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Economic and Health Implications of Early COVID-19 Lockdown Exits: Evidence from a Difference-in-Differences Analysis

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Abstract

The premature lifting of lockdowns during the COVID-19 pandemic created a trade-off between economic recovery and increased disease transmission, yet its true impact remains poorly understood. This study investigates the causal effect of ending lockdown policies on COVID-19 cases and deaths in Colombia, using sales tax holidays (TH) as a natural experiment. We analyze 1,105,215 observations from March 6, 2020, to December 31, 2021, using data from the Colombian Ministry of Health and Google Mobility. Applying a Difference-in-Differences approach, we find that, prior to vaccination, THs increased daily COVID-19 cases and deaths by 14% and 4% points, respectively, leading to net economic losses. After vaccines became available, economic gains from THs exceeded health costs. These findings underscore the trade-offs of ending lockdowns prematurely, which can have economic consequences. Policymakers can use these insights to weigh the benefits of relaxing lockdowns against health risks, emphasizing the role of vaccination and preparedness in future pandemics.

Keywords: Sales tax holidays, COVID-19, lockdown, health costs, vaccination campaign

1. Introduction

The COVID-19 pandemic forced governments globally to implement interventions to control COVID-19 transmission and deaths, along with other non-pharmaceutical interventions such as lockdowns, social distancing mandates, and mask requirements (World Health Organization, 2022). One of the first interventions implemented in 2020 was the lockdown, which aimed to limit public movement and reduce contact rates, thereby slowing viral transmission (World Health Organization, 2022). Although the intensity and timing of the lockdown varied by location, at a general level, it consisted of issuing a stay-at-home order (Haider et al., 2020; Pugh et al., 2022). Despite its implementation around the globe, little is known about the causal effect of lockdowns on COVID-19 cases and deaths. Lockdowns have economic and social implications, often slowing economic growth and impacting employment rates (Dzhuraeva et al., 2023; Qin et al., 2024; Sindhwani et al., 2022; Yamaka et al., 2022). Understanding the tradeoff between health gains and economic losses can help policymakers balance public health and economic objectives. This paper aims to contribute to this debate.

Answering the causal relationship between lockdown and COVID-19 transmission and deaths is plagued by endogeneity problems. As both outcomes are influenced by unobserved factors, assessing causality is challenging using observational data. This paper provides an innovative identification strategyto assess the causal effect of removing the lockdown on new COVID-19 cases and deaths. Specifically, we use Colombia's Sales Tax Holidays (TH) as natural experiments to observe how abrupt ends to lockdowns affect COVID-19 outcomes. Many countries worldwide have implemented a "Tax Holiday"to incentivize sales (Bajpai & Sachs, 1999; OECD, 2003; Robyn et al., 2010). The tax break generates abrupt ends to lockdown policies and price inducements for people to leave their homes to shop, reducing the households' lockdown costs and providing an exogenous variation to mobility regardless of the pandemic situation, as long as consumers go outside their homes to buy new goods and services instead of purchasing them online.

We took advantage of the exogenous variation in population movement by examining the case of Colombia. Firstly, the Colombian government maintained the lockdown throughout 2020, as well as after the implementation of vaccine campaigns. Unlike other settings, we expected that people went out during the tax holiday. This approach provides a unique setting, as high-income countries might see increased online shopping rather than in-person activities, while limited online infrastructure in Colombia drives more in-person participation. Furthermore, Colombia led the Latin American region in implementing non-pharmaceutical interventions to reduce COVID-19 transmission. According to the World Bank, Colombia reported significant macroeconomic indicators in 2020 (GDP growth: -7%;

GDP per capita: 5,307 USD) and 2021 (GDP growth: 10.7%; GDP per capita: 6,104 USD), reflecting the economic impact of the pandemic especially in 2020 and the importance of targeted measures like tax holidays for economic recovery.

Following several months of implementing the lockdown, the tradeoff between removing the COVID-19 lockdown increased (United Nations, 2020). Policymakers had to identify the most effective interventions to strike a balance between healthrisk and economic loss. For instance, in Colombia, a low- and middle-income country, the first case of COVID-19 was identified on March 6, 2020, and the Colombian government implemented a series of measures (Ministerio de Salud de Colombia, 2020). Initially, schools and universities were closed. On March 24, a mandatory national lockdown of 19 days began, which restricted the opening of non-essential businesses and mobility. Although the lockdown was periodically extended, it became progressively more flexible, allowing for the gradual opening of some economic activities. For example, the manufacturing and construction industry resumed on April 27, while furniture, vehicles, and other equipment businesses reopened on May 11. The mandatory national lockdown ended on August 30, 2020. Nevertheless, some local governments could impose measures tailored to their COVID-19 situation, particularly concerning internal mobility. In January 2021, school reopening began, and on February 17, the national government launched a COVID-19 vaccination campaign. Later, on June 2, all economic activities resumed.

This study explores how tax holidays in 2020 (pre-vaccine) and 2021 (post-vaccine) offer insights into the impact of lifted lockdowns on public health. In particular, it assesses whether the presence of vaccines in 2021 altered the health-economic tradeoff compared to 2020, highlighting how vaccination campaigns may shift the balance of these interventions. The evidence on the effect of lockdown on health and economic outcomes is mixed. Using a systematic review, Mendez-Brito et al. found that closing schools, workplaces, and businesses and banning public events were the most effective non-pharmaceutical interventions for controlling COVID-19 spread (Mendez-Brito et al., 2021). Similarly, Bonardi et al. (2020), using data from 184 countries, identified that the lockdown in high-income countries prevented approximately 650,000 deaths (Bonardi et al., 2020). On the other hand, Herby, Jonung, and Hanke (2022), in their meta-analysis, found that lockdown did not have a large effect (0.2%) in reducing COVID-19 mortality in Europe and the United States (Herby et al., 2020). Recent evidence from the United States, which has measured mortality by excess mortality, found that the lockdown appears to have had no effect on COVID-19 mortality but a negative effect on the employment rate (Kerpen et al., 2022; Pugh et al., 2022). Evidence from Colombia has found that financial incentives could increase mobility during the COVID-19 pandemic in 2020 and 2021 (Alvarez et al., 2022).

