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Hospital construction and emergency waiting time: Evidence from Nicaragua

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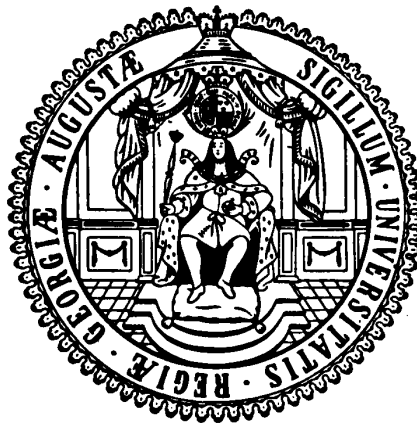
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Hospital construction and emergency waiting time: Evidence from Nicaragua

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Abstract

We investigate the impact of a large new public hospital on directly observed waiting times in emergency departments of other public hospitals in Nicaragua. Using a difference-in-differences design, we estimate a significant decrease in waiting time by 42% or 10.1 minutes in nearby hospitals compared to hospitals that are further away. The waiting time reduction is largest for nearby hospitals specialized in maternal and paediatric health, as these services overlap the most with those of the new hospital. Findings remain robust to facility and department controls, outlier exclusion, and alternative treatment definitions. A complementary cost-benefit analysis shows that, in addition to the immediate reduction in opportunity costs, the shorter waiting times can also contribute to a reduction in lost earnings by improving patients' health outcomes. Estimates suggest an amortization period of less than one year.

Keywords: waiting time, healthcare infrastructure, hospital construction, impact evaluation, emergency departments

Introduction

Long waiting times for medical emergencies are a major public health concern. Emergency waiting time threatens patients' health, reduces their satisfaction, increases monetary costs, and ultimately reduces demand for and access to healthcare, which can further jeopardize individuals' health (e.g., Derlet and Richards 2002; Guttman et al. 2011; Nabbuye-Sekandi et al. 2011; Rahman et al. 2011; Ogunfowokan and Mora 2012; Mataloni et al. 2018). Despite its relevance for patient welfare, there is little empirical evidence on solutions to reduce emergency waiting time in health facilities. Finding effective solutions is particularly relevant for low and middle-income countries, where public hospitals face the pressure of rapid population growth and urbanization. This is the case of Nicaragua, where urban population growth has grown rapidly over the last decades. As a result, demand for healthcare has outpaced supply, placing public healthcare facilities under enormous pressure (INIDE 2019). In response, a new public hospital, the country's largest at the time, started operations in the capital in 2018.

In this paper, we investigate the impact of the new public hospital's opening on waiting time in emergency departments (ED) of other public hospitals in Nicaragua. We rely on a difference-in-differences (DiD) design, using primary data of directly observed (i.e., *not* self-reported) waiting times in emergency departments and patient exit-surveys, before and after the hospital's opening. Treatment status is assigned based on geographic proximity to the new hospital: five hospitals in the same city (Managua) constitute the treatment group; three hospitals in other cities nearby (Masaya, Granada, León) constitute the control group.

Our DiD estimates suggest that the new hospital noticeably reduced waiting time in EDs by approximately 47%, which is equivalent to about 10 minutes. This estimate remains robust when controlling for changes in patient composition, excluding outliers, or using alternative treatment definitions. The new hospital, although offering general health services, operates with

a focus on maternal and paediatric healthcare. Reassuringly, we find that the reduction in waiting times is largest for nearby hospitals specialized in maternal and paediatric health, as these services overlap the most with the new hospital. Thus, women and children are the primary beneficiaries from the hospital's opening.

We provide additional insights to inform on the plausibility of the identifying assumptions. To inform about the plausibility of the parallel trend assumption, we document pre-trends across a series of socioeconomic and health indicators. To test for spill-over effects from treated to control hospitals, we use additional survey data on the place of residency of in- and outpatients, as well as administrative data on the regional distribution of healthcare personnel. We find no evidence for spill-over effects.

In a complementary cost-benefit analysis, we compare the ED's construction costs with the monetary value of reduced waiting. We account for the direct opportunity costs saved by a shorter waiting time for patients of working age. We further estimate the prevented loss of earnings due to improved health status for those conditions for which the literature has identified the causal impact of waiting times on health outcomes. This information is known for around 20 percent of our sample. We refrain from estimating the prevented loss of earnings for other patients, for whom this information is not available, and therefore provide a lower bound estimate of the monetary benefits of the new hospital. Even with this rather conservative approach, the benefits outweigh the ED's construction costs after less than one year.

This is the first quasi-experimental study to assess the causal impact and cost-benefit of a substantial increase in public healthcare infrastructure on waiting time in EDs in a low-income country. Thereby, we contribute to the existing literature in three ways. First, the existing literature on potential solutions to reduce waiting time in health facilities is small, especially in low- and middle-income countries.¹ In a review article, Hoot and Aronsky (2008) identify

improved demand management, business intelligence, and additional resources as approaches to reduce waiting time investigated in the literature. Additional resources in terms of personnel, medical units within existing hospitals, or hospital beds are found to reduce waiting time in EDs significantly. A reduction in working hours by general practitioners, on the other hand, is associated with a significant increase in waiting time for patients of primary care (Swami et al. 2018). Yet, the entire evidence on increased resources is limited to high-income countries and focuses on expansions of healthcare supply within a given facility. None of the reviewed studies evaluates the causal impact of an increase in healthcare supply as extensive as that achieved by opening an entirely new hospital.

Second, although the impact evaluation literature has been growing rapidly in recent years, evaluations of infrastructure projects remain relatively rare. Due to the typically small number and selection of treated sites and the long time lags between project completion and the manifestation of impacts, large infrastructure projects pose notable problems for rigorous impact evaluations. Moreover, identifying a valid counterfactual for a large, publicly available and geographically concentrated treatment, such as a public hospital, is more challenging than for household- or individual-level interventions. Several impact evaluations of infrastructure projects have been conducted in the transport, water supply, sanitation, and electrification sectors (see Andrés et al. 2013 for a comprehensive overview). To date, impact evaluations of healthcare infrastructure projects are rare.²

Third, the study adds to the scarce literature assessing waiting time and its determinants in health facilities in low- and middle-income countries. The few existing studies lack comparability with regards to where (outpatient department, inpatient department, or ED), when (e.g., before or after registration), and how (e.g., observing patients, asking patients, or asking health personnel) waiting time is measured. Our direct measurement through independent enumerators is superior to survey-based (self-reported) measures of waiting times

(e.g., Ofili and Ofovwe 2005; Oche and Adamu 2013; Wagenaar et al. 2016; Ahmad, Khairatul, and Farnaza 2017; Fazl et al. 2017).

Materials and Methods

Setting

Nicaragua's health system is divided into three regimes: (1) a contributory public regime covering formal workers and financed through insurance fees paid by employees and employers, (2) a non-contributory public regime providing individual healthcare and assistance for all citizens to guarantee free and universal healthcare access, and (3) a voluntary regime encompassing private and non-governmental healthcare. With a coverage of 65% of the total population in 2015, the non-contributory public regime is by far the most important one within the Nicaraguan healthcare system. Only 18% of the population was insured by the contributory, 11% relied on the voluntary private regime, and another 6% were insured by a specific social security system owned by the Ministry of Governance and the Ministry of Defence (Herrera 2006; Muiser, Sáenz, and Bermúdez 2011; Sequeira et al. 2011; PAHO 2017).³

Due to the lack of in-depth studies on the healthcare system in Nicaragua, further context on (1) and (3) is not available. However, it is highly likely that the healthcare regime (2), which is the central one for our study, operates with a high degree of separation from the others. The main reason behind this is that regimes seem to attend patient pools with very different purchasing power.⁴ For instance, 61% and 85% of adult patients and their relatives in emergency rooms of regime (2) have incomplete secondary schooling and complete secondary schooling as highest education levels, respectively, which is indicative of their socioeconomic status and their inability to afford healthcare in the other regimes. For our study, this suggests that substantial effects outside the non-contributory public regime are highly unlikely.

Despite the substantial public healthcare expenditure of the Nicaraguan government (8.6% of the GDP and 18.6% of the total government expenditure in 2015), healthcare provision suffers from a deficit in personnel and equipment capacity (World Bank 2020). In response to these shortages, in January 2018, a new general hospital was inaugurated in the capital, Managua. With 300 overnight- and 72 daybeds, it was by then the country's largest hospital. It belongs to the non-contributory healthcare regime and, although offering general services, specializes in maternal and paediatric care. Due to the good infrastructure surrounding the new hospital and the absence of an enforcement mechanism allocating patients to specific facilities, the benefits of the new hospital are available to the entire population of the department of Managua (Monfared, Garcia, and Vollmer 2021). The main aims of the new hospital are to meet the increasing demand for healthcare services, improve healthcare quality, and reduce out-of-pocket health expenditures.

