 1b shows the share of relationships with routing through the Panama Canal for U.S. firms. The mean of the distribution is 20% and the median is 30%. Figure 2a and figure 2b show routing shares grouped by the first digit and the first two digits of the NAICS code. Overall, reliance on the Panama Canal is fairly similar across industries. Naturally, not all supply-chain relationships are likely to rely on container shipping, and the route shares are measured with error. In this version, I address this possibility in robustness tests. In future versions, this challenge will be overcome by use of the aforementioned shipping records based on customs declarations.

To be able to conduct the analyses, I limit the sample to listed firms with financial data available. Therefore, the data captures a subsample of supply-chains biased towards large and listed customer firms in the United States. When capacity constraints occur, the Panama Canal Authority uses an auction system to determine passages. Hence, smaller, private firms may be more strongly affected by adverse weather if they are more financially constrained. The planned data improvements will help to provide a more accurate picture across all sizes of importers.

[1] The current approach likely increases measurement error in firms' exposure to routing through the Panama Canal. To improve on this aspect, I will obtain shipment-level data from S&P Panjiva. The data includes detailed records of shipment contents, trading partners, and departure and arrival ports and dates for more than 2 billion shipments. The coverage starts in 2007. For a detailed discussion of the data set see, e.g., Flaaen et al. [2023].

2.4 Precipitation

I study precipitation as the main source of water supply to the canal. For this purpose, I construct measures of firms' exposure to shortages at the firm-quarter-level using location-specific information from the ERA5 re-analysis data provided by the European Center for Medium-term Weather Forecasts (ECMWF). Re-analyses are generated by interpolating local temperature records using atmospheric models. ERA5 provides global hourly estimates of total precipitation per hour in metres on a 0.25° grid starting in 1979 (Hersbach et al. 2020). Figure 3 shows the aggregation of the data across the watershed. I use watershed shapefiles from the Smithsonian Tropical Research Institute [Smithsonian Tropical Research Institute, 2025] to determine the relevant area. I then interpolate ERA5 data on total precipitation between grid nodes and aggregate precipitation to cubic metres per month across the watershed area. This approach allows for a precise measurement of the water available for canal operations, providing insights into how climate-induced variability in rainfall affects global trade and firm performance. Figure 4 shows rainfall trends over time. Since Panama has a distinct rainy and dry season, trends are plotted separately. Accounting for firms' reporting schedules, I sum daily precipitation across the area of the watershed as well as the financial quarters as reported by firms. As an alternative measure of drought, I calculate the number of days of drought per month. Days of drought are defined as the number of days per financial quarter in which rainfall is less than the 10^th percentile of the distribution in rainfall for the same calendar month between 1970 and 1980. Intuitively, both measures are negatively correlated (-0.11). As the data on precipitation, monthly counts of drought days are aggregated and matched based on firms reporting schedules.

2.5 Gatun Lake Water Levels

In addition, I obtain historical information on daily water levels in the canal from the website of the Panama Canal Authority [Panama Canal Authority, 2025]. The data is plotted in Figure 5. Minimum levels of the reservoir are visibly becoming more volatile around 2014. In 2016, a major expansion was completed. The expansion introduced a new set of larger locks and increased capacity by allowing wider and heavier ships to transit. Hence, increases in volatility are likely driven both by drought conditions as well as the increased demand for water to operate the expanded locks after 2016.

3 Methodology

To study the impact of disruptions on firm performance, the tests leverage plausibly random variation in precipitation over the watershed of the Panama Canal. The canal operates using a lock system that depends on freshwater from Gatun Lake, which in turn is replenished by rainfall within the watershed. Each vessel transit requires a substantial amount of freshwater, which is released into the ocean afterwards as part of the lock operations. Precipitation is the main determinant of water availability, affecting both the number of ships that can pass through and the overall freight capacity of the canal.

When water levels drop, the Panama Canal Authority imposes draft restrictions, reducing the maximum allowable depth for vessels. This restriction primarily affects large container ships and bulk carriers, forcing them to either lighten their loads or seek alternative routes. To manage water shortages, the Panama Canal Authority employs multiple strategies, including the implementation of water conservation measures, adjustments to transit schedules, and modifications to lock operations. One of the key mechanisms for allocating scarce canal slots during times of reduced capacity is an auction system, where shipping companies bid for priority passage. This system creates price surges, disproportionately affecting firms that are highly dependent on just-in-time supply chains and those unable to afford the increased transit fees.

As mentioned before, a major structural change to the canal occurred with the Panama Canal Expansion Project, completed in June 2016. The expansion introduced a new set of larger locks and increased capacity by allowing wider and heavier ships to transit. This expansion fundamentally altered operations. To avoid confounding the results with changes stemming from the capacity expansion, I focus on the time period after 2016. For illustration purposes, I test the effect of rainfall on minimum water levels in the reservoir, Lake Gatun. The tests need to be asssessed with a grain of salt, since the Panama Canal Authority closely monitors rainfall and adjusts the number of transiting ships in response. However, net of managerial responses, I find that minimum water levels remain sensitive to rainfall in Table A.1. This result is consistent with operator and press reports that limited precipitation noticeably strains canal operations. The sensitivity of levels to rainfall increases post 2016, potentially suggesting that the canal might operate closer to capacity in terms of freshwater supply.

For a causal analysis, I focus on the effects of rainfall instead of using the data on changes in water levels in the reservoir over time. By leveraging variation in precipitation, I isolate the causal impact of climate-induced infrastructure bottlenecks on firm outcomes. Since rainfall is exogenous to the decisions of the canal authority and difference in demand for passing the canal over time, its fluctuations provide a natural experiment to assess how disruptions propagate through global supply chains. Importantly, because the geographic distance between the canal and U.S. firms limits direct weather-related effects, the observed economic impacts primarily stem from logistical disruptions rather than other environmental factors.

To explore the impact of precipitation-driven infrastructure disruptions on customer firm performance, I estimate the following equation:

$$y_{jq} = \beta P_q + \mu_{j,s} + \gamma_{g,t} + \delta_{h,t} + \epsilon_{jq}, \tag{1}$$

where y_{jq} represents firm performance (e.g., revenues over assets and operating income over assets) for customer firm j in financial quarter q, and P_q captures total precipitation over the Panama Canal watershed in quarter q. The specification includes *firm-by-season fixed effects* ($\mu_{j,s}$) to account for seasonal differences in firm operations, *NAICS 2-digit industry-by-year fixed effects* ($\gamma_{g,t}$) to control for industry-wide trends, and *state-of-headquarters-by-year fixed effects* ($\delta_{h,t}$) to absorb macroeconomic shocks at the regional level. Standard errors are clustered by year-quarter, as the variation in precipitation is time-based, and the main tests use two-way clustered standard errors at the firm and quarter level to account for both firm-level autocorrelation and time-specific shocks. Robustness tests estimate the results under alternative specifications, including models with one-way clustering by firm or time and those with only firm or time fixed effects. Robustness tests also address the possibility of lagged effects of precipitation.

4 Results

4.1 Effects of Capacity Constraints on Firm Performance

Table 2 shows the estimated effects of precipitation in the Lake Gatun watershed on U.S. firm performance. Firm performance is measured as revenues relative to lagged assets in Table 2c and operating income relative to lagged assets in Table 2d. Column headers in both panels indicate thresholds for customer firms' exposure to shipping through the Panama Canal, with exposure increasing from left to right. Columns (1)–(3) show the results for firms with low levels of exposure as in no recorded exposure in column (1), for firms with an exposure below the sample mean of 20% in column (2), and for firms with exposures below the sample median of 30% in column (3). Columns (4)–(7) progressively limit the sample to firms whose shipments rely increasingly on the Panama Canal, i.e., firms with exposures of more than 20, 30, 50, and 75%. The intention behind these splits is the comparison of precipitation effects across firms with varying levels of dependence on the canal. In Panel (a) and Panel (b), water supply is measured as the natural logarithm of precipitation conditional on time of the year due to the inclusion of firm times season fixed effects. In Panel (c) and (d), shortages are measured by the number of days of drought. Days of drought are defined as the number of days per financial quarter in which rainfall is less than the 10^th percentile of the distribution in rainfall for the same calendar month between 1970 and 1980.

[Insert Table 2 here.]