During the COVID-19 pandemic, policymakers faced constant tension between implementing lockdowns and mitigating economic losses. Understanding this tradeoff could improve the effectiveness of non-pharmaceutical interventions in future pandemics. However, assessing its magnitude is challenging due to endogeneity. To address this, we apply a Difference-in-Differences approach, using THs as exogenous shocks to assess the causal effect of abrupt ends to lockdown policies on COVID-19 cases and deaths following three sales THs in Colombia during 2020 (before the vaccination campaign) and three tax days in 2021 (after vaccination). We used the Colombian Ministry of Health's 2020 and 2021 databases containing the total number of COVID-19 cases and deaths. To assess mobility changes, we utilized the Google mobility indicator "Retail and Recreation," which tracks population movement to non-essential retail and recreational sites during THs. Having several days of tax cuts allows us to explore the possibility that this tradeoff would change as the epidemiological pattern changes. We found that mobility increased after each TH. Our analysis shows that, on average, TH led to approximately 14% and 4% points of new daily cases and deaths, respectively, before vaccines were available. Interestingly, after the vaccination campaign, differences in new cases and deaths after the TH declined or even disappeared. We also estimated the costs of hospitalization, ICU care, and the value ofa statistical life associated with COVID-19 deaths and compared them with the economic losses associated with the lockdown. According to previous research, the value of a statistical life in Colombia in 2022 is around 1.4 million USD (Kip Viscusi & Masterman, 2017). We found that the health costs of the lockdown were higher thanthe economic gains for the TH before vaccination. However, the economic gains of removing the lockdown were larger than the associated health costs once vaccines were available. These findings have two main implications. First, they suggest that lockdown is a cost-effective non-pharmacological intervention to reduce COVID-19 transmission and deaths before a COVID-19 vaccine was available. However, this relationship would reverse once the vaccine is available. We hope that these findings will inform the management of lockdowns during future pandemics. Finally, we also contribute to the literature by providing a valuable analytical framework to explore the causal effect of THs in other countries.

TH refers to a time when governments exempt some goods from sales tax. The first TH was implemented in the United States over 40 years ago when Michigan and Ohio used it in 1980 (Drenkard & Henchman, 2016; Janssen, 2012). However, this measure gained popularity in 1997 when New York implemented it (Robyn et al., 2010). Since then, it has been implemented at some point in most states and covers categories of goods such as clothing, school supplies, computers, energy star, and miscellaneous (Robyn et al., 2010). Similar policies have also been implemented in several countries around the world. Nevertheless, some concerns have been raised about TH. For example, it might give small savings to people with lower incomes than people with higher incomes (Janssen, 2012).

In Colombia, the first TH was implemented in 2020 to reactivate the economy and stimulate consumption due to the pandemic's impact on the supply and demand of goods and services. The Colombian government announced that three value-added tax exemption days would be implemented each year. The value-added tax in Colombia is 19%. According to decree 682 of 2020, the categories exempted from value-added tax during the TH were: (I) clothing, (II) clothing accessories, (III) sports equipment, (IV) school supplies, (V) goods and supplies for the agricultural sector, (VI) toys and games,and (VII) household appliances, computers, and communications equipment.

In 2020, the THs were held on June 19, July 3, and November 21 (Decree 682 of 2020). Household appliance purchases were made exclusively online during the last two dates. In 2021, the THs were on October 28, November 19, and December 3 (Decree 1314 of 2021). Payment methods during the THs for 2020 included debit and credit cards and other electronic payment mechanisms, while for 2021, cash, debit, credit cards, and other electronic methods were allowed. Purchases could be made in person or online, and individuals could purchase a maximum of three units of the same product. Additionally, in 2020 and 2021, a ceiling price for each good was established according to the category to which it belonged.

Note that in 2020, the Colombian government announced that three THs would be held every year. The TH days for 2020 were announced on May 21, almost six months before the last TH in 2020. In 2021, the announcement was made on October 20, at least two months before the last TH in December. Although policymakers could obtain information on forecasts for the COVID-19 situation for the next few days or months, many of these forecasts failed (Ioannidis et al., 2022). Therefore, policymakers had to make decisions under the uncertainty of not knowing the pandemic situation in the coming days or months.

2. Materials and Methods

Our study examines the causal impact of TH on COVID-19 outcomes, specifically the interactions between TH, mobility, COVID-19 cases and deaths, and economic costs. We hypothesize that TH increases mobility, as people are incentivized to shop in person, leading to higher COVID-19 transmission, hospitalizations, and mortality, especially in the pre-vaccination period. Additionally, we anticipate that the economic gains from retail activity during TH will be lower than the healthcare costs associated with COVID-19 cases in the pre-vaccine phase.

a. Sample and data

Our study focuses on COVID-19 cases, deaths, mobility, and testing efforts in Colombia. We used multiple sources for data collection:

COVID-19 Cases and Deaths: Data on daily COVID-19 cases and deaths was obtained from the Colombian Ministry of Health public database. This dataset provides case-level information on age, sex, and the municipality where each COVID-19 case was reported from March 6, 2020 (the date of the first reported case), to December 31, 2021.

Population Density: Data on population density by municipalities was sourced from Colombia's National Administrative Department of Statistics. The density variable is the number of inhabitants in a municipality divided by the area of the municipality in square kilometers.

Testing Efforts: Data on testing efforts was obtained from the Our World in Data dashboard, which provides daily counts of COVID-19 tests and confirmed cases for Colombia.

Mobility: We used Google Mobility data, specifically the "Retail and Recreation" mobility indicator, to measure changes in population movement at the national level for Colombia. Google Mobility reports data relative to a prepandemic baseline period (January 3 to February 6, 2020).

Economic Data: For economic estimates, we used hospitalization and ICU costs provided by the Colombian Ministry of Health, the value of a statistical life (VSL) from Masterman and Viscusi (2018), and revenue estimates from TH from Colombia's National Administrative Department of Taxes and Customs. The data on economic gains from each TH was obtained directly from the National Administrative Department of Taxes and Customs (DIAN) of Colombia. DIAN provided the total sales volume (physical and online transactions) for each tax-free day, as well as the corresponding monetary values in Colombian pesos.

b. Measures of variables

COVID-19 cases and deaths: We used daily counts of new COVID-19 cases and deaths from the Colombian Ministry of Health database.

Testing Efforts: Testing efforts were calculated as the daily number of COVID-19 tests divided by the daily number of confirmed cases. This indicator offers insights into a country's testing capacity, testing strategy, and the efficiency of testing. An increasing value might imply that testing efforts are becoming more comprehensive and that a larger proportion of cases are being identified. Conversely, a decrease in the number of tests conducted per new confirmed case might indicate that the testing infrastructure is overwhelmed, potentially leading to a reduced ability to identify new cases. This measure holds significance due to the potential bias introduced into our treatment effect analysis. Government preparedness for TH might lead to intensified testing efforts and, subsequently, increased case reporting post-TH. Because of that, rather than expecting an exponential surge in testing effort following each TH, our anticipation leans toward observing steady or declining values of testing efforts variable.