Data

We collected primary data from two patient surveys. The baseline survey took place in August and September 2017, roughly three to four months before the new hospital's opening. It covered five public hospitals within the department of Managua and three public hospitals in the surrounding departments: Masaya, Granada, and León. The endline survey was conducted in September and October 2019, roughly 21-22 months after the new hospital's opening.⁵ In addition to the eight pre-existing hospitals, the new hospital was also included at endline. During data collection, ED patients were randomly sampled at the entrance of the hospitals' EDs.⁶

The primary outcome is waiting time in EDs. Enumerators recorded the time of arrival and departure of patients at the main waiting room of EDs, and one out of three possible reasons for leaving it: (i) Attended by a doctor, (ii) transferred to another waiting room (out of enumerators'

sight), and (iii) left without being attended.⁷ The measurement of waiting time was accompanied by a short questionnaire conducted by the enumerators while patients were waiting. The questionnaire collected information on the patient's gender, age, educational attainment, and reason for visiting the ED.⁸ Waiting time was recorded on all days of the week but exclusively during daytime to ensure field staff safety. As a result, our data are only representative of daytime emergency departments.

In total, we collected waiting time observations for 5,078 patients (Table 1). The number of observations by facility is displayed in Figure A1 in the Appendix and varies across hospitals in proportion to actual patient flows of the facilities.⁹ In addition to the eight study hospitals, 377 observations of waiting time were collected in the new hospital during the endline survey. Figures A2 and A3 additionally show the number of observations by facility and enumeration day.

- TABLE 1 -

As a complement to the survey data, administrative data were provided by the Nicaraguan Ministry of Health (MINSa). The data contain facility-specific patient information, such as patient numbers, gender and age composition, treatments offered, as well as capacity information, e.g., number of beds, doctors, nurses, auxiliaries, and midwives. The administrative data are aggregated at the facility level and, thus, cannot be linked to individual patients in our primary data. Moreover, administrative data do not include waiting times. Therefore, administrative data are not used for the main analysis but rather for auxiliary checks on parallel trends, spill-overs, and sample representativeness. Table A1 lists the name, description, and source of all variables used within the analysis and argumentation.

Empirical methodology

To analyse whether the new hospital's opening affected ED waiting time in nearby public hospitals, we set up a DiD design. A before-after comparison of hospitals within Managua alone would be misleading, because observed differences could be influenced by trends unrelated to the hospital opening. Similarly, a cross-section analysis would be susceptible to bias since treatment and control status were not randomly assigned.

The opening of the new hospital was a one-time, large-scale, and locally-bounded event that caused a sharp increase in the availability of public healthcare services for the population in the department of Managua. It was expected to relieve pre-existing general public hospitals in the department, under the assumption that patient flows would spread over an increased number of facilities and thereby improve healthcare access for the department's entire population seeking care in public hospitals. All five general public hospitals that are located in the department of Managua and substantially overlap with the new hospital in provided services are defined as treatment hospitals (H1, H2, H3, H4, H5). In turn, the patient population in other more distant departments is expected to remain largely unaffected. Therefore, the three general public hospitals of the surrounding departments – Masaya, Granada, and León (H6, H7, H8, in random order to ensure data confidentiality) – are defined as control hospitals. Figure A4 shows the graphic distribution of the hospitals. Treatment definition at the department level reduces the risk of individuals self-selecting in or out of treated hospitals.

The DiD design compares changes in waiting time in treated hospitals before and after the new hospital's opening relative to changes in waiting time in control hospitals. Comparing the change in waiting time over time removes any time-invariant differences between treatment and control facilities. The DiD estimate can be interpreted as the causal effect of the new hospital if two main assumptions hold: (a) In the absence of the new hospital, waiting time in

treated facilities would have followed the same trend as in control facilities, and (b) there are no spill-over effects from treated to the control hospitals.¹⁰ In a later section, we discuss the plausibility and potential threats to these assumptions. The main DiD regression is specified as:

$$\text{asinh}(\text{waiting}_{iht}) = \beta_0 + \beta_1 \text{after}_t + \beta_2 \text{treat}_h \times \text{after}_t + \gamma_h + \varepsilon_{iht} \quad (\text{I})$$

where $\text{asinh}(\text{waiting}_{iht})$ is the inverse hyperbolic sine (IHS) transformation of waiting time (in minutes) of patient i seeking emergency care at hospital h in survey period t . Since waiting time is skewed towards high values, we follow Bellemare and Wichman (2020) and use the IHS transformation of waiting time as dependent variable in all specifications. In alternative specifications, we used (1) the natural logarithm of waiting time and added one minute either to each observations or only to observations with a waiting time of zero as done by Moscelli et al. (2018) and (2) the quartic root of waiting time as suggested by Thakral and Tô (2023).¹¹ Results of these alternative transformations are qualitatively very similar to those of our main specification with IHS. The dummy variable after_t equals one if the observation belongs to the post-opening period (2019) and zero otherwise. The specification includes hospital fixed effects γ_h , which capture the time-invariant hospital characteristics (e.g., size, location, accessibility, or management practices). The interaction term $\text{treat}_h \times \text{after}_t$ represents the variable of interest and is the difference in the change in waiting time between treatment and control hospitals.

We report both heteroscedasticity-robust standard errors and standard errors clustered at hospital-enumeration days which we expect to be the dimension at which the homogeneity assumption to be fulfilled (see Roth et al. 2023). Due to the limited number of hospitals, a higher level of clustering is not appropriate.¹² Sampling weights consider the year-specific patient load as well as patients' gender and age distribution across facilities. Weights are

adjusted to a multiplicative distance measure by raking to increase the representativeness of the study sample for the total patient population.

Previous research shows that waiting time correlates with several patient characteristics (e.g., Mohsin, Bauman, and Ieraci 1998; Goodacre and Webster 2005; Elkum et al. 2009). Thus, we control for patients' sociodemographics in an alternative regression specification (II). This alternative model isolates the direct effect of the new hospital on waiting time from potential indirect effects driven by changes in patient composition:

$$\text{asinh}(\text{waiting}_{iht}) = \beta_0 + \beta_2 \text{after}_t + \beta_3 \text{treat}_h \times \text{after}_t + \beta_4 X_{iht} + \gamma_h + \varepsilon_{iht} \quad (\text{II})$$

where X_{iht} is a vector of sociodemographic characteristics of patient i , namely gender, age, and education. Gender is a dummy variable set to one for female patients. Age and education are continuous variables measured in years. In complementary specifications, we include covariates at the department and facility level to control for hospital-specific and department-specific time-varying factors.

Results

Summary statistics

In our sample, patients wait on average 37 minutes at the Emergency Department's main waiting room (Table 2). The most frequent reason for leaving the main waiting room is being attended by a doctor (77%), followed by transfers to other waiting rooms (22%). Only 2% of observed patients leave without being attended. Figure A5 summarizes the most frequent reasons for visiting the EDs.

- TABLE 2 -

The average patient is a 33-year-old female with eight years of schooling. Relative to administrative data from the Ministry of Health on the total ED population, females are

overrepresented in our sample, whereas infants and children are underrepresented (Table A2). One likely reason for the limited representativeness is that our primary data only captures EDs between 6 am and 4 pm, whereas administrative data refer to the whole day. These differences further justify the use of sampling weights.

Figure 1 displays the considerable variation in waiting time across and within hospitals. In both years, the mean waiting time was lowest in treatment hospital H5, with 12 minutes on average in 2017. In 2017, waiting time was highest in control hospital H6 (77 minutes on average) and in 2019 in control hospital H7 (64 minutes on average). While for some hospitals (e.g., H5) waiting time does not vary too much across patients, for other hospitals we observe substantial variation (e.g., H1 and H6). An explanation for the low values and small variance in waiting times of H5 could be that it is a paediatric hospital with a more homogenous patient population. Generally, the distribution of waiting time is strongly skewed towards high values.¹³

- FIGURE 1 -

Figures A6 – A10 report summary statistics on waiting time by patient and visit characteristics. Using broader visit categories to allow a more systematic comparison shows that patients who came because of chronic conditions experience the longest waiting times. In contrast, waiting times are the shortest for infectious conditions. In accordance with previous studies (e.g., Elkum et al. 2009; Goodacre and Webster 2005), the day of the week also matters: Waiting times are shortest on Saturdays and longest on Sundays. In contrast, we do not observe noticeable variation concerning the arrival time. This finding might be traced back to our data collection not covering ED downtimes (4 pm - 6 am). Only marginal differences in waiting times can be observed across gender and educational levels. Women experience slightly longer waiting times than men, and waiting time varies more among patients without formal education. Remarkably

lower waiting times are observed for infants and young children. These findings persist even when we exclude observations from the children’s hospital (H5).