I first examine the results for revenues over assets in Panel (a) and (c). For precipitation measured in cubic metres, the results suggest that an expansion of water supply has a positive effect on revenues, in reverse also implying that periods of drought negatively affect firm performance when firms are substantially exposed to the canal. The estimated coefficients indicate that for firms in the highest exposure categories (Columns 6 and 7), a 1% decrease in precipitation is associated with an 0.0082 to 0.0084 percentage point reduction in revenues scaled by assets. For firms with no or limited exposure to shipping through the canal (Columns 1–3), the estimated coefficient on log precipitation is small and statistically insignificant. The effect becomes both larger and statistically significant at the 5% level when restricting the sample to firm-quarters where at least 20% or more of shipments are exposed to precipitation-related disruptions (Columns 4–7). Based on Column (4), a one standard deviation decrease in precipitation—equivalent to a 15.3% drop in rainfall—leads to a 0.53% reduction in revenues relative to assets. At the mean firm size ($4.27 billion in assets), this corresponds to an estimated revenue loss of approximately $4.69 million, while for a firm at the median asset level ($306 million), the same precipitation shock leads to a revenue loss of about $330,000. These results indicate that firms highly reliant on the canal face meaningful revenue declines when water shortages disrupt shipping routes.

In Panel (c), the results are corroborated by the measure of drought days both in terms of significance and magnitude. A one percent increase in drought days is associated with a significant decrease of firm revenues but only for firms with more than 20% exposure to the Panama Canal. The magnitudes are similar with a decrease in revenues of -0.86% in revenues for a one standard deviation increase in drought days. For within-month variation, this increase corresponds to 5.77 days.

For operating income over assets, Panel (b) shows that effects of precipitation are stronger and consistent even at low levels of exposure. Across all specifications, the coefficient on log precipitation is positive and statistically significant, meaning that increases of rainfall are beneficial, while abnormally low rainfall conditional on season has negative effects. For firms with exposures above the sample median (Column 5), a 1% decrease in precipitation corresponds to a 0.0014 percentage point increase in operating income scaled by assets at the 1% significance level. In economic terms, a one standard deviation decrease in precipitation—equivalent to a 15.3% drop in rainfall—leads to a 3.0% reduction in operating income relative to assets. At the median firm size ($306 million in assets), this translates to an estimated operating income loss of approximately $55,000. Again, using drought days as an alternative measure of water supply yields similar results. In Panel (d), an increase in drought days by one standard deviation corresponds to a reduction of operating income over assets of 3.88%.

The finding that operating income is affected across both high and low levels of exposure to the canal could be driven spillovers. In line with the high average exposures of firms in the U.S. economy [FreightWaves, 2024], it is likely that firms with lower reliance on the canal still interact with firms with high exposure, i.e., if their customers are affect or if they source inputs from affected firms. These types of connections could affect the operations of firms at lower levels of exposure for instance by slowing down customer demand for inputs [Barrot and Sauvagnat, 2016] or due to additional costs being passed on. The similar effect across all levels of exposures would be consistent with this interpretation. Again, the results are corroborated by the measure of drought days in Panel (d). A one percent increase in drought days is associated with a decrease in operating income over assets regardless of firms exposure to the canal.

These baseline result indicates that the earnings of firms in the U.S. are highly sensitive to water supply to the Panama Canal. I conduct three different robustness tests. First, I estimate the results with variations in the specification of fixed effects. As Table A.2 shows, the results for both revenues and operating income for the average firm in the sample hold with specifications limited to firm, quarter, and year fixed effects as well as with more granular controls for industry-year as well as state-year dynamics. Second, Table A.3 shows that the results are robust when clustering standard errors by firm, time, and firm and time. Columns 1-3 show the results for revenues over assets, and Columns 4-6 show the results for operating income scaled by assets. All estimate corroborate the idea that decreases in precipitation lead to decreases in firm performance. Third, I test for lagged effects in Table A.4. For revenues, results seem to be concentrated in the contemporaneous quarter, suggesting that disruptions to the canal affect firms without long delays. The only exception is a significant effect of rainfall on revenues over assets in both the contemporaneous and next quarter in Column (3). For operating income, the samples with the lowest levels of exposure are to small for the estimation of two-way clustered fixed effects. However, at all other levels with exposure shares of 20% or higher, the results do not suggest lagged effects beyond the contemporaneous quarter. Overall, the results are plausible since shipping time to the U.S. is relatively short once ships pass the canal.

[Insert Table 3 here.]

The mechanisms behind the effect require further investigation. Table 3 shows cross-sectional tests for the effects on operating income over assets. In Panel (a), precipitation is measures as the log of rainfall in cubic metres. In panel (b), drought days are measured as the log of days below the 10^{th} percentile of the distribution per calendar month between 1970 and 1980. In column (1), I interact the measure of precipitation with an indicator that labels service industries. Included industries are classified based on the first two digits of the NAICS code, and cover 51 (Information), 52 (Finance and Insurance), 53 (Real Estate), 54 (Professional, Scientific, and Technical

Services), 55 (Management of Companies and Enterprises), 56 (Administrative and Support and Waste Management and Remediation Services), 61 (Educational Services), 62 (Health Care and Social Assistance), 71 (Arts, Entertainment, and Recreation), 72 (Accommodation and Food Services), and 81 (Other Services). In line with the expectation that the effects should be attenuated in service industries, the sign of the coefficient is negative in Panel (a) and positive in Panel (b). However, the effects are not statistically significant (-0.0007, $p = 0.24$). Column (2) introduces an interaction with an indicator for industries in which firms are likely to rely on container shipping. The coefficient for the interaction term is positive and highly significant in Panel (a) only (0.0020, $p < 0.01$). A positive effect is consistent with the notion that firms heavily engaged in containerized trade experience greater sensitivity to precipitation-related disruptions. Column (3) includes an interaction term for firms located on the U.S. West Coast following the intuition that firms on the West Coast might rely less on routing through the canal since trade between the U.S. and Asia is not affected. The estimated coefficient is statistically insignificant in Panel (a) and negative and significant in Panel (b). This result is puzzling and might suggest that the measure of exposure in terms of inferred routes is noisy. Data on shipping records will help overcome this challenge.

Due to the auction system, it is likely that larger and less financially constraint firms are less affected by capacity shortages. To test whether the results are consistent with this mechanism in the cross-section, Column (4) interacts precipitation with firm size and sales turnover. The interaction with mean assets is negative and significant (-0.0231, $p < 0.05$) in Panel (a), suggesting that larger firms are less sensitive to precipitation-driven disruptions, potentially due to greater supply-chain flexibility or diversified sourcing strategies. In contrast, the interaction with mean sales turnover is positive and significant (0.0072, $p < 0.05$) in Panel (a), indicating that firms with higher sales turnover might be more vulnerable to disruptions, possibly due to tighter inventory cycles and greater reliance on efficient logistics networks. Signs and significance in Panel (b) are consistent with these effects.

As a robustness test, I also interact the measure of precipitation with an indicator for the period affected by Covid, i.e., 2020 and 2021. As the estimate in Column (6) shows, the exclusion does not alter the magnitude or significance of the result for both measures of water supply.

So far, the results indicate that precipitation-driven disruptions at the Panama Canal affect firm revenues and profitability, with stronger effects observed for firms engaged in containerized shipping and those with higher sales turnover. These findings suggest that precipitation variability may influence firms' operational dynamics and potentially alter input costs. To further investigate these channels, I next examine how precipitation affects firm expenses.

[Insert Table 4 here.]

Table 4 presents OLS regressions on the effects of precipitation on the natural logarithm of costs of goods sold (COGS) (Columns 1–4) and sales, general, and administrative expenses (SGA) (Columns 5–8). In Panel (a), I use the continuous rainfall measure for water supply. Columns 1 and 5 (2 and 6) show the effects for firms with less than the mean (median) exposure to the canal. Columns 3 and 7 (4 and 8) show the results for firms above the median exposure. Both for firms with low and high levels of exposure, the results suggest that reduced precipitation decreases the COGS. The coefficient on log precipitation is negative and statistically significant across all specifications. The magnitude implies that a 1% increase in precipitation reduces COGS by approximately 0.045 percentage points (Column 4, significant at the 10% level). The magnitude for relatively less exposed firms is similar. In contrast to the effects on revenues, the adverse effects of decreases in precipitation are therefore not solely driven by high exposures. In principle, this result is consistent with the previously discussed spillovers between highly directly affected and less affected firms. For instance, if firms have no direct exposure to the Panama Canal as a shipping route but rely on inputs from firms that do, increased costs from higher auction prices might be passed through. Also, if disruptions lead to shortages of inputs, these shortages could affect input prices available to U.S. firms in aggregate.

In contrast, to the COGS, it is less clear whether disruptions could affect sales, general, and administrative expenses. In line with this expectation, the results in Columns 5–8 show no significant effect of precipitation on SG&A expenses. Across all specifications, the estimated coefficients on log precipitation are small and statistically insignificant (ranging from -0.0015 to 0.0017), with t-statistics close to zero. If reduced rainfall causes re-routing and higher transportation costs, it is plausible that the effects materialize in the COGS rather than the less sensitive SGA. The results are consistent in Panel (b), measuring constraints by drought days. In the subsequent analyses, I focus on the continuous measures of rainfall but will expand the results using different measures of drought.