Google Mobility is an indicator that provides information on changes in the mobility of people associated with policies implemented to address the COVID-19 pandemic. This source provides information about mobility by day and geographic area. We used the Google mobility indicator for Retail and Recreation at the national level for Colombia to measure the average mobility seven days before and on the TH. Higher negative numbers indicate lower mobility.

Economic estimates: Economic outcomes were estimated using multiple indicators. Hospitalization and ICU costs for COVID-19 care were estimated based on the 10-day and 14-day service durations and payments recommended by the Colombia Ministry of Health. The economic value of lives lost was calculated using the VSL for Colombia. Finally, economic gains from each TH were derived from data provided by Colombia's National Administrative Department of Taxes and Customs. All monetary values were standardized to U.S. dollars for the year 2022.

c. Models and data analysis procedure

We conducted various analyses to identify the causal effect of lockdowns on the number of cases and deaths following three THs in Colombia in 2020 (before the vaccination campaign) and three tax cuts in 2021 (after vaccination). Firstly, we performed a descriptive analysis to compare the mobility seven days before and after the TH. This allowed us to evaluate whether the TH had an impact on encouraging people to leave their homes. Secondly, we conducted a descriptive analysis to compare the average testing capacity (testing efforts) during the seven days preceding and following each TH for both years. This assessment enabled us to gauge the government's preparedness for the TH. Third, we performed a descriptive analysis to observe the distribution of the number of COVID-19 cases by sex, age, and population density variables seven days before and seven days after each TH for both years. To assess the impact of TH on COVID-19 cases and deaths, we employed a Difference-in-Differences (DiD) approach using similar dates from the opposite year as control dates (e.g., comparing June 19, 2020, to June 19, 2021), see Appendix A. This design helps isolate the effect of the TH while accounting for seasonality and time-invariant factors that could influence COVID-19 case and death trends on similar dates across years. Robust standard errors were used as well.

We selected a range of 7 days before and 7 days after each TH and control date to capture short-term impacts while minimizing potential confounding from other events. Given the short period of our comparisons, we do not expect the COVID-19 hospitalization capacity to have changed in the country between the analysis periods. Although COVID-19 cases and deaths associated with the TH may continue to appear beyond 7 days, this 7-day post-TH window serves as a conservative timeframe to capture the most immediate effects. Control dates were chosen based on proximity to the TH dates but adjusted to prevent overlap, thereby ensuring that the before and after periods for TH and control dates do not interfere with one another.

Our outcome variable is the logarithm of daily new COVID-19 cases and deaths. The logarithm of cases and deaths was given one value for dates with zero cases to prevent those data points from being converted into missing values. The main predictor is an interaction term between two binary indicators: "TH vs. Control" (differentiating TH dates from control dates) and "Before vs. After" (indicating the 7-day periods before and after each TH or control date). This interaction captures the differential change in COVID-19 cases and deaths attributable to the TH. Models were adjusted for demographic characteristics, including daily average age, daily sex distribution, and population density. The unit of analysis for the DiD was at the daily level (t), and the general OLS model is specified as follows:

Equation 1:

$$\log(COVID19_t) = \beta_0 + \beta_1 TH_t + \beta_2 After_t + \beta_3(TH_t \times After_t) + \beta_4 Age_t + \beta 5\ Female_t + PopuDensity_t + K_{m,t} + \mu_t$$

log(Covid19$_t$) is the logarithm of the daily number of new COVID-19 cases and deaths. **TH$_t$**: Binary indicator (1 for TH date, 0 for control date). **After$_t$**: Binary indicator (1 for the 7 days after TH or control date, 0 for the 7 days before). $\beta 3(TH_t \times After_t)$: Interaction term measuring the DiD effect of TH on COVID-19 cases. **Age$_t$** is the daily average age of reported COVID-19 cases. **Female$_t$** is the daily sex distribution of reported COVID-19 cases. **PopuDensity$_t$** is the fixed effect of the population density variable. **K$_{m,t}$** is the fixed effect at the municipal level. **μ_t**: Error term.

We employed a three-step approach to estimate the causal impact of THs on COVID-19 cases and deaths: First, we estimated the cumulative effect of all six THs, capturing aggregate impacts on case and death trends from increased mobility during tax-free days. Second, we separated analyses by year (2020 and 2021) to account for differences in lockdown policies and vaccine availability. In 2020, national lockdown measures were in effect, with more restrictive mobility and no vaccination campaign, while 2021 saw relaxed restrictions and an advancing vaccination campaign.

Third, we estimated the effect of each individual TH to assess heterogeneous impacts, anticipating variation in results after the two THs in 2020 due to the phased relaxation of lockdown policies. After August 2020, national lockdown measures shifted to municipality-level discretion, allowing local governments to tailor mobility restrictions based on local COVID-19 conditions. Jason et al. (2022) found that high-density municipalities in Colombia reported lower mobility than low-density ones during the pandemic, likely due to stricter local enforcement (Jason et al., 2022). We also tested visually the parallel trends assumption of our DiD approach (see Fig. 2).

In addition, we conducted a robustness check by location density. Given the variation in mobility across municipalities after August 2020—where high-density municipalities in Colombia experienced lower mobility than low-density ones during the pandemic(Jason et al., 2022), we hypothesized that COVID-19 case trends during the first two THs in 2020 would not differ significantly between high- and low-density municipalities due to uniform national mobility restrictions. Also, we expected lower COVID-19 case growth in high-density areas, where mobility was reportedly more restricted. However, with the progression of the vaccination campaign in 2021, we anticipated that differences in COVID-19 case trends between high- and low-density municipalities would diminish or disappear, reflecting a reduced policy impact as immunity levels increased. To test these hypotheses, we ran DiD models comparing COVID-19 case trends between high- and low-density municipalities across the 7-day periods before and after each TH. Finally, we estimated the number of new COVID-19 cases and deaths for each TH in 2020 and 2021, back-transformed from the log scale DiD estimates using the Duan smearing transformation method (Duan, 1983).

To analyze the costs and economic gains associated with the TH, we used the number of cases and deaths from the DiD models. Although we recognize that hospitalizations, ICU admissions, and deaths related to COVID-19 may occur beyond this period, we prefer to use these conservative results derived from the DiD analysis.