Table 3 reports OLS correlates of (IHS) waiting time, pooling data across waves and hospitals. Waiting times are, on average, higher in 2019 than in 2017 but the difference is not statistically significant. Female patients wait less on average after controlling for hospital fixed effects (columns 2-4). Descriptively, waiting time also slightly increases in patient’s age, even after including hospital, day-of-the-week, and hour-of-arrival fixed effects (columns 3-4). Once hospital fixed effects are included, we find no systematic correlation between waiting times and patients’ education (columns 2-4). The descriptive correlates of waiting time remain very similar when endline data for the new hospital is included (column 5).

- TABLE 3 –

Main estimation results

Table 4 presents simple means comparisons of waiting time by reason for leaving the main waiting room. Overall, we estimate an average 53% reduction in waiting time in EDs of treatment hospitals compared to control hospitals as the result of the opening of the new hospital.¹⁴ This overall effect, shown in Panel A, emerges from a *reduction* in mean waiting time in treatment hospitals (from 3.46 points, or approx. 32 minutes, in 2017 to 3.10 points, or approx. 22 minutes, in 2019) and an *increase* in mean waiting time in control hospitals (from 3.67 points, or approx. 39 minutes, in 2017 to 4.07 points, or approx. 58 minutes, in 2019).

- TABLE 4 -

The overall negative estimate can be decomposed by the reason for leaving the main ED waiting room. Between baseline and endline, waiting time until being attended by a doctor increases in both groups, but the increase is smaller in treatment than in control hospitals (Table 4, Panel B). After the opening of the new hospital, waiting time to be transferred to another waiting

room decreases substantially in treatment facilities while it increases in control facilities (Table 4, Panel C).¹⁵

Table 5 extends the simple DiD model (reproduced in column (1)) by adding facility fixed effects in column (2), weighting observations for representativeness by patients' sex and age in column (3), controlling for patient characteristics in column (4), and controlling for patients' broad visit category in column (5).

- TABLE 5 -

Across all specifications, we find a negative and statistically significant effect of the hospital's opening on waiting times. Including hospital fixed effects reduces the magnitude of the effect to an average reduction in waiting time of 47 - 53%. Using the counterfactual outcome, this is equivalent to a reduction by 10.1 - 11.4 minutes.¹⁶ Taking into account the results of previous studies on the association of waiting time and patient welfare, a reduction of this extent can be considered as medically relevant.¹⁷ The effect size remains stable after sample weighting or controlling for patient characteristics, suggesting that changes in sample representativeness or patient composition do not explain the average reduction in waiting time. Additionally controlling for the visit reason slightly reduces the effect size, but the effect remains large and highly significant. Table A3 further shows that the share of patients attended by a doctor increased in treatment relative to control hospitals, whereas the share of patients transferred to another waiting room declined.

Due to the nature of most medical emergencies, we expect the general demand for ED healthcare to be rather inelastic to supply changes. Nevertheless, the increased supply of public ED healthcare might have caused parts of the population of the treated department Managua to shift from private to public ED healthcare since they expect lower waiting times or improved

quality. In this case, our estimate is, if anything, more conservative, given that we do not observe changes in patients' healthcare-seeking behavior.

The new general hospital has a special focus on maternal and paediatric services. Therefore, we expect the reduction in waiting time to be stronger in treatment hospitals specialized in maternal and paediatric services and for patients of these population groups. Table 6 reports effect heterogeneity across facilities' specialization (column 1), patients' gender (column 2), and patients' age (column 3). As expected, the reduction in waiting time is especially pronounced in the two hospitals specializing in maternal and paediatric services (column 1) and for patients younger than 15 (column 3). For female patients, the reduction in waiting time is also larger, but the differential effect is relatively small and statistically insignificant (column 2).

- TABLE 6 -

We further assess whether the effect on ED waiting time differs between patients' health conditions. We generate nine sub-samples and run reason-specific regressions based on the nine broad categories of visit reasons. Figure A11 reports the estimation coefficients, the 90% confidence interval, and the significance level for the nine regressions and the total sample. The reduction in waiting is most strongly pronounced among patients who visit the EDs because of infectious conditions, trauma and injuries, and pregnancy and reproductive health. The more substantial reduction among pregnant patients mirrors the earlier findings of larger effect sizes for hospitals specializing in maternal services and among female patients.

Robustness checks

Ideally, the parallel trend assumption could be supported by the absence of differential pre-trends in waiting time between the treatment and control group. However, ED waiting time data are not available before 2017. Hence, to assess the plausibility of the parallel trend assumption, we turn to a second-best approach and show that aggregate departments' sociodemographic and

healthcare indicators followed similar trends and are comparable in their levels across the departments during the years before the new hospital opened.¹⁸ Figure A12 shows that the population growth rate in all four departments was mostly stable in the ten years before the baseline, except for some irregularities between 2011 and 2013. Health insurance contributions of the insured in the four departments also followed a similar trend with almost identical levels in the four years before the baseline survey.¹⁹ There was significantly more volatility in mortality rates, yet we do not detect a visible discrepancy comparing the treatment with the control departments. Comparable departmental trends and levels can also be observed for most healthcare indicators per 10,000 population (Figure A13). Hospital beds and the number of doctors and nurses evolved in parallel prior to the hospital opening. Selective deviations exist regarding the number of consultancies for the years 2012 and 2015 which might be explained by an irregularity in assigning the status *external* and *emergency* consultation in the departments Masaya and Granada.

Besides the supportive evidence for parallel trends preceding the hospital construction, it is important to ascertain the absence of any intervening events that differentially affected waiting time in EDs of public hospitals of treatment and control departments during the evaluation period. In 2018, Nicaragua experienced intense political and social unrest and Managua was most strongly affected by the conflict (GIEI Nicaragua 2019). While we cannot directly control for this shock in our regression framework, we note that the endline data were collected in September and October of 2019, when the situation had arguably stabilized. Thus, results are not directly affected by any ongoing unrest. In an attempt to control for potential supply-side implications of the unrest, i.e., relocation of healthcare personnel, we estimate DiD models (presented in Table A4) that control for the number of doctors (column (4)) and nurses (column (5)) per consultations at the hospital level. The negative effect of the new hospital's opening on ED waiting time remains sizable and statistically significant after controlling for these supply-

side variables. On the demand-side, concerns that the unrest might have differentially affected departments' population growth and patient composition are alleviated by the parallel trends in population change and per capita healthcare contribution across departments even after 2018 (Figure A12) and by the robustness of the DiD estimates when controlling for patient characteristics (Table 4, column (2)).

Furthermore, Nicaragua experienced a dengue outbreak in 2019. Figure A14 displays the number of dengue cases per 10,000 residents at the department level for available years (2014-2020). The incidence of dengue evolves quite similarly in all four departments, but León was slightly more affected in 2018 and 2019.

To address these events that differentially affected treatment and control departments, Table A5 presents estimation results after excluding one of the control departments at a time and shows that a single control hospital does not drive results. Excluding Granada reduces the effect size, but the effect remains negative and highly significant. Likewise, excluding León or Masaya from the control group does not alter the overall results. Table A6 further extends the regressions by controlling for department-specific characteristics. The negative DiD estimate remains robust and significant when controlling for population, annual nominal revenue growth, and dengue cases per population. Changes in the size of the coefficient are marginal.

We further assess the sensitivity of the results to alternative definitions of treatment status. We first compute a continuous treatment variable using the distance (kilometers) from each pre-existing facility to the new hospital. Table A7 column (2) confirms that distance to the new hospital positively and significantly affects waiting time: the closer a facility is to the new hospital, the more pronounced the reduction in ED waiting time. A second alternative treatment definition concerns the unit of assignment. Until now, treatment status is defined at the hospital level. Thus, the analyses focus on alleviation effects for pre-existing facilities caused by the

new hospital but exclude observations from the new hospital. Alternatively, if treatment status is defined at the department level, the new hospital joins the treatment group (the control group remains unchanged). Table A7 column (3) shows that including observations from the new hospital slightly reduces the effect size, which can be explained by the fact that the new hospital is not among the best-performing hospitals concerning ED waiting time.