Taken together, the documented effects on costs fit in with the previous findings on revenues and profitability. Whereas the effect on revenues is concentrated in highly affected firms, the results show that operating incomes are sensitive to water supply across the whole spectrum of firms' exposures. This difference would be consistent with the effects on operating income being driven by costs, i.e., if costs get passed on or increase in aggregate.

[Insert Table 6 here.]

The previous findings suggest that water supply to the Panama Canal influences firm revenues, costs, and profitability. However, disruptions might also affect inventory management, asset depreciation, and turnover dynamics, as firms reallocate resources to mitigate logistical uncertainties. Table 6 explores these effects differentiating firms based on their exposure to routing through the Panama Canal as in the previous tests.

First, Panel (a) shows the effects on inventory adjustments. Columns (1) and (2) suggest that firms with lower exposure to the Panama Canal (less than 20% and less than 30%) hold increased inventory when precipitation decreases, with coefficients for abnormal precipitation of -0.0258 ($p < 0.10$) and -0.0228 ($p < 0.10$). These effects suggest that firms less reliant on the canal may still experience increased logistical frictions. However, for firms with higher exposure to the canal (less than 20% and less than 30%), the estimated effects are smaller and statistically insignificant, suggesting that the effects on inventories could be attributable to spillover effects within the economy.

Second, In Panel (b), I test whether deviations of water supply from the seasonal expectation lead to increased depreciation. For instance, such increases could be possible if shipments of perishable goods get delayed or if goods can no longer be sold following delays and possible contract infringements. However, the results show no significant effects of precipitation on firm depreciation rates across all exposure thresholds. The coefficients range from 0.0027 to -0.0180, with all estimates failing to reach conventional significance levels.

Third, Panel (c) examines possible effects on inventory turnover, defined as COGS divided by inventory holdings but shows no statistically significant relation with precipitation. The estimated effects range from -0.0286 to -0.0485, with all coefficients remaining statistically insignificant.

Fourth, Panel (d) tests the effects of decreased precipitation and possible delays on sales turnover. The results shows strong and statistically significant effects of precipitation on sales turnover (revenues divided by inventory). The estimated coefficients increase across exposure thresholds, ranging from 0.0331 ($p<0.10$) for firms with less than 20% exposure to 0.0637 ($p <0.01$) for firms with more than 30% exposure. These findings are in line with the idea that firms highly exposed to canal disruptions experience greater sales velocity when precipitation increases, possibly due to changes in demand allocation, order fulfillment strategies, or pricing dynamics during trade route disturbances.

4.2 Effects of Capacity Constraints on Financing

The previous findings suggest that shortages in water supply to the canal can influence firm revenues, costs, and working capital. If inventory dynamics in particular are driven by delayed transportation, an interesting question relates to who bears the costs of the tied up capital. In other words, delays in deliveries are likely to coincide with depleted cash holdings or increases in trade credit from either party. Table 7 examines these potential adjustments. The effects on accounts payable are shown in Panel (a) and the effects on accounts receivable are shown in Panel (b). Exposure to the Panama Canal increasing from left to right in each panel.

[Insert Table 7 here.]

The results in Panel (a) suggest that firms with higher exposure to the Panama Canal increase their accounts payable in response to decreases in precipitation. While the estimated coefficients in Columns (1)–(3) are small and statistically insignificant, the coefficients become larger in magnitude and statistically significant at the 1% level in Columns (4)–(7). Specifically, for firms with more than 20% of shipments routed through the canal (Column 4), a 1% decrease in precipitation is associated with a 0.0362 to 0.0370 percentage point increase in accounts payable relative to assets. For firms more dependent on canal shipping, the costs of tied up capital may be in part borne by suppliers providing trade credit for longer periods of time.

Panel (b) examines the effects of precipitation on firms' accounts receivable, which capture credit extended to customers. The results similarly indicate a shift in trade credit specifically among firms with higher canal exposure. While the estimated effects in Columns (1)–(3) are small and statistically insignificant, firms more reliant on canal shipping (Columns 5–7) exhibit a significant increase in accounts receivable when precipitation decreases. The coefficients for the amount of rainfall relative to seasonal expectations range from -0.0214 to -0.0238, with statistical significance emerging at the 10% level for firms with more than 30% exposure to canal shipping. These findings suggest that affected firms also need to extend trade credit to customers for prolonged periods, perhaps reflecting dissipating delays across the supply-chain.

The results indicate that water supply to the Panama Canal influences firms' short-term financial strategies. When precipitation decreases, both accounts payable and accounts receivable increase. In contrast, when water is more abundant, the amount of capital tied up in trade credit decreases. This findings suggest that firms both increase reliance on extended supplier obligations while simultaneously also extending more credit to customers when precipitation is scarce.

Frictions in canal operations and increases auction prices for passages may also affect firms' broader financial positioning, particularly their cash holdings and investment decisions. If firms experience pressure from limits in water supply and passages, cash reserves could be adversely affected. In a world with financial constraints, the decreases in cash holdings of less exposed firms could be expected to lead to reduced investment. In contrast, in the absence of financial constraints, the costs of capacity constraints in shipping could make long-term investments more attractive to relieve the reliance on suppliers and exposure to the canal. For instance, such investments could involve acquisitions or large-scale investments in plant, property, and equipment.

Table 8 examines these potential responses by analyzing the effects of precipitation variability on cash holdings (Panel a), capital expenditures (Panel b), short-term investments (Panel c), and long-term investments (Panel d). Across all four panels, exposures to the Panama Canal increase from left to right.

[Insert Table 8 here.]

The results in Table 8 indicate that firms with lower exposure to canal shipping (less than 20% and less than 30%) decrease their cash holdings in response to reduced precipitation, with significant coefficients of 0.0598 ($p<0.05$) and 0.0755 ($p<0.01$), respectively. In times with positive precipitation surprises relative to seasonal expectations, cash holdings increase. However, for firms more dependent on the Panama Canal (more than 20% and more than 30%), the estimates for these effects are smaller and statistically insignificant. While these patterns are somewhat surprising, they could be consistent with the effects documented on trade credit. Whereas more exposed firms show significant movement in extended and received trade credit, less exposed firms might be negatively affected due to a pass down of increased costs or other indirect factors influencing their liquidity. In this case, it is unlikely that the costs of delays would be absorbed by trade partners. Hence, shocks to cash reserves might be buffer for more directly affected firms but not for others. As mentioned before, further investigating these questions will be possible with more precise data on route utilization.

In contrast to the idea that transitory shortages might make investments, e.g., in local suppliers or make instead of buy decisions look more attractive, the results in Panel (b) indicate no statistically significant relationship between drought and capital expenditures, with coefficients ranging from -0.6207 to -0.4070 and t-statistics near zero. This null result might suggest that firms do not systematically adjust long-term capital investments in response to temporary drought-driven supply-chain disruptions. Unlike short-term liquidity decisions, capital expenditures are typically planned in advance, and it is plausible that the underlying investments might not be responsive to temporary trade constraints. The current analyses focuses on contemporaneous disruptions except for the robustness tests on the effect on firm performance earlier. However, future versions will address lagged responses more comprehensively.

Panel (c) shows adjustments in short-term investments, including marketable securities and other liquid financial instruments. This type of investment decreases significantly for firms with low exposure to the canal (less than 20% and less than 30%) when precipitation decreases, with coefficients of 0.4040 ($p<0.01$) and 0.3535 ($p<0.01$), respectively. In reverse, the investments seem to expand when water supply is more abundant, potentially lowering transportation costs and relaxing input markets. In both directions, the pattern is in line with the effects of constraints on cash holdings concentrated in the groups of less exposed firms. Potentially, these results together with the effects on costs and operating income for less exposed firms point towards spillovers. Firms with minimal canal exposure face indirect costs from trade partners in the economy with higher exposures. If their financing is constraint, a depletion of cash could coincide with lower capacities to hold short-term financial assets when shipping bottlenecks occur. In line with the absence of the cash effect and absorption of shocks through trade credit for highly exposed firms, firms more reliant on the canal (more than 20% and more than 30%) show small and statistically insignificant effects.

These estimates indicate that highly exposed firms do not systematically adjust their short-term investment portfolios in response to high precipitation or drought conditions.

Finally, Panel (d) shows the effects on long-term investments. Long-term investments increase for firms highly dependent on the canal (more than 20% and more than 30%), with coefficients of 0.1564 ($p<0.05$) and 0.1543 ($p<0.05$), respectively. These estimates imply that investments expand when shipping constraints are relaxed, and contract otherwise. Therefore, they could be indicative of the existence of financial constraints. Future analyses will explore this possibility in detail. Firms with lower exposure to the canal (less than 20% and less than 30%) show no significant changes in long-term investment behavior.