We obtained the average hospitalization and ICU rates for COVID-19 for each year in Colombia (2020: hospitalization 5% and ICU 1%; 2021: hospitalization 0.10% and ICU 0.10%) from the Pan American Health Organization reports about COVID-19 in Colombia. Using that information and the excess new cases from the DiD for each of the THs, we calculated the fraction of people who would go to hospitalization and ICU. Then, we estimated the total hospitalization and ICU costs using the reference payment rates stipulated by the government for 10 and 14 days, respectively, and the fraction of people who would go to hospitalization and ICU.

Likewise, we computed the excess mortality for each TH using the Values of a Statistical Life for Colombia in 2022, which according to Masterman and Viscusi, is around 1.4 million. The sum of hospitalization costs, ICU costs, and Values of a Statistical Life were categorized as the health economic losses due to the TH. Finally, we estimated the difference between the health economic losses and the economic gains due to the TH.

The research design outlined above follows the empirical approach utilized by Anupam et al. in assessing the impact of major United States marathons on mortality (Jena et al., 2017). Their methodology employed an analysis to contrast mortality before and after marathon dates. Additionally, they employed as a reference the mortality before and after marathon dates in areas unaffected by marathons. The marathons can increase hospital arrival times, consequently raising the risk of mortality. In a similar vein, our study involves a comparison of COVID-19 cases and deaths before and after implementing the TH. For reference dates, we selected periods unaffected by the TH, given its nationwide implementation. In our case, the tax exemption on goods may lead to heightened mobility, subsequently increasing the risk of COVID-19 cases and deaths.

This study uses publicly available, anonymized secondary data from the Colombian Ministry of Health and Google Mobility. As no personally identifiable information was collected or used, ethical approval was not required.

3. Results

We observed a peak in mobility precisely on each TH date when compared to the seven days before and after, across all TH dates. Notably, for the first TH in 2021 (October 28), there was a marked increase in mobility that continued to rise over the following days, coinciding with Halloween weekend, with the highest peak occurring on October 31 (Fig. 1).

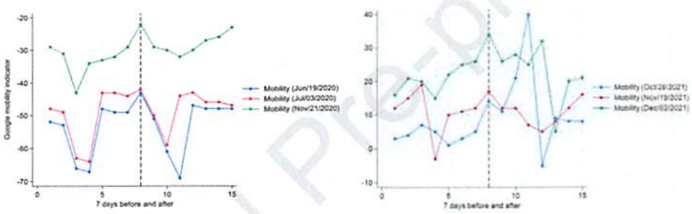

Fig 1. Mobility during tax holiday dates

The graphs display mobility trends surrounding the tax holidays (TH) in 2020(left) and 2021 (right), measured over a 7-day window before and after each TH date. The dotted line indicates the exact day each TH was implemented.

We observed that there is no significant difference in the number of testing efforts before and after the implementation of the TH (Appendix B). In 2020, specifically for the first TH, we noted that there was a slight decrease in the number of COVID-19 tests conducted to detect new confirmed cases after the TH. However, this difference was only a single test. The remaining values for the seven-day periods before and after the TH in 2020 were identical. In 2021, although the number of tests conducted per case was higher than in

2020, we did not observe any exponential difference before and after each TH.

Table 1 presents the distribution of COVID-19 cases by age, sex, and population density seven days before and after the six TH. We found that the distribution of cases by sex and age variables was balanced before and after the TH. In 2020, most cases were male, while in 2021, they were primarily female, and the average age for both years was around 40 years old.

Table 1: Sociodemographic characteristics of COVID-19 cases during the sales tax holidays

	2020		2021	
Variable	**7 days before**	**7 days after**	**7 days before**	**7 days after**
	Jun/19/2020		**Oct/28/2021**	
Sex % (n)				
Female	45.74 (9,437)	46.77 (14,025)	53.92 (6,268)	54.25 (6,391)
Male	54.26 (11,194)	53.23 (15,964)	46.08 (5,357)	45.75 (5,389)
Mean age-year (SD)	39.49 (18.32)	39.34 (18.05)	39.91 (20.01)	39.74 (20.10)
Population by quartile % (n)				
Q1	11.24 (1,316)	11.53 (2,086)	11.93 (957)	15.62 (1,300)
Q2	6.35 (743)	4.85 (877)	20.12 (1,614)	21.39 (1,781)
Q3	9.35 (1,094)	9.95 (1,801)	9.30 (746)	10.39 (865)
Q4	73.06 (8,552)	73.68 (13,333)	58.65 (4,705)	52.60 (4,379)
	Jul/3/2020		**Nov/19/2021**	
Sex % (n)				
Female	46.84 (16,990)	47.47 (23,140)	53.44 (8,501)	54.45 (8,181)
Male	53.16 (19,280)	52.53 (25,604)	46.56 (7,406)	45.55 (6,844)
Mean age-year (SD)	39.47 (17.82)	39.32 (17.77)	39.87 (19.59)	40.29 (19.27)
Population by quartile % (n)				
Q1	9.25 (2,277)	8.75 (3,195)	16.31 (1,980)	12.94 (1,574)
Q2	4.25 (1,047)	5.03 (1,835)	19.36 (2,350)	15.56 (1,893)
Q3	10.57 (2,603)	11.74 (4,284)	13.05 (1,584)	13.92 (1,693)
Q4	75.93 (18,699)	74.48 (27,180)	51.27 (6,223)	57.58 (7,004)
	Nov/21/2020		**Dec/3/2021**	
Sex % (n)				
Female	52.09 (26,129)	52.06 (30,300)	53.70 (7,246)	53.69 (6,732)
Male	47.91 (24,036)	47.94 (27,905)	46.30 (6,247)	46.31 (5,806)
Mean age-year (SD)	40.25 (18.22)	40.02 (17.97)	40.98 (19.55)	40.56 (19.14)
Population by quartile % (n)				
Q1	16.06 (6,777)	12.65 (6,156)	10.91 (1,239)	11.24 (1,200)
Q2	16.63 (7,016)	14.79 (7,199)	13.25 (1,505)	12.60 (1,346)
Q3	13.09 (5,522)	11.36 (5,530)	13.22 (1,501)	14.17 (1,513)
Q4	54.22 (22,880)	61.19 (29,780)	62.63 (7,113)	61.99 (6,620)

a. *Impact of the sale tax holiday on the number of cases and deaths by Covid- 19*

The results from the DiD models reveal complex impacts of TH on COVID-19 case trends, with effects varying across years, specific TH dates, and location densities (table 2). Also, the parallel trends assumption was met, as pre-treatment trends in COVID-19 cases and deaths for TH and control dates followed a similar trajectory before the TH event (see Fig. 2).