The new hospital could have caused two types of spill-overs on control facilities. On the one hand, there could be positive spill-overs if patient flows to control facilities are partially absorbed by the new hospital. On the other hand, negative spill-overs could occur if healthcare personnel from control facilities is reallocated to the new hospital. Using additional data from an exit-survey that was conducted with in- and outpatients in the course of the same project evaluation, we find no evidence for the first type of spill-over (Figure A15). Only 4.5% of the in- and outpatients of the new hospital live in departments outside Managua. Compared to other public hospitals in Managua, this share is relatively low. Further, neither among treatment nor control hospitals can substantial changes in the share of patients living in another department be observed between 2017 and 2019.²⁰ This suggests that positive spill-over effects might rather be minor. With respect to supply-side, i.e., negative spill-overs, administrative data from MINSA do not indicate a shift from healthcare personnel from control departments to Managua. The number of healthcare personnel almost remained constant at department level both in control departments and Managua (Figure A13). The increased healthcare supply in Managua seems to be mainly generated by an increased facility-capacity, whereas the personnel capacity did not change. Administrative data at the facility level confirm that the number of doctors and nurses declined in all pre-existing public hospitals of Managua between 2017 and 2019.

Even when using inverse-hyperbolic-sine transformed waiting time as outcome variable, some observations still deviate from the overall distribution. Table A8 displays estimation results after dropping outlier observations based on facility-specific and facility-wave-specific z-scores

(± 3.0 and ± 2.5 , respectively) of waiting time. Estimated coefficients and standard errors remain qualitatively unchanged in all specifications.

Cost-benefit analysis

The available project documents indicate a total cost of 51,389,132 USD for the construction of the new hospital.²¹ As the present analysis concentrates on the new hospital's emergency department, the cost-benefit analysis focuses on costs and benefits associated with the emergency department.

Our most simplistic approach (Table 7, column 1) approximates the costs by assuming that the relative size of the ED building to the hospital as a whole equals the construction costs ratio. Using Google satellite data, we calculate the size of the ED and the share of the total costs to be 5%.²² As EDs tend to have a higher equipment density compared to in- and outpatient departments, we double the cost share of the ED to be 10% in column (2). In column (3), we account for the hospital's ongoing maintenance costs and apply the relative cost ratio proposed by Graham et al. (2015) of 1-1-5 (construction - facility management - operations and staff).

- TABLE 7 -

Concerning the benefits of the hospital construction, we start by only using the reduced opportunity costs of ED waiting time and assuming that working-age patients would invest the saved waiting time in income-generating activity (column 1). We can then calculate the forgone income based on the latest available records of ILOSTAT (2014) for the average monthly earnings of employees and average weekly working hours of employed persons in Nicaragua.²³

If we assume that all indicators remain constant or develop at a similar pace, column (1) shows that only the economic benefits of the reduced waiting time would outweigh the ED's construction costs after 18.51 years.²⁴ Applying the higher ED cost ratio doubles the

amortization period, including maintenance costs prolongs the period by 3.7 years, and considering both aspects jointly lifts the amortization time to 44.43 years.

Aside from the benefits directly related to the opportunity costs of waiting time, previous studies have shown the importance of reduced waiting time for health outcomes, for example, through a reduction in mortality and risk of readmission (e.g., Man et al. 2020). A meticulous cost-benefit analysis considering this for our context is not possible, given that calculation parameters are unknown. However, we can make an approximation by making credible assumptions and borrowing from estimates of the treatment delay-health outcome relationship from other contexts, so that we can impute them to some of the patients with medical conditions in the relevant categories visiting the newly constructed hospital.

We do this for three types of patients. Patients A with cerebrovascular accidents, B with heart-related emergency problems, and C with emergency injuries. Almekhlafi et al. (2021) suggest that a 10-minute delay in emergency rooms can lead to a loss of 1.8 months of healthy life for patients with ischemic stroke. Scholz et al. (2018) indicate that a 10-minute treatment delay on average might result in 3 deaths out of 100 patients with heart attacks. Alarhayem et al. (2019) suggest that patients with lower extremity arterial injuries have a 6% rate of amputation if undergoing treatment within 60 minutes, a rate that doubles if instead treatment occurs 1 to 3 hours after the accident takes place.

Using our observational data, we calculate that every year 12,690, 16,552, and 62,346 patients of the respective categories A, B, and C visit the study samples treatment hospitals. For patients A, we obtain foregone benefits of more than six million USD.²⁵ For the 3% of patients B that presumably died due to the delay, we calculate a net present value of foregone earnings for their remaining working life period of about 68 million USD.²⁶ Lastly, for patients C, we assume that the share of patients suffering lower extremity arterial injuries reduces from 12 to 6%

among patients who visited the ED because of injury and poisoning and waited more than 60 minutes. We further assume that amputation reduces earnings for the remaining working life by 20%, thereby obtaining saved foregone earnings of more than 20 million USD.²⁷ The additional reduction in foregone earnings caused by the health-related benefits of the reduced waiting time cut the redemption period to less than one year. Given the lack of scientific references for the relationship between treatment delay and health outcomes, we only cover 20% of the patients in our sample. Hence, the estimates represent only a lower-bound estimate of the benefits.

Discussion

This study empirically evaluates the impact of opening a new general public hospital in the capital of Nicaragua on ED waiting time in nearby pre-existing hospitals. Drawing on a DiD design, we compare the change in waiting time before and after the opening between patients seeking emergency care in hospitals located in the same department (treatment) and patients seeking care in distant hospitals located in surrounding departments (control).

Our analysis adds several insights to the scarce literature on determinants of waiting time in health facilities of low- and middle-income countries. The DiD analysis reveals that EDs of treatment hospitals experienced a significant reduction in waiting time by 47% or 10.1 minutes compared to control hospitals after the opening of the new hospital. Results are robust to extending the model with facility fixed effects, sampling weights, and controlling for patient characteristics. The induced reduction in waiting time was more pronounced in hospitals sharing the same specializations as the new hospital, i.e., maternal and paediatric services. The cost-benefit analysis shows that the benefits of reduced waiting time offset the construction costs of the ED within less than one year.

Overall, the results indicate that expanding the healthcare supply effectively reduces waiting time in pre-existing facilities, especially among facilities offering similar specializations.

¹ There is a broad literature on the reduction of waiting time with respect to waiting lists for elective surgeries (e.g., Siciliani, Borowitz, and Moran 2013; Moscelli et al. 2018), which are conceptually different from the time patients have to wait when they seek attention in a health facility.

² One exception is Croke et al. (2020), who apply a DiD design to examine the impact of Ethiopia’s health centre construction program on healthcare access, delivery, and outcomes.

³ For a more detailed overview of the referral scheme in the Nicaraguan healthcare system, see Monfared, Garcia, and Vollmer (2021).

⁴ As an example, childbirth in regime (2) is free of charge, whereas private hospitals may charge more than 1000 USD for the use of facilities and medical supplies during childbirth, an amount that does not include physician fees (HVP, 2024). We believe that such amounts are simply not affordable for the vast majority of patients visiting healthcare facilities of regime (2).

⁵ The difference in timing between baseline and endline surveys is one month and unlikely to bias the results. Climatic conditions are very similar in August, September, and October with monthly precipitation varying only by 23.52 mm and mean temperature by 0.3°C (World Bank 2023). Any potential short-term seasonal patterns are typically less pronounced and subject to random fluctuations which should not bias the results.

⁶ Randomness was established by choosing the 4th patient entering the waiting area at the beginning of each work shift and then always selecting every second patient who entered the ED. Study participants, or their accompanying person, had to be older than 15 years and were required to seek care in the ED of the respective facility.

⁷ Due to privacy, hygiene, and security reasons enumerators were only allowed to enter the main waiting room.

⁸ Visit reasons were recorded as free text entries. After translating the responses to English, the answers were standardized, and condensed. Through text analysis we identified the most frequent answers and grouped them into 24 categories trying to minimize the number of answers that cannot be linked. The remaining answers that could not be linked were allocated into the option “Other”. In a second step, we further combined the 24 categories into eight broader categories to allow a more systematic assessment of the visit reasons.

⁹ At the time of the baseline no precise numbers on facility-specific patient flows were available and we relied on the opinion of local experts to determine an adequate number of days per facility. When administrative data became available after the endline, we used these data to calculate sampling weights in order to ensure representativeness of the patient surveys.

¹⁰ Our setting follows the classical DiD set up with only two groups and two periods. Thus, problems emerging in more complicated designs, e.g., more than two groups and periods, variation in treatment timing, or non-binary treatments, discussed in the recent DiD literature (see for example Goodman-Bacon 2021 and de Chaisemartin and D’Haultfoeuille 2023) do not apply here.

¹¹ In this setting, a waiting time of zero means that a patient was admitted immediately.

¹² This limitation is shared by studies investigating treatments at geographically aggregated levels, such as Cawley et al. (2022).

¹³ To enable a better presentation of the data, outlier observations with waiting times larger than 1.5 times the inter-quartile-range will no longer be shown in the subsequent graphs.