5 Conclusion

This study examines how precipitation-induced disruptions at the Panama Canal affect U.S. firm performance, financial strategies, and supply-chain adjustments. Using variation in precipitation over the Lake Gatun watershed, I document a series of firm-level responses to natural constraints on global trade routes. The results highlight that firms, particularly those highly reliant on the canal for shipping, adjust their revenues, costs, inventory management, trade credit, and investment strategies in response to supply-chain disruptions. However, some of the findings also point towards spillovers of the effects towards less exposed firms. These findings contribute to the growing literature on climate risk, supply-chain resilience, and financial decision-making under uncertainty.

A key takeaway from the analysis is that firms highly exposed to canal disruptions experience stronger revenue decreases than less exposed firms. When less rainfall than seasonally expected reduces water levels in the canal, firms with greater supply-chain reliance on this route are likely to face increased transportation costs and delays, perhaps leading to a response in trade patterns. These disruptions likely create pricing pressures and demand shifts, benefiting some firms while constraining others. At the same time, costs of goods sold (COGS) decline during drought periods, particularly for firms with lower exposure to the canal, suggesting that logistical adjustments and shifts in sourcing may influence input costs. Data on trade patterns, prices, and quantities of sourced inputs will be help to explicitly test for these possibilities.

In terms of financial decision-making, the results indicate that drought conditions at the canal influence firms' liquidity management and investment strategies. Firms less reliant on the canal decrease cash holdings and short-term investments, suggesting that they do not face strong financial pressures during disruptions. However, firms highly dependent on canal shipping increase long-term investments, possibly as a strategic response to mitigate future risks associated with supply-chain disruptions.

Beyond firm-level implications, the findings underscore the broader macroeconomic significance of climate-induced infrastructure disruptions. The Panama Canal is a critical node in global trade, and its sensitivity to climate variability poses systemic risks to supply chains. As climate change increases the frequency and severity of drought conditions, disruptions to global trade routes may become more persistent, amplifying economic volatility for firms highly dependent on maritime logistics. The results suggest that while firms adapt through liquidity management, trade credit adjustments, and supply-chain re-allocations, prolonged disruptions could impose greater financial and operational costs over time.

From a managerial perspective, these findings highlight the need for firms to develop more flexible supply-chain strategies, particularly those reliant on climate-sensitive trade routes. Firms could benefit from diversifying transportation networks, securing alternative suppliers, or increasing buffer inventory levels to hedge against trade disruptions. Additionally, liquidity planning and financial flexibility are critical tools for mitigating the impact of climate-related infrastructure shocks.

From a policy perspective, the results reinforce the importance of infrastructure resilience and climate adaptation measures for global trade. Investments in water conservation, alternative transportation networks, and port capacity expansion could reduce the economic impact of climate-induced trade bottlenecks.

References

Acemoglu, D. and P. D. Azar (2020). Endogenous production networks. *Econometrica 88*(1), 33–82.

Acharya, V. V., T. Johnson, S. Sundaresan, and T. Tomunen (2022). *Is physical climate risk priced? Evidence from regional variation in exposure to heat stress.* Number w30445. National Bureau of Economic Research Cambridge, MA, USA.

Addoum, J. M., D. T. Ng, and A. Ortiz-Bobea (2020). Temperature shocks and establishment sales. *The Review of Financial Studies 33*(3), 1331–1366.

Antràs, P., T. C. Fort, and F. Tintelnot (2017). The margins of global sourcing: Theory and evidence from us firms. *American Economic Review 107*(9), 2514–64.

Banerjee, S., S. Dasgupta, and Y. Kim (2008). Buyer–supplier relationships and the stakeholder theory of capital structure. *Journal of Finance 63*(5), 2507–2552.

Bansal, R., D. Kiku, and M. Ochoa (2016). Price of long-run temperature shifts in capital markets. Unpublished working paper 22529, National Bureau of Economic Research.

Barrot, J.-N. and J. Sauvagnat (2016). Input specificity and the propagation of idiosyncratic shocks in production networks. *The Quarterly Journal of Economics 131*(3), 1543–1592.

Boehm, C. E., A. Flaaen, and N. Pandalai-Nayar (2019). Input linkages and the transmission of shocks: Firm-level evidence from the 2011 Tōhoku earthquake. *The Review of Economics and Statistics 101*(1), 60–75.

Carvalho, V. M., M. Nirei, Y. U. Saito, and A. Tahbaz-Salehi (2021). Supply chain disruptions: Evidence from the great east japan earthquake. *The Quarterly Journal of Economics 136*(2), 1255–1321.

CNBC (2023). Drought threatens major european river trade route, with ripples across the continent. Accessed: 2025-02-25.

Cohen, L. and A. Frazzini (2008). Economic links and predictable returns. *Journal of Finance 63*(4), 1977–2011.

Custodio, C., M. A. Ferreira, E. Garcia-Appendini, and A. Lam (2022). Economic impact of climate change. *Nova SBE Working Paper Series* (645).

Dang, V. A., N. Gao, and T. Yu (2023). Climate policy risk and corporate financial decisions: Evidence from the nox budget trading program. *Management Science 69*(12), 7517–7539.

European Space Agency (2022). Drought causes yangtze to shrink. Accessed: 26 February 2025.

Flaaen, A., F. Haberkorn, L. Lewis, A. Monken, J. Pierce, R. Rhodes, and M. Yi (2023). Bill of lading data in international trade research with an application to the covid-19 pandemic. *Review of International Economics 31*(3), 1146–1172.

FreightWaves (2024). Why the panama canal is so important to trump. Accessed: 2025-02-25.

Ginglinger, E. and Q. Moreau (2023). Climate risk and capital structure. *Management Science 69*(12), 7492–7516.

Halili, G. (2022). searoute-py: A python package to calculate the shortest sea route between two points on earth. https://github.com/genthalili/searoute-py. Accessed: 2025-02-26.

Heiland, I., A. Moxnes, K. H. Ulltveit-Moe, and Y. Zi (2019). Trade from space: Shipping networks and the global implications of local shocks.

Hersbach, H. (2016). The ERA5 atmospheric reanalysis. *AGUFM 2016*, NG33D–01.

Hersbach, H., B. Bell, P. Berrisford, S. Hirahara, A. Horányi, J. Muñoz-Sabater, J. Nicolas, C. Peubey, R. Radu, D. Schepers, et al. (2020). The era5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society 146*(730), 1999–2049.

Hertzel, M. G., Z. Li, M. S. Officer, and K. J. Rodgers (2008). Inter-firm linkages and the wealth effects of financial distress along the supply chain. *Journal of Financial Economics 87*(2), 374–387.

Hong, H., F. W. Li, and J. Xu (2019). Climate risks and market efficiency. *Journal of Econometrics 208*(1), 265 – 281. Special Issue on Financial Engineering and Risk Management.

Kumar, A., W. Xin, and C. Zhang (2019). Climate sensitivity and predictable returns. Working Paper, Available at SSRN 3331872.

Li, Q., H. Shan, Y. Tang, and V. Yao (2024). Corporate climate risk: Measurements and responses. *The Review of Financial Studies 37*(6), 1778–1830.

Lim, K. (2018). Endogenous production networks and the business cycle. Working Paper.

NASA Earth Observatory (2022). The mississippi is mighty parched. Accessed: 2025-02-25.

Oberfield, E. (2018). A theory of input–output architecture. *Econometrica 86*(2), 559–589.

Panama Canal Authority (2025). Panama canal water reports. Accessed: 2025-02-26.

Pankratz, N., R. Bauer, and J. Derwall (2023). Climate change, firm performance, and investor surprises. *Management Science 69*(12), 7352–7398.

Ponticelli, J., Q. Xu, and S. Zeume (2023). *Temperature and local industry concentration.* Number W31533. National Bureau of Economic Research.

Sautner, Z., L. Van Lent, G. Vilkov, and R. Zhang (2023). Pricing climate change exposure. *Management Science 69*(12), 7540–7561.

Schlenker, W. and C. A. Taylor (2019). Market expectations about climate change. Working Paper 25554, National Bureau of Economic Research.

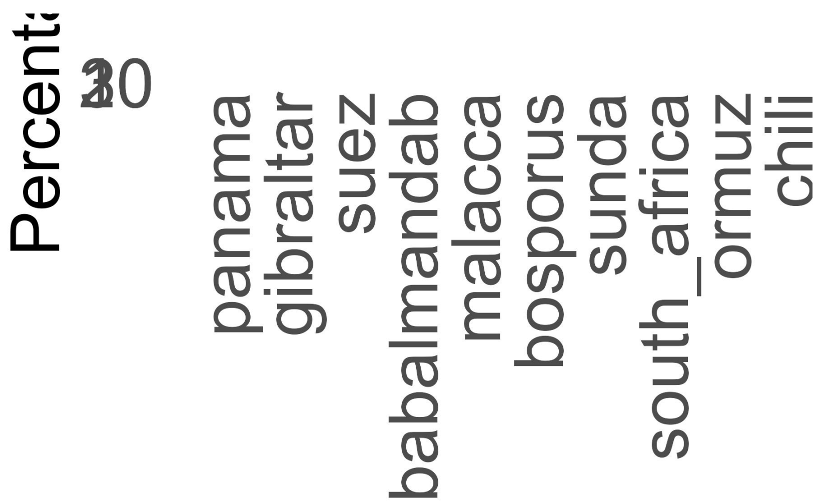
Smithsonian Tropical Research Institute (2025). Smithsonian tropical research institute open data portal – panama. Accessed: 2025-02-25.