For COVID-19 cases, Panel A shows the aggregate effect of the THs, pooling all tax holiday dates together and disaggregating by year. The pooled effect indicates a 10.9 percentage point increase in COVID-19 cases attributable to THs ($p < 0.001$) (table 2 and Fig 2). In 2020, the effect was particularly strong, with THs contributing a 13.9 percentage point rise in cases ($p < 0.001$). This aligns with our assumption that limited immunity and strict mobility restrictions early in the pandemic would amplify the impact of gatherings on THs. By contrast, in 2021, we observed an 8.5 percentage point decrease ($p < 0.001$) in COVID-19 cases on THs. This finding likely reflects the effects of increased immunity, reduced restrictions, and shifting public behaviors as vaccination coverage expanded, consistent with our hypothesis regarding diminished TH effects over time driven mainly by high-density locations.

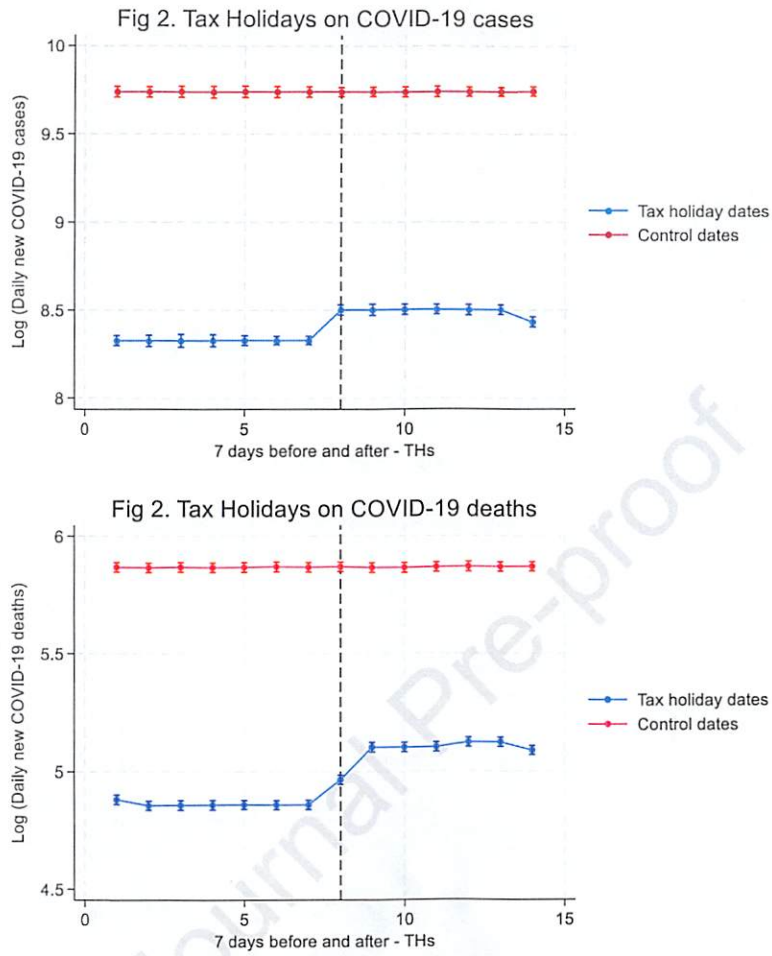

Fig 2. Pooled effect of Tax Holidays on COVID-19 cases and deaths

Note: This figure presents the DiD pooled effect of tax holidays on the logarithm of daily COVID-19 cases and deaths (y-axis), comparing 7 days before and 7 days after all six tax holidays (blue line) with corresponding all control dates (red line) from the opposite year. The vertical dashed line marks the transition from the pre- to post-tax holiday period. The parallel trends in the pre-treatment period for tax holidays and control dates provide visual evidence supporting the parallel trends assumption required for the DiD approach. Error bars indicate 95% CIs.

Panel B analyzes individual THs in 2020, revealing substantial increases in COVID-19 cases associated with the June 19 and July 3 holidays, with proportional point changes of 38.6 ($p < 0.001$) and 63.6 ($p < 0.001$), respectively. The November 21 TH shows a small but significant decrease of 1.2 percentage points ($p < 0.001$), potentially indicating the effect of evolving public health measures and altered mobility patterns in the latter half of 2020. These results are consistent with our assumptions, suggesting that early THs saw heightened case spikes due to stricter and national lockdowns and limited public immunity.

Panel C examines THs in 2021. The October 28 holiday produced a significant increase of 34.8 percentage points in COVID-19 cases ($p < 0.001$). The following THs on November 19 and December 3, however, had negative effects, with case reductions of 1.8 ($p < 0.001$) and 29.7 ($p < 0.001$) percentage points, respectively. The proximity of the October 28 TH to Halloween may have influenced this spike, as increased gatherings and social interactions extended into the subsequent TH, intensifying transmission. These results support our hypothesis that increased immunity in 2021 mitigated the impact of most THs, though holiday clustering (like Halloween) can still prompt notable spikes.

For the robustness check models, Panel D assesses variations in COVID-19 cases by municipality density for the 2020 THs. In low-density areas with respect to high-density locations, no significant increases are observed for the June 19 and July 3 holidays (0.024 and 0.009, respectively), whereas the November 21 holiday shows a modest increase of 0.9 percentage points ($p < 0.001$). This finding aligns with our assumption that high-density areas experienced stronger restrictions and mobility effects, resulting in less spread than in low-density municipalities after the second TH in 2020.

Panel E presents a similar analysis for the 2021 THs in low-density areas. The October 28 holiday shows a significant decrease in cases by 5.4 percentage points ($p < 0.001$), while the November 19 holiday exhibits an increase of 4.5 percentage points ($p < 0.001$). The December 3 holiday shows no significant effect, indicating varied responses in lower-density areas based on the timing and social context of each TH. These findings are consistent with our hypothesis that mobility and immunity changes across 2021 influenced the impact of THs, with location density acting as a moderating factor.

Overall, these results demonstrate that tax holidays initially drove up COVID-19 cases in 2020, particularly in high-density areas. However, their impact shifted in 2021, with reductions in cases for most THs, likely due to the cumulative effects of vaccination and easing restrictions. The influence of holiday clustering, as seen with the October 28 TH near Halloween, highlights the role of social behaviors in amplifying or mitigating case trends around tax holidays.

The number of observations in the models varies across THs due to fluctuations in daily reported COVID-19 cases, reflecting the pandemic's trajectory. High transmission periods increased sample sizes, while lower transmission reduced them. Density models (Table 2, Panels D and E) focus on the lowest and highest density quartiles, inherently reducing the sample size.