¹⁴ In the present asinh-level estimation model, the effect sizes in percent changes are calculated as $(e^\beta - 1) * 100$. Effect size in percent are also displayed in the table as “ \approx % change”.

¹⁵ The analysis excludes patients who left the ED without being attended since the dataset covers too few observations of this subgroup (48 in baseline and 89 in endline). These patients might differ from the rest of the sample with respect to specific unobservable characteristics that influence waiting time such as the urgency of their visit.

¹⁶ The counterfactual outcome is calculated based on the sum of the treatment mean at baseline and the control group trend. At baseline, the average waiting time was 32 minutes in treated ED and waiting time increased by 67% in the control group. This gives a counterfactual outcome of 21.52 minutes.

¹⁷ Pines et al. (2007) claim that each additional 10 minutes of waiting time increases the odds ratio of patient and nurse reported compromised care by 1.05. Further, Man et al. (2020) associates a 15-minute increase in waiting time with a hazard ratio of 1.13 for all-cause mortality at 1 year and 1.08 for all-cause readmission at 1 year, among patients who received intravenous tissue plasminogen activator for acute ischemic stroke after 45 minutes of hospital arrival. Almekhlafi et al. (2021) suggests that a 10-minute delay in emergency rooms can lead to a loss of 1.8 months of healthy life for patients with ischemic stroke.

¹⁸ Kahn-Lang and Lang (2020) argue that DiD approaches are generally more plausible if treatment and control groups are not only similar in pre-trends but also in levels prior to treatment. Our setting fulfils both criteria. Additional tests for parallel pre-trends, as summarized for example in Roth et al. (2023), are not applicable to the present setting. For the years prior to the hospital construction only administrative department data are available and observations of four departments would not allow enough variation.

¹⁹ Health insurance contributions are approximated using the percentage contribution rates insured have to pay out of their salary as listed on the official website of INSS (2019), the annual salaries of all insured reported by INIDE (2019), and the number of active insured per year reported by INIDE (2019).

²⁰ Our treatment definition at the department level identifies all pre-existing public hospitals located in Managua with provided services substantially overlapping with the new hospital as treatment hospitals. Thus, patients shifting between treatment hospitals does not put at risk our identification. Further, the demand for ED services can be expected to be rather inelastic and an increased healthcare supply should not have caused a rise in the demand for ED services. Even if the patient composition changed differentially over time between treatment and control departments, the results of Table 5 column (4) showed that patient characteristics are not driving our results of a significantly reduced ED waiting time.

²¹ These documents were shared with the evaluation team but are not publicly available. According to later press releases the final hospital costs might have risen up to 90,000,000 USD (see REINAR, S.A. 2018).

²² The calculations also take into account that the ED building is single-storey while the rest of the hospital is two-storey. The available data would further allow to calculate the cost share based on the share of beds or number of patients in the ED department, but these would rather be useful to estimate the share of maintenance costs, and less useful for the construction costs.

²³ The number of ED patients per year is calculated using the average number of ED patients in all treated hospitals and the new hospital from August and September 2019 and assuming that the number of patients is the same for all other months.

²⁴ Discount rates, inflation, wage trends, etc. are not taken into account.

²⁵ Foregone benefits are calculated as product of the number of annual stroke patients in treatment hospitals, the monthly earnings, and the 1.8 months of healthy life lost.

²⁶ The net present value is calculated as product of the number of annual patients in treatment hospitals with heart-related emergency problems excluding stroke patients, the three percent share of patients that die, the average remaining working life period, and annual earnings. We use the average age of 39.6 years of patients with heart-related emergencies and 60 years as working life expectancy to calculate the average remaining working life period.

²⁷ The reduction in loss of earnings is calculated as product of the number of annual patients in treatment hospitals with injury and poisoning who waited more than 60 minutes, the 6-percentage point reduction in the share of amputations, the average remaining working life period, and the reduction of annual earnings by 20%.

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Tables

Table 1: Sample by treatment status and data collection.

	Waiting time in EDs			N° of hospitals
	Baseline (2017)	Endline (2019)	Total	
Control	1,178	1,275	2,453	3
Treatment	1,162	1,463	2,625	5
Total (excl. new)	2,340	2,738	5,078	8

Notes: The table considers only observations with complete information on waiting time and sociodemographic characteristics.

Table 2: Summary statistics

	Mean	Median	SD	Min	Max
Waiting time (mins)	37.19	22	46.30	0	437
<i>Reason for leaving waiting room:</i>					
Attended by a doctor, %	76.51			0	1
Transferred to another waiting room, %	21.74			0	1
Left without being attended, %	1.75			0	1
Female, %	0.66			0	1
Age	32.75	29	20.55	0	105
Infant (< 1 year), %	1.99			0	1
Child (1 – 14 years), %	15.16			0	1
Adult (> 15 years), %	82.85			0	1
Years of schooling	8.07	9	4.40	0	19
<i>N</i>	5,078				

Notes: The table considers only baseline and endline observations with complete information on waiting time and sociodemographic characteristics.

Table 3: Waiting time correlates

	All emergency patients: $\text{asinh}(\text{waiting})$			
	(1)	(2)	(3)	(4)
2019	0.014 (0.037)	0.019 (0.031)	0.021 (0.032)	0.027 (0.032)
Female	0.100 (0.040)**	-0.152 (0.035)***	-0.156 (0.035)***	-0.125 (0.033)***
Age	0.020 (0.001)***	0.008 (0.001)***	0.008 (0.001)***	0.009 (0.001)***
Years of schooling	0.012 (0.005)***	0.003 (0.004)	0.003 (0.004)	0.004 (0.004)
Facility FE	No	Yes	Yes	Yes (incl. new)
Day of week FE	No	No	Yes	Yes
Arrival hour FE	No	No	Yes	Yes
<i>N</i>	5,078	5,078	5,078	5,455
R^2	0.087	0.377	0.389	0.377
Adjusted R^2	0.086	0.375	0.386	0.374

Notes: The table reports OLS coefficients. Column (4) includes endline (2019) observations for the new hospital. The dependent variable is $\text{asinh}(\text{waiting})$. Robust standard errors are displayed in parentheses (***) $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 4: Means comparison of waiting time

	Baseline (2017)			Endline (2019)			DiD-estimator
	Treatment	Control	Difference	Treatment	Control	Difference	
Panel A: All observations							
asinh(waiting)	3.46	3.67	-0.205 (0.048)*** [0.172]	3.10	4.07	-0.965 (0.056)*** [0.250]***	-0.760 (0.074)*** [0.330]**
≈ % change							-0.532
N	1,134	1,158	2,292	1,455	1,242	2,697	4,989
Panel B: Patients attended by a doctor							
asinh(waiting)	3.61	3.82	-0.208 (0.050)*** [0.145]	3.66	4.39	-0.728 (0.052)*** [0.185]***	-0.520 (0.073)*** [0.234]**
≈ % change							-0.406
N	710	1,063	1,773	1,135	977	2,112	3,885
Panel C: Patients transferred to another waiting room							
asinh(waiting)	3.21	1.98	1.236 (0.085)*** [0.199]***	1.11	2.86	-1.758 (0.093)*** [0.268]***	-2.994 (0.126)*** [0.332]***
≈ % change							-0.950
N	424	95	519	320	265	585	1,104

Notes: The table reports the results from a simple means comparison, i.e., Model I. Panel A shows the results for all emergency patients. Panel B reduces the analysis to patients attended by a doctor, and Panel C to patients transferred to another waiting room. The dependent variable is $\text{arsinh}(\text{waiting})$. The coefficients indicating the differences and the difference-in-difference were calculated with robust standard errors, which are displayed in parentheses, and clustered standard errors displayed in squared brackets (***) $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 5: Change in waiting time.

	All emergency patients: asinh(waiting)				
	(1)	(2)	(3)	(4)	(5)
Treatment*after	-0.760 (0.074)*** [0.330]**	-0.640 (0.062)*** [0.187]***	-0.649 (0.079)*** [0.284]**	-0.637 (0.075)*** [0.253]**	-0.605 (0.075)*** [0.254]**
Female				-0.122 (0.042)*** [0.043]***	-0.106 (0.041)** [0.041]**
Age				0.013 (0.001)*** [0.003]***	0.011 (0.001)*** [0.003]***
Years of schooling				0.014 (0.004)*** [0.005]***	0.014 (0.004)*** [0.005]***
≈ % change	-0.532	-0.473	-0.477	-0.471	-0.454
N	4,990	4,990	4,990	4,990	4,990
R ²	0.067	0.381	0.343	0.371	0.383
Facility and Month FE	No	Yes	Yes	Yes	Yes
Sampling weights	No	No	Yes	Yes	Yes
Patient characteristics	No	No	No	Yes	Yes
Visit reasons	No	No	No	No	Yes

Notes: The table reports the results from simple means comparisons in column (1), column (2) adds facility fixed effects, column (3) displays results from Model I, column (4) shows results from Model II, and column (5) adds visit reasons to Model II. The dependent variable is $\text{arsinh}(\text{waiting})$. Robust standard errors are displayed in parentheses and clustered standard errors in squared brackets (***) $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 6: Heterogeneity in the change in waiting time.