U.S. Energy Information Administration (2024). Drought limits commercial traffic in the panama canal, affecting lng tanker flows. Accessed: 2025-02-25.

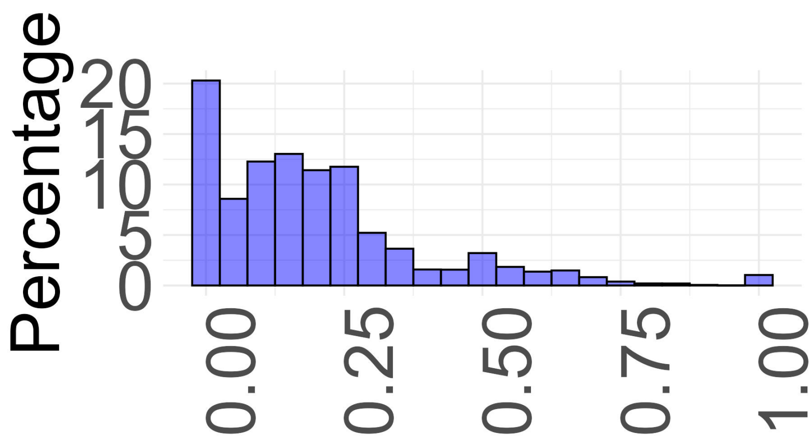
Zhang, P., O. Deschenes, K. Meng, and J. Zhang (2018). Temperature effects on productivity and factor reallocation: Evidence from a half million chinese manufacturing plants. *Journal of Environmental Economics and Management 88*, 1–17.

Tables and Figures

Figure 1: Economic Significance of the Panama Canal



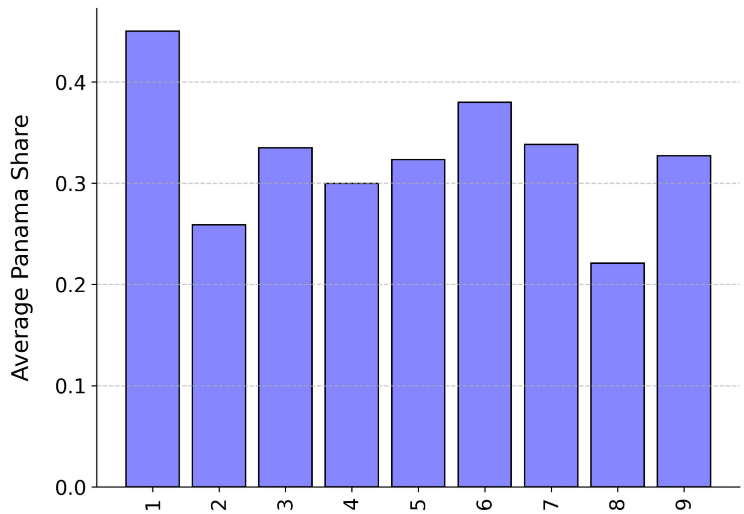
(a) Distribution of Traversed Passages



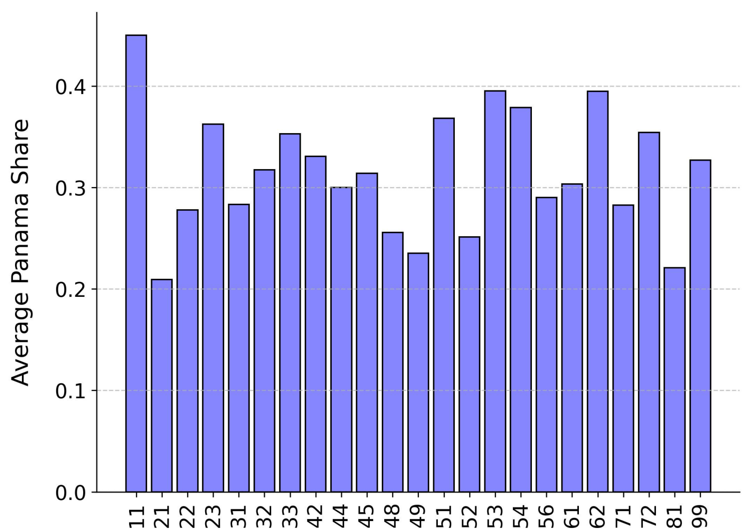
(b) Share of Supply-Chain Relationships through Panama Canal

Notes: Figure (a) shows the distribution of traversed passages estimated based on the locations of customers and suppliers in Factset Revere. Sea routes are derived using the sea route python package. Routing is unlikely to deviate from most efficient rout in most cases but the estimated data will be replaced with actual shipping records based on customs declarations in the next iteration of this manuscript. Figure (b) shows the average share of supplier relationships estimated to traverse the Panama Canal by customer firm.

Figure 2: Reliance on Panama Canal by Industry



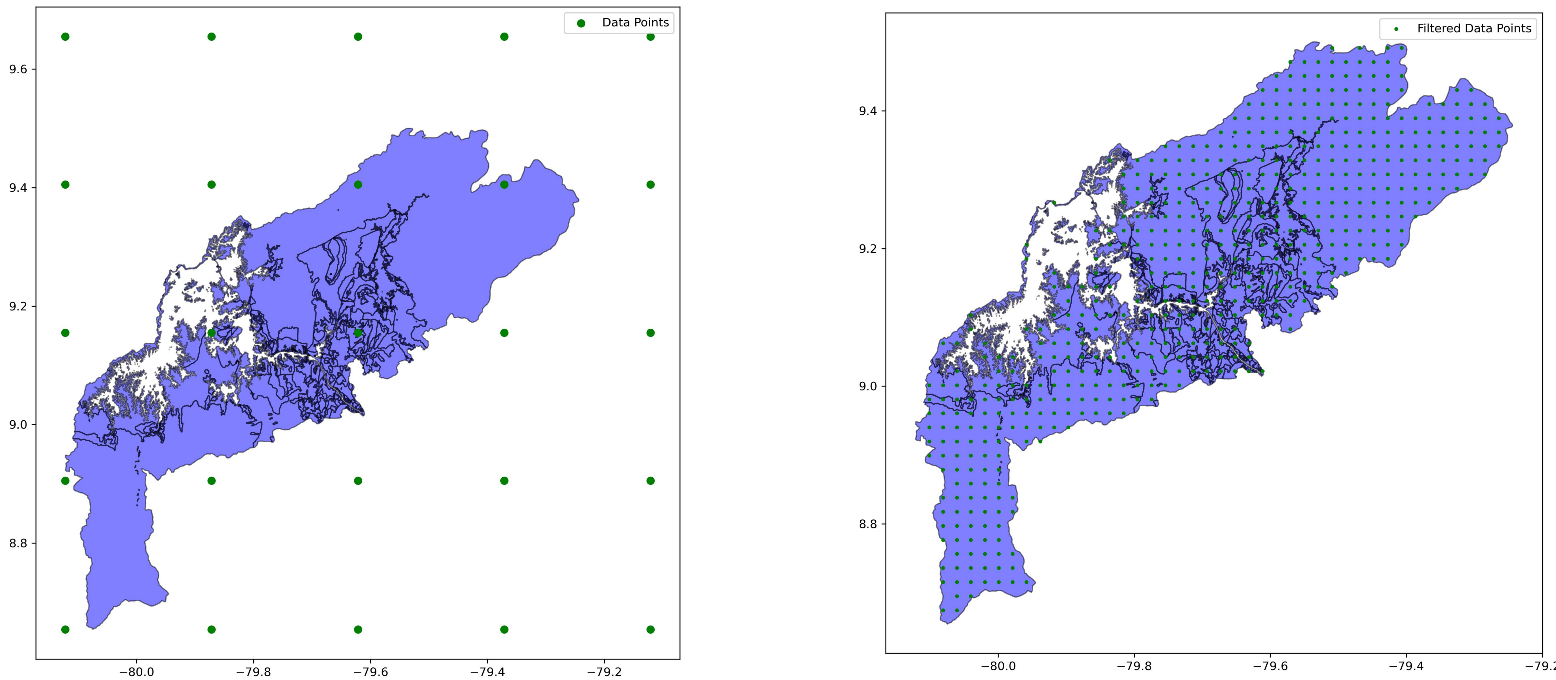
(a) Panama Canal: Exposed Share by Industry (NAICS 1)



(b) Panama Canal: Exposed Share by Industry (NAICS 2)

Notes: Figure (a) shows the average share of supply chain relationships routed through the Panama Canal per customer firm across broad industry groups assigned based on the first digit of the NAICS code. Figure (b) shows the distribution assigning groups based on the second digit of the NAICS code.