Table 2: Impact of sales tax holidays on the number of new cases in 2020-2021: Results from Difference in Difference models

	Log cases 7 days		
	Panel A: Aggregate effect of tax holidays		
	Tax holidays pooled effect	*Tax holidays effect in 2020*	*Tax holidays effect in 2021*
	0.109***	0.139***	-0.085***
Robust standard errors	0.003	0.002	0.003
Observations	1,105,215	433,733	671,482
R-squared	0.413	0.275	0.660
	Panel B: Sales tax holidays in 2020		
	Tax holiday 19Jun20	Tax holiday 03Jul20	Tax holiday 21Nov20
	0.386***	0.636***	-0.012***
Robust standard errors	0.003	0.002	0.004
Observations	396,896	320,122	105,274
R-squared	0.88	0.88	0.90
	Panel C: Sales tax holidays in 2021		
	Tax holiday 28Oct21	Tax holiday 19Nov21	Tax holiday 03Dec21
	0.348***	-0.018***	-0.297***
Robust standard errors	0.004	0.003	0.004
Observations	133,564	112,375	126,816
R-squared	0.91	0.88	0.86
	Panel D: Mobility variation by location density in the tax holiday (2020)		
Ref: *High-density locations*	Tax holiday 19Jun20 (Low density)	Tax holiday 03Jul20 (Low density)	Tax holiday 21Nov20 (Low density)
	0.024	0.009	0.009***
Robust standard errors	0.017	0.006	0.004
Observations	7,349	18,248	57,930
R-squared	0.421	0.419	0.148
	Panel E: Mobility variation by location density in the tax holiday (2021)		
Ref: *High-density locations*	Tax holiday 28Oct21 (Low density)	Tax holiday 19Nov21 (Low density)	Tax holiday 03Dec21 (Low density)
	-0.054***	0.045***	0.000
Robust standard errors	0.010	0.007	0.011
Observations	7,880	11,972	10,621
R-squared	0.097	0.109	0.066

Note: Table 2 presents the results from the Difference-in-Difference models, estimating the effects of sales tax holidays (TH) on the log of new COVID-19 cases over a 7-day period before and after each TH date. Panel A shows the aggregate effects of all THs, with separate estimates for 2020 and 2021. Panels B and C present results for individual TH dates in 2020 and 2021, respectively. Panels D and E report TH effects over the 7-day period before and after each TH, stratified by municipality density (low-density locations: quartile 1 vs. high-density locations: quartile 4) for 2020 and 2021, and its reference category (*Ref: High-density locations*) for these models is high-density municipalities (quartile 4). The number of observations (cases included in the models) varies across THs due to fluctuations in daily reported COVID-19 cases. Higher transmission periods resulted in larger samples, while lower case counts led to fewer observations. Density-specific models (Panels D and E) include only the lowest (Q1) and highest (Q4) density municipalities. *** p< 0.01, ** p< 0.05, * p < 0.1.

The DiD results on the effect of THs on COVID-19 deaths reinforce our previous findings on their impact on COVID-19 cases, both in terms of trend direction and statistical significance across aggregate models, yearly breakdowns, and individual THs (Table 3).

Panel A (Table 3) presents the pooled estimate across all six THs, showing a 5.7 percentage point increase in COVID-19 deaths following THs ($p < 0.001$), consistent with prior evidence that THs led to higher case counts (Table 2, Figure 2). In 2020, THs resulted in a 4.2 percentage point rise in deaths, aligning with the observed increase in COVID-19 cases during that period. Conversely, in 2021 observed a decline in COVID-19 deaths, likely reflecting higher vaccination coverage, relaxed restrictions, and shifting public behavior. This decline may be driven by high-density municipalities, which enforced stricter mobility policies and had higher vaccination rates. As shown in our COVID-19 case models, these municipalities reported lower COVID-19 cases (Table 2, Panels D and E).

Panel B (Table 3) examines individual THs in 2020, highlighting sharp increases in COVID-19 deaths following the June 19 (34.1 percentage points) and July 3 (49.4 percentage points) THs. However, after the shift in COVID-19 policies from national to municipal-level enforcement, we observe a decline in deaths following the November 21 TH, mirroring similar patterns observed for the November 19 and December 3 THs in 2021. These reductions likely reflect variation in mobility enforcement and vaccination policies, with high-density municipalities enforcing stricter restrictions and achieving greater vaccine coverage. As previously shown in our case models, these municipalities played a critical role in driving national trends.

A key exception is the October 28 TH in 2021, which resulted in a notable 52.8 percentage point increase in COVID-19 deaths. The proximity of this TH to Halloween likely amplified transmission, as extended social gatherings increased case numbers, ultimately leading to a rise in mortality. This finding underscores how holiday clustering and behavioral spillovers can intensify COVID-19 risks, even in a period of higher immunity.

These results further strengthen our previous findings, demonstrating that while THs initially fueled increases in cases and deaths, their effects diminished over time due to immunity gains and localized enforcement policies. However, event clustering (e.g., Halloween) remained a key driver of pandemic dynamics (Table 3).

Table 3: Impact of sales tax holidays on the number of new deaths in 2020-2021: Results from Difference in Difference models

		Log deaths 7 days	
		Panel A: Aggregate effect of tax holidays	
	Tax holidays pooled effect	*Tax holidays effect in 2020*	*Tax holidays effect in 2021*
	0.057***	0.042***	-0.090***
Robust standard errors	0.003	0.001	0.002
Observations	1,105,215	433,733	671,482
R-squared	0.311	0.057	0.666
		Panel B: Sales tax holidays in 2020	
	Tax holiday 19Jun20	Tax holiday 03Jul20	Tax holiday 21Nov20
	0.341***	0.494***	-0.052***
Robust standard errors	0.002	0.001	0.003
Observations	396,896	320,122	105,274
R-squared	0.862	0.816	0.916
		Panel C: Sales tax holidays in 2021	
	Tax holiday 28Oct21	Tax holiday 19Nov21	Tax holiday 03Dec21
	0.528***	-0.093***	-0.346***
Robust standard errors	0.003	0.002	0.002
Observations	133,564	112,375	126,816
R-squared	0.939	0.887	0.924

Note: Table 3 presents the results from the Difference-in-Difference models, estimating the effects of sales tax holidays (TH) on the log of daily new COVID-19 deaths over a 7-day period before and after each TH date. Panel A shows the aggregate effects of all THs, with separate estimates for 2020 and 2021. Panels B and C present results for individual TH dates in 2020 and 2021, respectively. The number of observations (cases included in the models) varies across THs due to fluctuations in daily reported COVID-19 cases. Higher transmission periods resulted in larger samples, while lower transmission periods led to fewer observations. *** p< 0.01, ** p< 0.05, * p < 0.1.