	All emergency patients: asinh(waiting)		
	(1)	(2)	(3)
treatment * after	-0.525 (0.096)*** [0.369]	-0.567 (0.141)*** [0.340]	-0.070 (0.071) [0.182]
treatment * after * specialized	-0.392 (0.101)*** [0.358]		
treatment * after * female		-0.121 (0.172) [0.193]	
treatment * after * infant			-1.412 (0.417)*** [0.443]***
treatment * after * child			-1.750 (0.207)*** [0.337]***
≈ % change	-0.409	-0.433	-0.068
<i>N</i>	4,989	4,989	4,989
<i>R</i> ²	0.421	0.346	0.458
Facility and Month FE	Yes	Yes	Yes
Sampling weights	Yes	Yes	Yes

Notes: The table shows the estimation results when applying Model I and expanding it by an interaction term indicating whether observations belong to a treatment facility, the post-opening period, and (1) a specialized hospital or (2) whether the patient is female or (3) whether the patient belongs to the indicated age group. The coefficients for the interaction term treatment*after report the effect of the new hospital on the omitted categories, i.e., (1) unspecialized hospital or (2) male patient, or (3) adult patient. The coefficients of the triple interaction term indicate the additional effect of seeking care in (1) a specialized hospital, (2) being female, or (3) belonging to the indicated age group. The dependent variable is *asinh(waiting)*. Robust standard errors are displayed in parentheses and clustered standard errors in squared brackets (***) $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

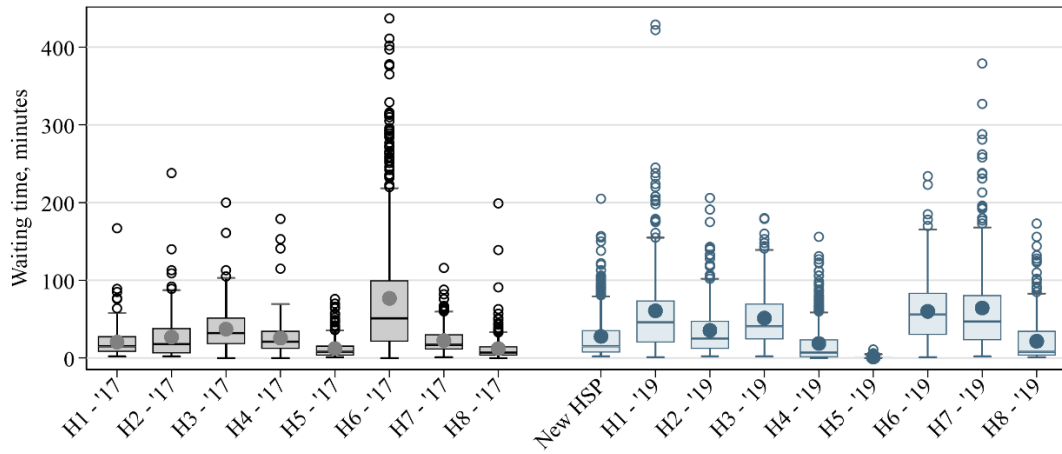
Table 7: Estimated construction costs of the new ED.

	Baseline	Higher ED cost share	Operation costs	Combination (2) + (3)	Health-related benefits	
	(1)	(2)	(3)	(4)	(5)	
Costs	Hospital construction costs, USD	51,389,132.00				
	Area of new hospital, m ²	31,501.47				
	Area of ED, m ²	1,617.05				
	Cost share of ED	0.05	0.10		0.10	
	<i>ED construction costs, USD</i>	2,637,933.91	5,275,867.82		5,275,867.82	5,275,867.82
	<i>ED facility management, USD</i>			87,931.13	175,862.26	175,862.26
	<i>ED operation and staff, USD</i>			439,655.65	879,311.30	879,311.30
Benefits	Reduced waiting time per patient, min	10.10				
	Average monthly earnings, USD	377.00				
	Average weekly working hours	42.20				
	Average hourly earnings of employees, USD	2.13				
	Potential earnings for 1 patient, USD	0.36				
	Annual ED patients, treated + new	551,736.00				
	Share of patients aged ≥ 15 years	0.72				
	<i>Foregone earnings of waiting time, USD</i>	142,497.77	142,497.77	142,497.77	142,497.77	142,497.77
<i>Foregone future earnings of patients with</i>						
... cerebrovascular accidents (2.3%), USD					8,611,288.63	
... heart-related emergencies (3.0%), USD					45,827,031.69	
... emergency injuries (11.3%), USD					20,506,138.60	
Benefit-cost ratio	18.51	37.02	22.21	44.43	0.08	

Notes: The table reports the cost-benefit analysis for the new ED. The new hospital's and ED's surface area was measured based on satellite data from google maps. The calculations on the reduced opportunity costs are based on data on earnings and working hours from ILOSTAT (2014). The share of patients in working age is based on the share of patients aged 15 years and older reported in the ANUARIO of 2019 (INIDE 2019). The approximation of operation costs in column (3) is based on the rule of thumb of a ratio of 1:1:5 of Graham et al. (2015) and a assumed life span of 30 years for the new hospital. The share of patients suffering from specific diseases is based on the share observed in our dataset and evidence from earlier studies on the relationship between treatment delay and health outcomes.

Figures

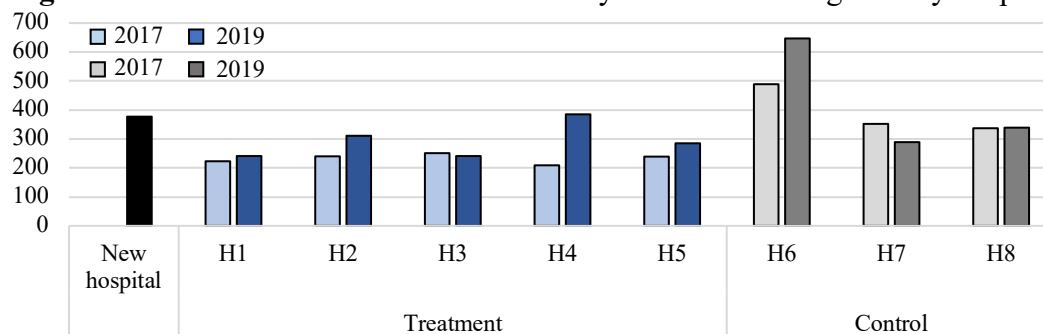
Figure 1: Waiting time by facility.



Notes: The graphic displays the variation in waiting time across and within facilities. The boxplots indicate each hospital's median, 25th and 75th percentile, and lower and upper whisker. Points plotted outside represent waiting times larger than 1.5 times the inter-quartile range. The additional dot within each boxplot indicates the mean waiting time. Baseline observations are displayed in black and endline observations in blue.

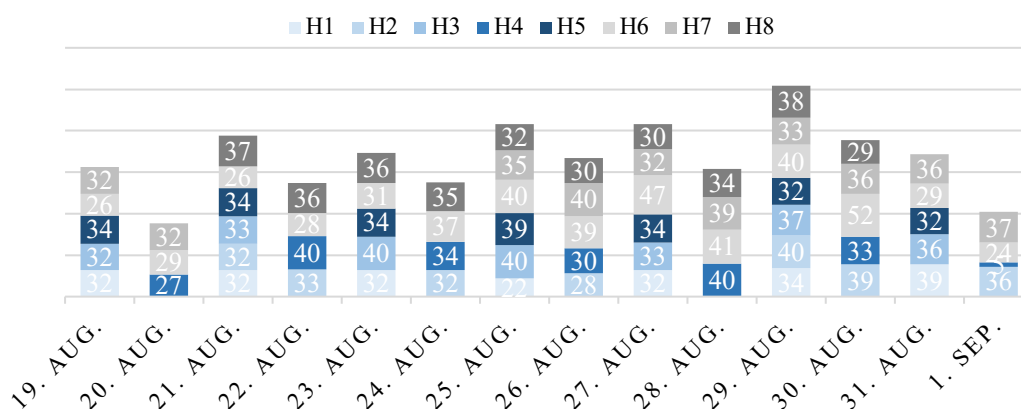
Appendix

Figure A1: Number of observations of directly observed waiting time by hospital.