Figure 3: Aggregation of Precipitation Data over the Watershed

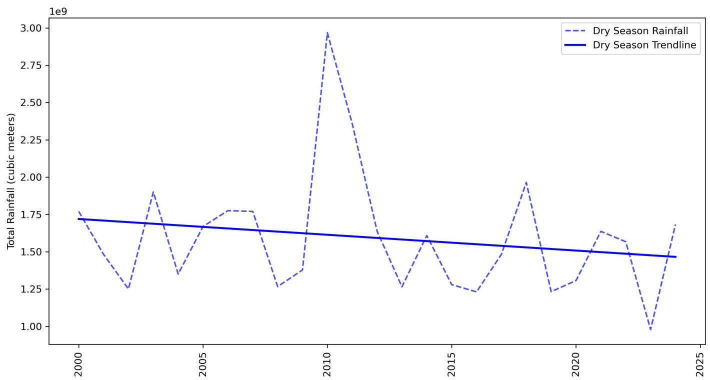


(a) Gatun Lake watershed and ERA5 grid nodes

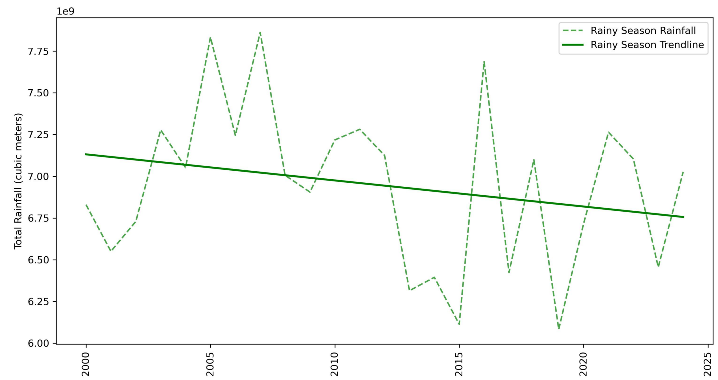
(b) Interpolation of ERA5 data points

Notes: This figure shows the aggregation of data on precipitation from ERA5. The shapefile in Figure (a) marks the boundaries of the watershed of Gatun Lake. Green dots indicate ERA5 grid nodes. Figure (b) shows the interpolated observations of precipitation masked by the area of the watershed.

Figure 4: Rainfall Trends by Season over Time



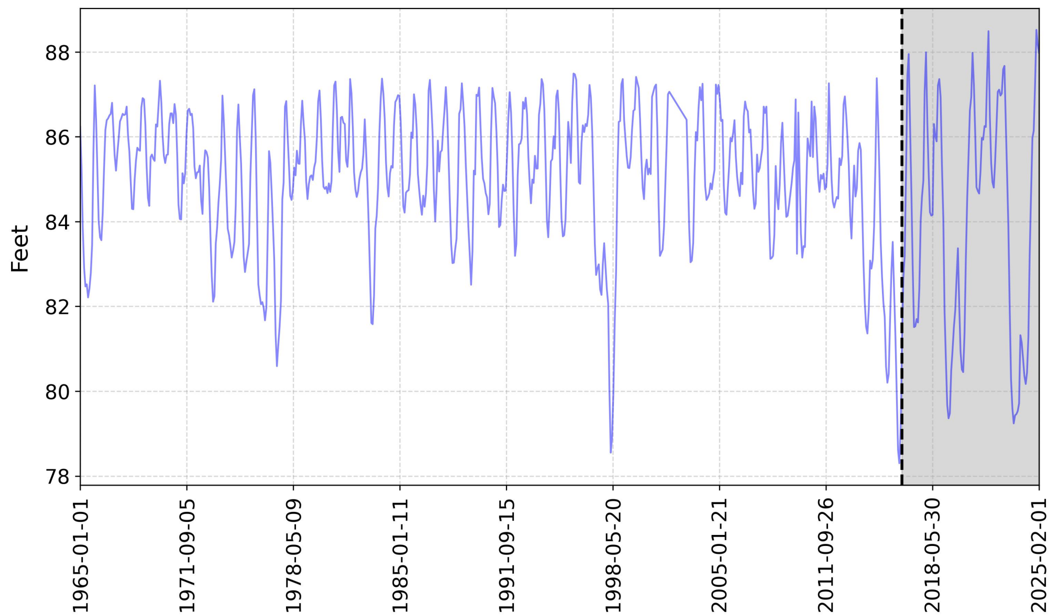
(a) Rainfall Trends in the Dry Season



(b) Rainfall Trends in the Rainy Season

Notes: This figure shows precipitation trends over the watershed of Gatun Lake over time. The aggregation is illustrated in Figure 3. Figure (a) shows the trend in the dry season from December to April. Figure (b) shows the trend in the rainy season from May to November.

Figure 5: Historical Water Levels in Lake Gatun



(a) Gatun Lake Minimum Water Level

Notes: This figure shows the historical distribution of water levels in Gatun Lake. Gatun Lake is an artificial freshwater lake approximately 26 m above sea level that forms a major part of the Panama Canal. Locks allow ships to pass from the Atlantic to the Pacific ocean. The canal was created June 27, 1913. In June 2016, a major expansion of the canal was completed, doubling capacity of the Panama Canal by adding a new traffic lane, enabling more ships to transit the waterway, and increasing the width and depth of the lanes and locks, allowing larger ships to pass. The expanded canal began commercial operation on 26 June 2016. The begin of operations marks the start of the sample period shaded in gray.

Table 1: **Summary Statistics**

Notes. This table shows the summary statistics for all measures of precipitation, drought, and firm performance. Financial and accounting measures are shown in million U.S. dollar. All observations are at the year-quarter level.

	N	Mean	StDev	p25	Median	p75
Precipitation (cubicm)	1147673	2.14e+09	9.83e+08	1.25e+09	2.45e+09	3.02e+09
Precipitation within Month (cubicm)	1147673	-24.001	3.28e+08	-2.19e+08	-3.32e+07	1.88e+08
Drought Days	1147673	11.934	5.808	7.000	11.000	16.000
Drought Days within Month	1147673	-0.000	5.769	-4.538	-0.538	3.971
Minimum Water Level of Gatun Lake	1079337	83.808	2.093	83.000	84.520	85.270
Maximum Water Level of Gatun Lake	1112901	86.246	2.038	85.440	86.590	87.790
Revenues over Lagged Assets	674684	0.207	0.226	0.041	0.144	0.295
Revenues	801930	480.314	1453.076	1.788	32.504	240.153
Operating Income over Lagged Assets	639209	0.006	0.042	-0.007	0.009	0.026
Operating Income	845716	59.275	206.803	-0.763	1.431	24.431
Assets	838660	4266.292	14668.022	35.771	305.999	1887.430
Cost of Goods Sold	863915	291.955	927.644	1.465	15.006	127.472
Sales, General, Administrative Expenses	695185	76.943	241.303	1.766	7.957	39.374
Inventories	826749	151.900	541.245	0.000	1.480	42.442
Depreciation	784063	26.132	80.902	0.101	1.243	11.681
Accounts Payable	835338	486.853	2024.894	1.408	12.130	131.027
Accounts Receivable	825345	680.972	2824.563	1.487	25.481	227.171

Table 2: **Effects of Precipitation on U.S. Firm Performance**

Notes. This table shows OLS regressions on the effects of rainfall in the Lake Gatun watershed on the performance of firms in the United States. Revenues in panel (a) and (c) and operating income in panel (b) and (d) are scaled by assets lagged by one year. In panel (a) and (b), precipitation is measures as the log of accumulated rainfall across the area of the watershed of Lake Gatun in cubic metres. In panel (c) and (d), drought days are measures as the number of days below the 10^{th} percentile of the distribution per calendar month between 1970 and 1980. The sample period is 2016 to 2024. Column headers indicate thresholds for the exposure of shipping through the Panama Canal by customer firm. From left to right, exposure to the canal increases. Included fixed effects are indicated in the table. Robust standard errors clustered at the firm and year-quarter level are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

(a) Revenues/L.Assets

	None	<20%	<30%	>20%	>30%	>50%	>75%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ln Precipitation	0.0021	0.0008	0.0013	0.0078**	0.0081**	0.0082**	0.0084**
	(0.59)	(0.18)	(0.34)	(2.36)	(2.40)	(2.40)	(2.40)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13845	19389	24961	126544	120972	112923	109402
Firms	469	652	833	5558	5377	5101	4978
R^2	.878	.882	.878	.774	.771	.765	.761