Finally, after back-transforming the estimates from the DiD models, we found that in 2020, THs increased the number of cases by approximately 11,000 and deaths by 265, while in 2021, the increase was 2,847 cases and 74 deaths (Table 4).

Table 4. Estimated COVID-19 Cases and Deaths on Sales Tax Holidays: Back-Transformed Estimates

Dates	Number of cases	Number of deaths
Panel A: Sale tax holidays in 2020		
Jun/19/2020	2,292	99
Jul/3/2020	8,860	166
Nov/21/2020	N/A	N/A
Panel B: Sale tax holidays in 2021		
	Number of cases	Number of deaths
Oct/28/2021	2,847	75
Nov/19/2021	N/A	N/A
Dec/3/2021	N/A	N/A

This table presents the estimated number of new COVID-19 cases and deaths on each sales tax holiday in 2020 and 2021, back-transformed from the log scale using the Duan smearing transformation method (Duan, 1983). Estimates are derived from the Difference-in-Differences models, where the primary outcome is the log of new COVID-19 cases and deaths for each tax holiday. "N/A" indicates instances where no increase in the number of cases or deaths was observed.

b. Economic estimates

In 2020, health sector losses ($398 million) from TH-related hospitalizations, ICU care, and deaths exceeded economic gains ($369 million). In 2021, with vaccines available, economic gains ($1,471 million) surpassed health sector losses ($112 million). (Table 5).

Table 5. Economic gains and losses by the sale tax holidays

Tax holiday	Hospitalization costs 10 days (US $)	ICU costs 14 days (US $)	Values of a Statistical Life per number of deaths (US $)	Total health economic losses (US $)	Total economic gains for the tax holiday (US $)	Difference (economic gains - health losses)
			2020			
Jun/19/2020	$ 388,627	$ 165,870	$ 147,804,809	$ 148,359,306	$ 64,365,118	$ -83,994,188
Jul/3/2020	$ 1,502,284	$ 582,901	$ 247,834,326	$ 249,919,511	$ 108,020,558	$ -141,898,953
Nov/21/2020	N/A	N/A	N/A	N/A	$ 197,392,237	$ 197,392,237
Total	$ 1,890,911	$ 748,771	$ 395,639,136	**$ 398,278,818**	**$ 369,777,914**	**$ -28,500,904**
			2021			
Oct/28/2021	$ 9,655	$ 18,730	$ 111,973,340	$ 112,001,725	$ 387,377,112	$ 275,375,387
Nov/19/2021	N/A	N/A	N/A	N/A	$ 513,087,924	$ 513,087,924
Dec/3/2021	N/A	N/A	N/A	N/A	$ 570,828,790	$ 570,828,790
Total	**$ 9,655**	**$ 18,730**	**$ 111,973,340**	**$ 112,001,725**	**$ 1,471,293,826**	**$ 1,359,292,101**

N/A refers to cases where no increase in the number of cases/deaths was found. All costs are in US dollars for 2022.

4. Discussion

In this study, we found that TH led to increased mobility and a significant rise in COVID-19 cases, hospitalizations, ICU admissions, and mortality, particularly in the pre-vaccination period. During this time, healthcare costs associated with COVID-19 cases exceeded economic gains from retail activity, but this tradeoff reversed after vaccines became available. Our use of TH as a natural experiment provides unique causal evidence on the health-economic impact of ending early lockdown policies, offering valuable insights for policymakers, especially in low- and middle-income countries where limited evidence on these tradeoffs exists.

During the COVID-19 pandemic, policymakers were constantly concerned about the tradeoff between implementing lockdown measures and the associated economic losses. Given the endogeneity of this phenomenon, assessing the effect of lockdown on health or economic outcomes is challenging. Previous studies have primarily used excess mortality and unemployment rates as measures to estimate the potential effect of the lockdown on the economy and health outcomes (Kerpen et al., 2022; Pugh et al., 2022), but this may provide a limited view of the phenomenon. Our study utilized a unique opportunity to measure the effect of abrupt ends to lockdown policies by examining the exogenous effect of TH during various phases of the lockdown in Colombia.

The tax break generates abrupt ends to lockdown policies and provides price inducements for people to leave their homes and shop, thereby reducing the costs of the lockdown for households. This also provides an exogenous variation to mobility, regardless of the pandemic situation, as long as consumers go outside their homes to purchase goods and services instead of buying online. Similar to the UK's Eat Out to Help Out (EOTHO) scheme, which encouraged people to eat out and increased footfall in the food service sector through financial incentives (Gonzalez-Pampillon et al., 2024), Colombia's TH induced in-person shopping through price reductions.

Given that approximately 11,000 new cases and 265 new deaths were attributable to the temporary removal of the lockdown in 2020 when a COVID-19 vaccine was not available, this may suggest that the lockdown is a potentially effective non-pharmacological intervention that can be used in future pandemics to prevent transmission and deaths associated with infectious diseases, such as COVID-19. However, the value of this intervention should be evaluated differently if other pharmacological interventions to prevent transmission and severity, such as a vaccine against COVID-19, are available. Studies on the EOTHO scheme also highlighted the public health risks associated with incentivized gatherings, finding that the increased footfall led to a rise in COVID-19 infection clusters within a week of implementation (Fetzer, 2022). This supports our findings on the health impact of TH.

Although non-pharmacological measures such as the use of masks, social distancing, and hand washing were available in 2020, their proper adoption can always be a challenge, leading to increased hospitalizations, ICU admissions, or deaths during THs. However, in 2021, HTs had reduced or did not significantly affect the number of COVID-19 cases, and deaths might be because vaccines were already available in Colombia. By the time the first TH was implemented on October 28, 2021, approximately 60% of the population had already received at least one dose of the vaccine, according to the Our Worldin Data dashboard.

The observed negative effect of THs on COVID-19 cases in November and December 2021 likely reflects increased immunity, localized mobility restrictions, and shifts in enforcement dynamics. By late 2021, Colombia had made substantial progress in vaccination, particularly in high-density urban areas with higher immunization rates. Widespread vaccination reduced infection severity, transmission rates, and symptoms, influencing testing behaviors, as individuals with mild or asymptomatic infections were less likely to seek testing, leading to fewer reported cases. Consequently, the expected relationship between increased mobility and rising COVID-19 cases during THs may have weakened, particularly in high-density urban areas where immunization rates were higher.