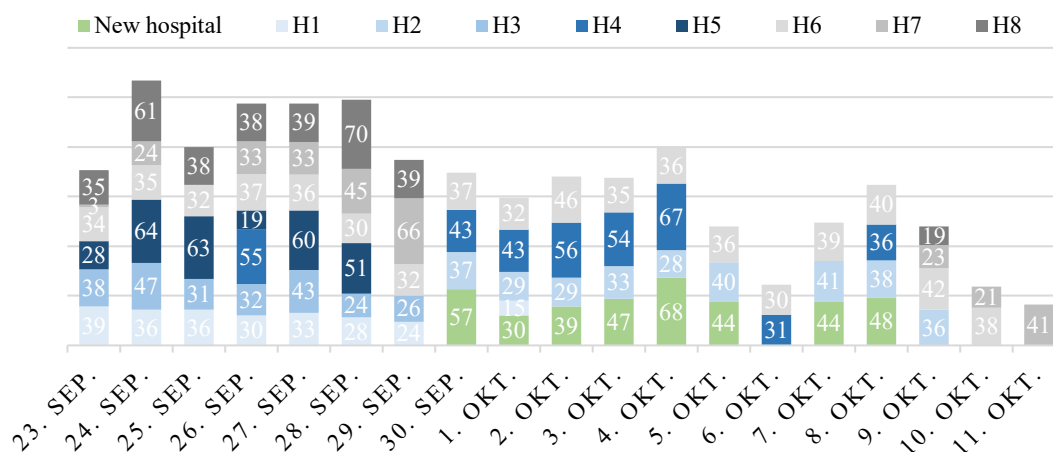
Notes: The graphic shows the number of observations collected during base- and endline for each hospital. Only observations with complete information on objective waiting time and sociodemographic patient characteristics are counted (gender, age, and educational attainment).

Figure A2: Number of observations by hospital and enumeration day, baseline 2017.



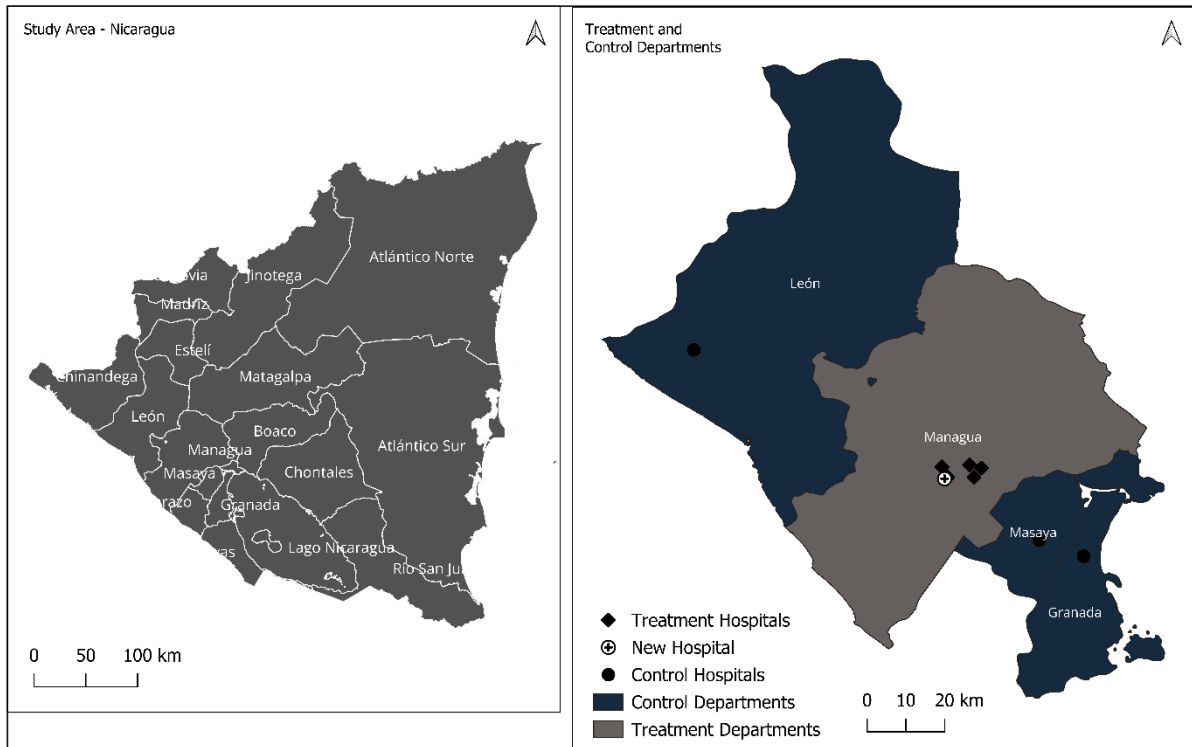
Notes: The graphic shows the number of observations collected during baseline by hospital and day of data collection. Only observations with complete information on objective waiting time and sociodemographic patient characteristics (gender, age, and educational attainment) are counted.

Figure A3: Number of observations by hospital and enumeration day, endline 2019.



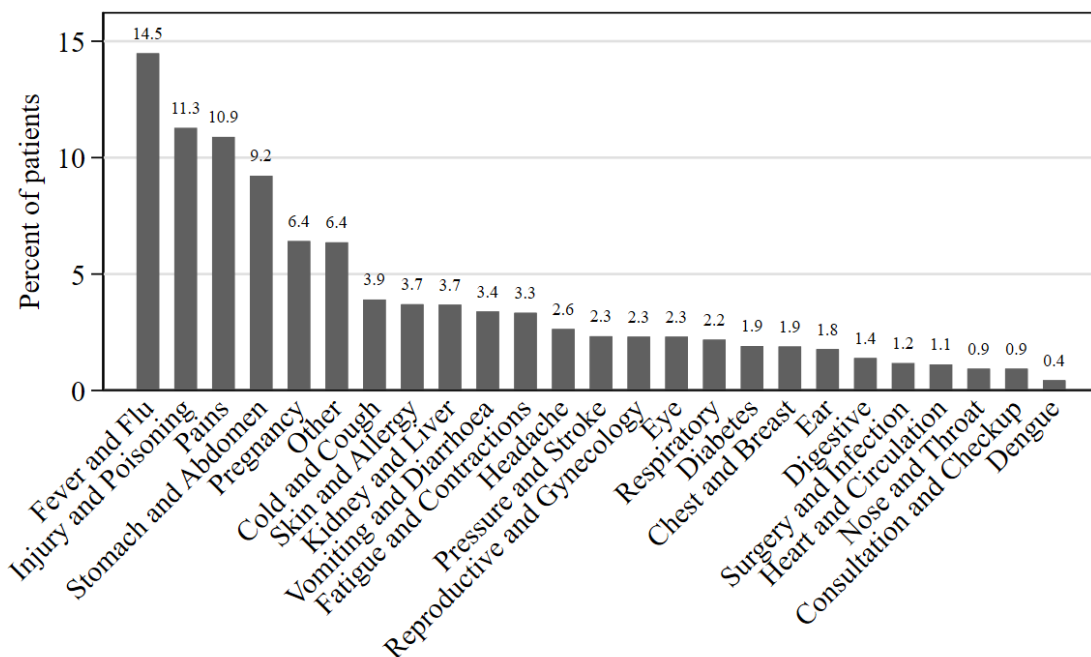
Notes: The graphic shows the number of observations collected during endline by hospital and day of data collection. Only observations with complete information on objective waiting time and sociodemographic patient characteristics (gender, age, and educational attainment) are counted.

Figure A4: Study setting.



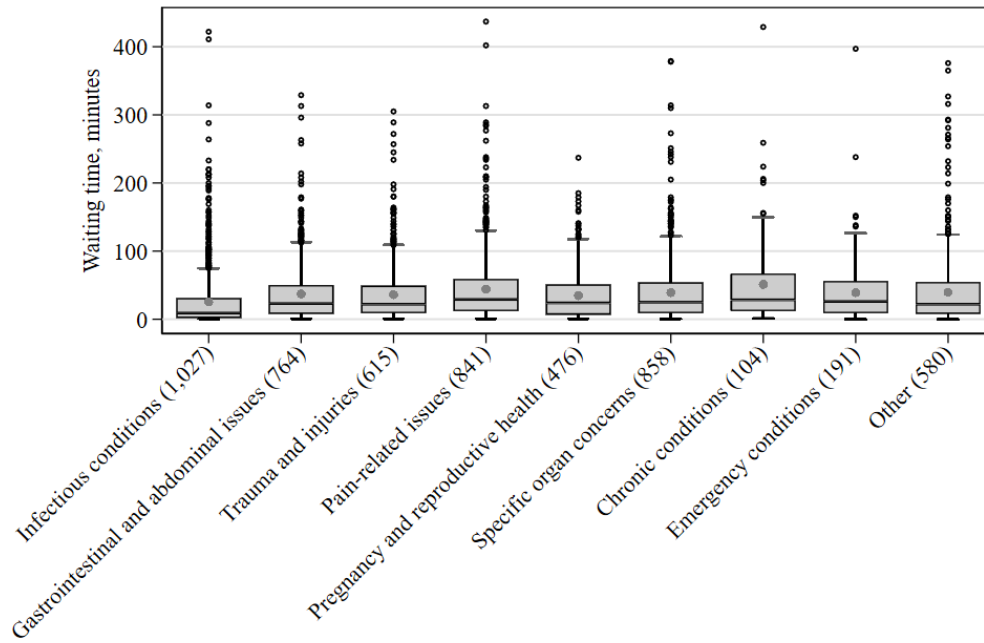
Notes: The map shows the location of the treatment and control departments within the study country Nicaragua as well as the location of the hospitals.