(b) Op. Income/L.Assets

	None	<20%	<30%	>20%	>30%	>50%	>75%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ln Precipitation	0.0025***	0.0021**	0.0018**	0.0014***	0.0014***	0.0014***	0.0013***
	(2.74)	(2.44)	(2.35)	(2.93)	(3.00)	(3.03)	(2.85)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14576	20013	25569	118537	112981	104792	101418
Firms	512	701	891	5574	5384	5097	4976
R^2	.742	.732	.735	.753	.75	.748	.746

Table 2: **Effects of Precipitation on U.S. Firm Performance (continued)**

(c) Revenues/L.Assets

	None	<20%	<30%	>20%	>30%	>50%	>75%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Drought Days	-0.0031	-0.0023	-0.0022	-0.0045***	-0.0046***	-0.0047***	-0.0048***
	(-1.50)	(-1.16)	(-1.24)	(-2.84)	(-2.88)	(-2.91)	(-2.91)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13731	19204	24718	125894	120380	112418	108926
Firms	469	652	833	5551	5370	5094	4971
R^2	.879	.883	.879	.774	.771	.765	.761

(d) Op. Income/L.Assets

	None	<20%	<30%	>20%	>30%	>50%	>75%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Drought Days	-0.0014**	-0.0011**	-0.0010*	-0.0006**	-0.0006**	-0.0006**	-0.0006**
	(-2.28)	(-2.00)	(-1.97)	(-2.10)	(-2.10)	(-2.21)	(-2.16)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14442	19809	25310	117649	112148	104048	100704
Firms	512	701	891	5560	5370	5083	4962
R^2	.742	.732	.736	.753	.75	.748	.747

Table 3: **Effects of Precipitation on U.S. Firm Performance in the Cross-Section**

Notes. This table shows OLS regressions on the effects of rainfall in the Lake Gatun watershed on operating income scaled by assets lagged by one year for firms in the United States. In panel (a), precipitation is measures as the log of accumulated rainfall across the area of the watershed of Lake Gatun in cubic metres. In panel (b), drought days are measures as the number of days below the 10^{th} percentile of the distribution per calendar month between 1970 and 1980.The sample period is 2016 to 2024. Included fixed effects are indicated in the table. Robust standard errors clustered at the firm and year-quarter level are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

(a) Precipitation

	Operating Income/Lagged Assets					
	(1)	(2)	(3)	(4)	(5)	(6)
Ln Precipitation	0.0018**	0.0007**	0.0014***	0.0016***	-0.0000	0.0015***
	(2.56)	(2.02)	(2.90)	(3.03)	(-0.02)	(2.93)
Ln Precipitation × Service Industries	-0.0007					
	(-1.17)					
Ln Precipitation × Container Shipping		0.0020***				
		(3.24)				
Ln Precipitation × West Coast			0.0010			
			(1.22)			
Ln Precipitation × Mean Assets				-0.0000**		
				(-2.48)		
Ln Precipitation × Mean Sales Turnover					0.0072**	
					(2.25)	
Ln Precipitation × Covid						-0.0001
						(-0.11)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	138555	138555	138555	138555	124039	138555
Firms	6275	6275	6275	6275	5595	6275
R^2	.754	.754	.754	.754	.754	.754

(b) Drought Days

	Operating Income/Lagged Assets					
	(1)	(2)	(3)	(4)	(5)	(6)
Drought Days	-0.0008*	-0.0005**	-0.0006*	-0.0008**	-0.0000	-0.0005**
	(-1.77)	(-2.39)	(-1.94)	(-2.22)	(-0.03)	(-2.35)
Drought Days × Service Industries	0.0002					
	(0.62)					
Drought Days × Container Shipping		-0.0006				
		(-1.50)				
Drought Days × West Coast			-0.0006*			
			(-1.72)			
Drought Days × Mean Assets				0.0000*		
				(1.94)		
Drought Days × Mean Sales Turnover					-0.0033***	
					(-2.78)	
Drought Days × Covid						-0.0014
						(-1.01)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	137463	137463	137463	137463	123260	137463
Firms	6261	6261	6261	6261	5587	6261
R^2	.754	.754	.754	.754	.754	.754

Table 4: **Effects of Precipitation on Firm Expenses**

Notes. This table shows OLS regressions on the effects of rainfall in the Lake Gatun watershed on the costs of goods sold (COGS) and sales, general, and administrative expenses (SGA) of firms in the United States. COGS (columns 1-4) and SGA (columns 5-8) are scaled by assets lagged by one year. The sample period is 2016 to 2024. Included fixed effects are indicated in the table. Robust standard errors clustered at the firm and year-quarter level are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

(a) Precipitation

	Ln CoGS				Ln SGA Exp.			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln Precipitation	-0.0546**	-0.0468*	-0.0444*	-0.0453*	-0.0006	0.0017	-0.0011	-0.0015
	(-1.99)	(-1.75)	(-1.85)	(-1.90)	(-0.06)	(0.18)	(-0.07)	(-0.09)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20816	26767	143975	138024	17945	23108	129675	124512
R^2	.973	.973	.952	.949	.983	.984	.961	.958

(b) Drought Days

	Ln CoGS				Ln SGA Exp.			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Drought Days	0.0289***	0.0245**	0.0255**	0.0262**	-0.0049	-0.0056	-0.0009	-0.0007
	(2.68)	(2.28)	(2.44)	(2.50)	(-1.41)	(-1.55)	(-0.11)	(-0.09)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20603	26485	143026	137144	17770	22880	128899	123789
Firms	704	897	5903	5710	612	785	5635	5462
R^2	.973	.973	.952	.949	.983	.984	.961	.958

Table 6: **Effects of Precipitation on Inventory, Turnover, and Depreciation**

Notes. This table shows OLS regressions on the effects of rainfall in the Lake Gatun watershed on inventory as part of working capital and depreciation of firms in the United States. Panel (a) shows the effects on inventory, panel (b) on depreciation, panel (c) on inventory turnover as cost of goods sold divided by inventory, and panel (d) on sales turnover as revenues divided by inventory. Column headers indicate the exposure of firms to routing through the Panama Canal. For example, $< 20\%$ indicates a share of less than 20% of suppliers with routes through the canal. The sample period is 2016 to 2024. Included fixed effects are indicated in the table. Robust standard errors clustered at the firm and year-quarter level are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

(a) Inventory

	Share < 20%	Share < 30%	Share > 20%	Share > 30%
	(1)	(2)	(3)	(4)
Ln Precipitation	-0.0258*	-0.0228*	-0.0151	-0.0151
	(-1.88)	(-1.69)	(-1.16)	(-1.15)
Firm-Season FE	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	15603	20528	87773	82848
R^2	.965	.965	.948	.945

(b) Depreciation

	Share < 20%	Share < 30%	Share > 20%	Share > 30%
	(1)	(2)	(3)	(4)
Ln Precipitation	0.0027	0.0014	-0.0174	-0.0180
	(0.26)	(0.17)	(-1.36)	(-1.38)
Firm-Season FE	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	19348	25040	135585	129893
R^2	.978	.977	.954	.951

(c) Inventory Turnover

	Share < 20%	Share < 30%	Share > 20%	Share > 30%
	(1)	(2)	(3)	(4)
Ln Precipitation	-0.0286	-0.0199	-0.0453	-0.0485
	(-1.07)	(-0.82)	(-1.37)	(-1.42)
Firm-Season FE	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	15276	20078	85058	80256
R^2	.894	.897	.817	.814

(d) Sales Turnover

	Share < 20%	Share < 30%	Share > 20%	Share > 30%
	(1)	(2)	(3)	(4)
Ln Precipitation	0.0331*	0.0358**	0.0623***	0.0637***
	(1.73)	(2.00)	(3.40)	(3.46)
Firm-Season FE	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	13942	18533	71807	67216
R^2	.93	.932	.858	.855

Table 7: **Effects of Precipitation on Trade Credit**

Notes. This table shows OLS regressions on the effects of rainfall in the Lake Gatun watershed on trade credit. Accounts payable are shown in panel (a) and accounts receivable in panel (b). The sample period is 2016 to 2024. Included fixed effects are indicated in the table. Robust standard errors clustered at the firm and year-quarter level are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

(a) Ln Accounts Payable

	None	<20%	<30%	>20%	>30%	>50%	>75%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ln Precipitation	-0.0159	-0.0154	-0.0169	-0.0362***	-0.0366***	-0.0370***	-0.0362***
	(-0.83)	(-0.79)	(-0.84)	(-2.80)	(-2.88)	(-2.77)	(-2.72)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14647	20539	26434	152065	146170	137829	134063
R^2	.974	.979	.978	.963	.962	.961	.96