Beyond vaccination, mobility enforcement differences likely contributed to the negative effect observed in late 2021. Following the transition to municipal-level lockdown measures in August 2020, local governments assumed greater discretion over mobility restrictions. In high-density municipalities, authorities imposed stricter measures, including crowd limitations and enhanced public health interventions during THs. These restrictions may have offset the expected rise in COVID-19 cases, particularly in urban centers with greater regulatory capacity. The findings align with prior evidence from Colombia, indicating that local enforcement played a crucial role in shaping pandemic outcomes, particularly as national-level restrictions eased (Jason et al., 2022).

Differences in enforcement and immunity levels also contributed to the heterogeneous impact of THs. As shown in Table 2 (Panels D and E), TH effects varied by population density. In low-density areas with weaker mobility restrictions (Jason et al., 2022), COVID-19 cases increased after THs, reinforcing the link between mobility and disease transmission in the absence of strong mitigation measures. In contrast, in high-density municipalities, stricter enforcement and higher vaccination rates mitigated the expected rise in cases, contributing to an overall decline in reported infections at the national level. These results support the hypothesis that as vaccination coverage increased, the policy impact of THs diminished, particularly in regions with additional public health interventions.

It is important to highlight the potential heterogeneous impact of THs. During the THs, people had the option to shop in person or online. Thus, it is possible that high-income individuals were more inclined to shop online, while low-income individuals preferred in-person shopping. However, the online shopping culture in Colombia is limited, and the infrastructure for online shopping was also limited (Janneth & Suárez, 2020), particularly in 2020. As a result, there were numerous complaints about the non-functioning of virtual portals for shopping during THs (García, 2020).

The limited literature on the effect of lockdowns on health and economic outcomes is due to the difficulty of addressing the endogeneity of lockdowns. In this context, we propose an innovative identification strategy using freely available data sources such as COVID-19 case data and the Google mobility indicator. The latter provides information for different countries, sub-regions, and dates, making it a valuable resource for future studies interested in exploring this issue. Our approach offers a useful framework for generating evidence to inform future pandemic preparedness efforts.

Limitations

While our study provides a robust approach to assess the causal impact of TH on COVID-19 outcomes, several limitations should be acknowledged. First, as a national policy affecting the entire population, TH limits our ability to observe its effects in control areas or in a randomized context. To address this, we applied a DiD approach, which relies on the assumption of parallel trends, meaning that without TH, COVID-19 case trends on TH dates would have mirrored those on control dates (the same dates in the prior or following year). We confirmed this assumption by verifying parallel trends before TH dates and observing a significant increase in COVID-19 cases on TH dates.

Second, our analysis employs a 7-day post-TH window in the DiD model, which may not fully capture all infections and mortality, as some cases and deaths could occur beyond this period. However, this short window enhances causal identification by minimizing confounding from policy changes, mobility shifts, and broader pandemic dynamics. It also helps control for time-invariant factors, such as ICU and hospitalization capacity, which are unlikely to change significantly within a few days. By focusing on the immediate impact of tax holidays, this approach reduces the risk of overlapping effects from subsequent events. Future studies could explore longer post-TH windows to better assess delayed mortality impacts.

Moreover, although government preparedness for TH might have influenced testing capacity, we found that testing efforts were largely consistent in the 7 days before and after each TH, helping to reduce potential testing-related biases.

Finally, our economic analysis does not account for indirect costs, such as out-of-pocket healthcare expenses and long-term effects on mental health and productivity. Future research with broader datasets and longer observation periods could provide a more comprehensive understanding of these indirect impacts, further extending the findings of our study.

Conclusions

This study provides causal evidence that TH in Colombia led to increased COVID-19 transmission, particularly in the pre-vaccination period, highlighting the need to weigh public health risks against economic gains when relaxing lockdown policies during a pandemic. While retail-driven mobility can stimulate economic activity, the associated health costs are substantial when immunity levels are low. This tradeoff shifts as vaccination rates increase, suggesting that the economic benefits of TH become more favorable in vaccinated populations. These findings offer a framework for policymakers to consider in future pandemic scenarios, especially in similar socioeconomic settings, although caution is needed as the results may not generalize across diverse income levels and healthcare capacities.

Pandemic responses should aim to balance health and economic priorities. During high-transmission periods, incentives for in-person activity, such as TH, may provide limited net benefits if healthcare costs exceed economic gains. As vaccination becomes widespread, policies can support economic recovery by allowing more mobility. Future pandemic preparedness should combine vaccines with nonpharmaceutical interventions like masking, social distancing, and hygiene practices to reduce transmission risks when economic incentives are in place. Additionally, high health expenditure and resilient healthcare infrastructure are crucial for effective crisis management, enabling better vaccine distribution and improving capacity to handle case surges.

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Ethical approval: This research used secondary publicly available anonymized data and therefore, no ethical approval is required.

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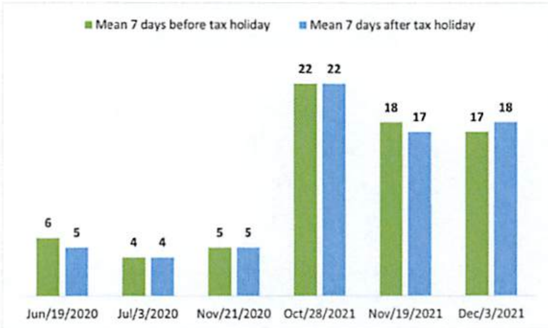
Appendix A. Tax Holiday and control dates for COVID-19 analysis

Year	Tax Holiday (TH) Date	Control Date
2020	Jun/19/2020	Jun/19/2021
2020	Jul/03/2020	Jul/03/2021
2020	Nov/21/2020	Oct/20/2021
2021	Oct/28/2021	Oct/28/2020
2021	Nov/19/2021	Nov/11/2020
2021	Dec/03/2021	Dec/03/2020

Appendix B. Number of COVID-19 tests performed per new case by tax holiday dates



Economic and Health Implications of Early COVID-19 Lockdown Exits: Evidence from a Difference-in-Differences Analysis

Highlights

- Tax holidays increased COVID-19 cases and deaths before vaccination.
- Before vaccines, health costs from THs exceeded economic gains.
- After vaccines, THs brought more economic benefits than health costs.

Economic and Health Implications of Early COVID-19 Lockdown Exits:

Evidence from a Difference-in-Differences Analysis

This study uses publicly available, anonymized secondary data from the Colombian Ministry of Health and Google Mobility. As no personally identifiable information was collected or used, ethical approval was not required.