(b) Ln Accounts Receivable

	None	<20%	<30%	>20%	>30%	>50%	>75%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ln Precipitation	0.0049	0.0058	0.0089	-0.0214	-0.0232*	-0.0238*	-0.0228*
	(0.33)	(0.32)	(0.55)	(-1.64)	(-1.75)	(-1.76)	(-1.66)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14822	20554	26450	138182	132286	123745	120022
R^2	.976	.978	.979	.957	.955	.953	.952

Table 8: **Effects of Precipitation on Cash and Investments**

Notes. This table shows OLS regressions on the effects of rainfall in the Lake Gatun watershed on cash holdings and measures of investments. Cash holdings are shown in panel (a), capital expenditures calculated as the increase in plant, property plust depreciation in panel (b), short-term investments in panel (c), and long-term investments in panel (d). The sample period is 2016 to 2024. Included fixed effects are indicated in the table. Robust standard errors clustered at the firm and year-quarter level are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

(a) Cash Holdings

	Share < 20%	Share < 30%	Share > 20%	Share > 30%
	(1)	(2)	(3)	(4)
Ln Precipitation	0.0598**	0.0755***	0.0318	0.0287
	(2.12)	(3.14)	(0.92)	(0.79)
Firm-Season FE	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	19708	25441	137142	131409
R^2	.892	.892	.892	.889

(b) Capital Expenditures

	Share < 20%	Share < 30%	Share > 20%	Share > 30%
	(1)	(2)	(3)	(4)
Ln Precipitation	-0.6207	-0.4489	-0.3853	-0.4070
	(-0.53)	(-0.35)	(-0.73)	(-0.83)
Firm-Season FE	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	14965	18492	119246	115712
R^2	.676	.676	.709	.704

(c) ST Investments

	Share < 20%	Share < 30%	Share > 20%	Share > 30%
	(1)	(2)	(3)	(4)
Ln Precipitation	0.4040***	0.3535***	-0.0143	-0.0216
	(3.85)	(3.44)	(-0.19)	(-0.27)
Firm-Season FE	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	16155	20491	114588	110255
R^2	.271	.267	.252	.252

(d) LT Investments

	Share < 20%	Share < 30%	Share > 20%	Share > 30%
	(1)	(2)	(3)	(4)
Ln Precipitation	0.3456	0.3321	0.1564**	0.1543**
	(1.45)	(1.43)	(2.17)	(2.36)
Firm-Season FE	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	12279	15286	101500	98494
R^2	.383	.375	.355	.355

Appendix

Table A.1: **Lake Gatun Water Levels and Precipitation**

Notes. This table shows OLS regressions on the correlations between water levels in Lake Gatun and rainfall. The number of observations refers to months. Column 1 and 4 show the effect on minimum water levels, Column 2 and 5 show the effect on the mean, and Column 3 and 6 show the effects on the maximum water levels. The sample period is 1965 to 2024 in Columns 1-3 and 2016 to 2024 in Columns 4-6. Robust standard errors are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

	Pre-2016 Expansion			Post-2016 Expansion		
	(1)	(2)	(3)	(4)	(5)	(6)
Ln Precipitation	0.0313***	0.1268***	0.0211***	0.0467***	0.0402***	0.0293***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	658188	691752	691752	421149	421149	421149
R^2	.272	.0701	.45	.34	.334	.279

	Pre-2016 Expansion			Post-2016 Expansion		
	(1)	(2)	(3)	(4)	(5)	(6)
Drought Days	-0.0051***	0.0461***	-0.0035***	-0.0286***	-0.0274***	-0.0256***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	658188	691752	691752	414742	414742	414742
R^2	.174	.0707	.392	.384	.385	.352

Table A.2: **Robustness to Different Sets of Fixed Effects**

Notes. This table shows OLS regressions on the effects of rainfall in the Lake Gatun watershed on the performance of firms in the United States. Revenues in panel (a) and operating income in panel (b) are scaled by assets lagged by one year. The sample period is 2016 to 2024. Included fixed effects are indicated in the table. Robust standard errors clustered at the firm and year-quarter level are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

(a) Revenues/L.Assets

	(1)	(2)	(3)	(4)	(5)	(6)
Ln Precipitation	0.0066**	0.0074**	0.0070**	0.0067**	0.0064*	0.0065*
	(2.29)	(2.47)	(2.11)	(2.03)	(1.97)	(1.98)
Firm FE	Yes	No	No	No	No	No
Quarter FE	Yes	No	No	No	No	No
Year FE	Yes	Yes	No	No	No	No
Firm-Season FE	No	Yes	Yes	Yes	Yes	Yes
NAICS2 Industry-Year FE	No	No	Yes	No	No	No
NAICS3 Industry-Year FE	No	No	No	Yes	No	No
NAICS4 Industry-Year FE	No	No	No	No	Yes	Yes
State-Year FE	No	No	No	No	No	Yes
Observations	225537	221539	146079	146071	146043	145897
R^2	.748	.771	.783	.789	.801	.804

(b) Op. Income/L.Assets

	(1)	(2)	(3)	(4)	(5)	(6)
Ln Precipitation	0.0010**	0.0011**	0.0015***	0.0015***	0.0015***	0.0015***
	(2.03)	(2.15)	(2.97)	(2.84)	(2.88)	(2.90)
Firm FE	Yes	No	No	No	No	No
Quarter FE	Yes	No	No	No	No	No
Year FE	Yes	Yes	No	No	No	No
Firm-Season FE	No	Yes	Yes	Yes	Yes	Yes
NAICS2 Industry-Year FE	No	No	Yes	No	No	No
NAICS3 Industry-Year FE	No	No	No	Yes	No	No
NAICS4 Industry-Year FE	No	No	No	No	Yes	Yes
State-Year FE	No	No	No	No	No	Yes
Observations	205678	200761	138683	138671	138629	138501
R^2	.68	.723	.751	.758	.767	.769

Table A.3: **Robustness under Alternative Clustering**

Notes. This table shows OLS regressions on the effects of rainfall in the Lake Gatun watershed on the performance of firms in the United States. Revenues in columns (1) to (3) and operating income in columns (4) to (6) are scaled by assets lagged by one year. The sample period is 2016 to 2024. Included fixed effects are indicated in the table. Robust standard errors are in parentheses and clustered as indicated in the column headers. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

(a) Revenues and Operating Income over Assets

	Firm	Year-Quarter	Firm + Year-Quarter	Firm	Year-Quarter	Firm + Year-Quarter
	(1)	(2)	(3)	(4)	(5)	(6)
Ln Precipitation	0.0069***	0.0069*	0.0069**	0.0015***	0.0015***	0.0015***
	(5.99)	(1.91)	(2.10)	(5.99)	(2.70)	(2.98)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	145934	145934	145934	138555	138555	138555
R^2	.787	.787	.787	.754	.754	.754

Table A.4: **Lagged Effects of Precipitation on Firm Performance**

Notes. This table shows OLS regressions on the effects of rainfall in the Lake Gatun watershed on the performance of firms in the United States. Revenues in panel (a) and operating income in panel (b) are scaled by assets lagged by one year. The sample period is 2016 to 2024. Included fixed effects are indicated in the table. Robust standard errors clustered at the firm and year-quarter level are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

(a) Revenues/L.Assets

	None	<20%	<30%	>20%	>30%	>50%	>75%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ln Precipitation	0.0043**	0.0055***	0.0063***	0.0102***	0.0102***	0.0103***	0.0105***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Ln Precip. (t-1)	0.0161	0.0160	0.0155**	0.0098	0.0099	0.0131	0.0137
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Ln Precip. (t-2)	-0.0006	0.0016	0.0036	0.0080	0.0080	0.0085	0.0092
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6724	9440	12167	62511	59786	55875	54166
R^2	.889	.892	.885	.771	.769	.763	.759

(b) Op. Income/L.Assets

	None	<20%	<30%	>20%	>30%	>50%	>75%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ln Precipitation	0.0018	0.0018	0.0016	0.0008***	0.0008***	0.0007***	0.0006***
	(.)	(.)	(.)	(0.00)	(0.00)	(0.00)	(0.00)
Ln Precip. (t-1)	0.0074	0.0068	0.0044	-0.0010	-0.0009	-0.0011	-0.0013
	(.)	(.)	(.)	(0.00)	(0.00)	(0.00)	(0.00)
Ln Precip. (t-2)	-0.0002	0.0000	0.0002	0.0002	0.0001	0.0000	-0.0001
	(.)	(.)	(.)	(0.00)	(0.00)	(0.00)	(0.00)
Firm-Season FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7119	9789	12503	58813	56103	52112	50465
R^2	.737	.728	.733	.749	.746	.744	.742