Figure A5: Categorization of visit reasons.



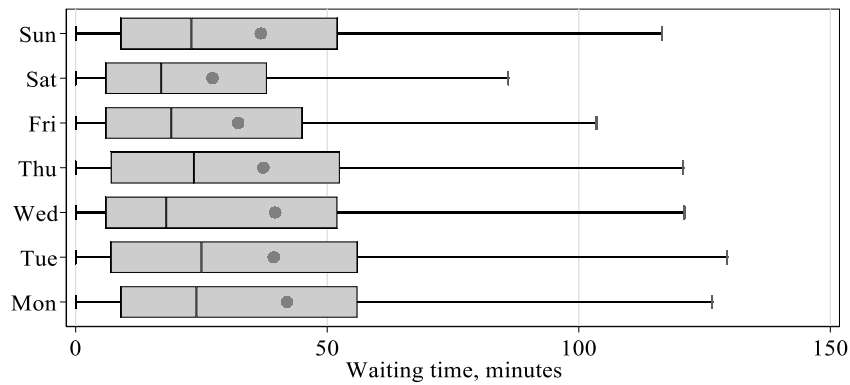
Notes: The graphic displays the reasons why patients visit the EDs. Visit reasons were recorded as free text entries in Spanish. For the categorization, answers were first translated into English, standardized, and condensed. Then, an algorithm identified the most frequent answers and grouped them into as many categories as necessary to minimize the number of answers that cannot be linked to one of the categories. This results in 24 categories and one option “Other”.

Figure A6: Waiting time by visit reason.



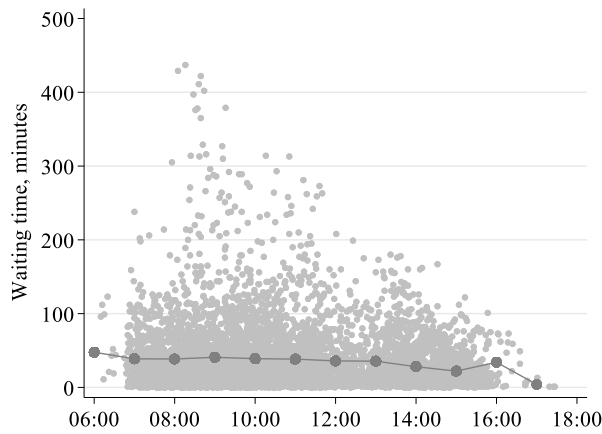
Notes: The graphic displays the variation in waiting time across the broad categorization of visit reasons. The boxplots indicate each category’s median, 25th and 75th percentile, and lower and upper whisker. Points plotted outside represent waiting times larger than 1.5 times the interquartile range. The additional dot within each boxplot indicates the mean waiting time.

Figure A7: Waiting time by day of the week.



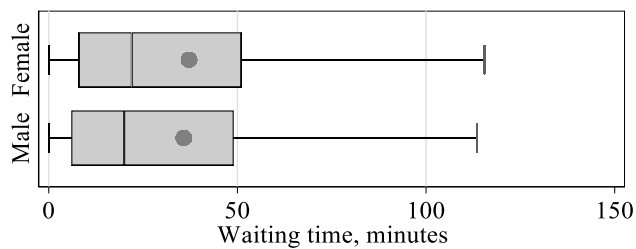
Notes: The graphic displays the variation in waiting time over the weekdays for the base- and endline observations. The boxplots indicate the median, 25th and 75th percentile, and lower and upper whisker for each day of the week. The additional point within each boxplot indicates the mean waiting time. Observations with waiting times larger than 1.5 times the interquartile range are not shown.

Figure A8: Waiting time by time of arrival.



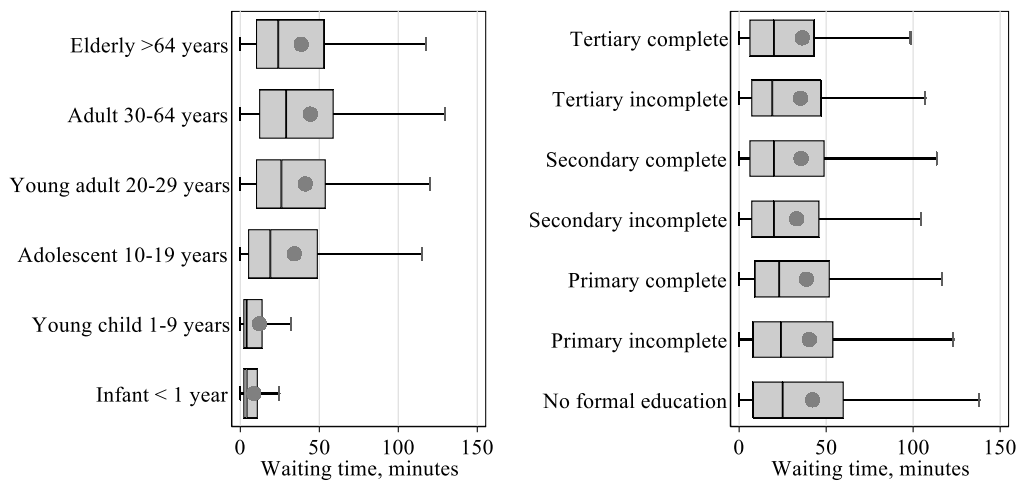
Notes: The scatterplot shows observations for waiting time by the patient’s time of arrival (light grey) from base- and endline. The point-line represents the average waiting time for each hourly time bin of arrival (dark grey). Average waiting time was calculated over hourly time-bins, i.e., the average waiting time of all patients that arrived within one hour. For example, the time bin of 09 am was calculated for all patients who arrived between 09:00 and 09:59.

Figure A9: Waiting time by patient characteristics (I).



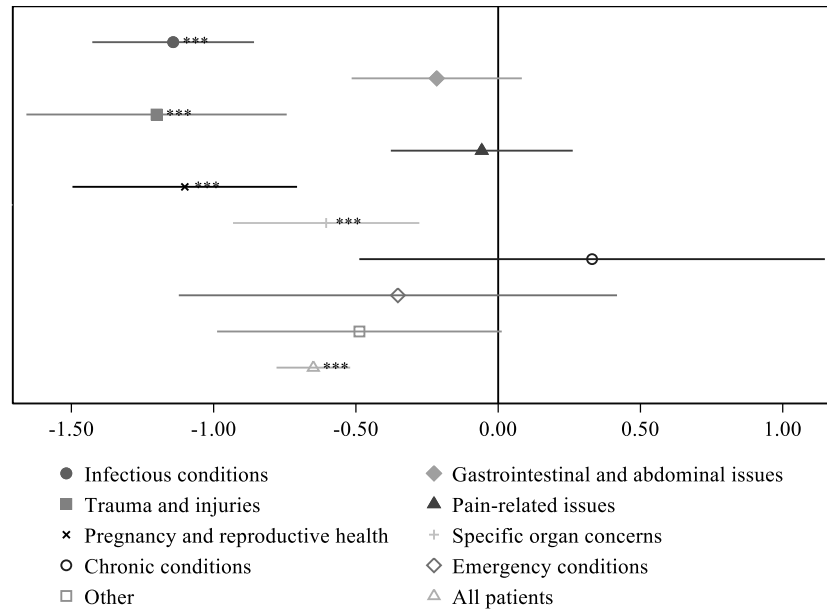
Notes: The graphic displays the variation in waiting time by patients’ gender. Observations from base- and endline and control and treatment groups are combined. The boxplots indicate the median, 25th and 75th percentile, and lower and upper whisker for males and females. The additional point within each boxplot represents the mean perceived waiting time. Observations with waiting times larger than 1.5 times the inter-quartile range are not shown.

Figure A10: Waiting time by patient characteristics (II).



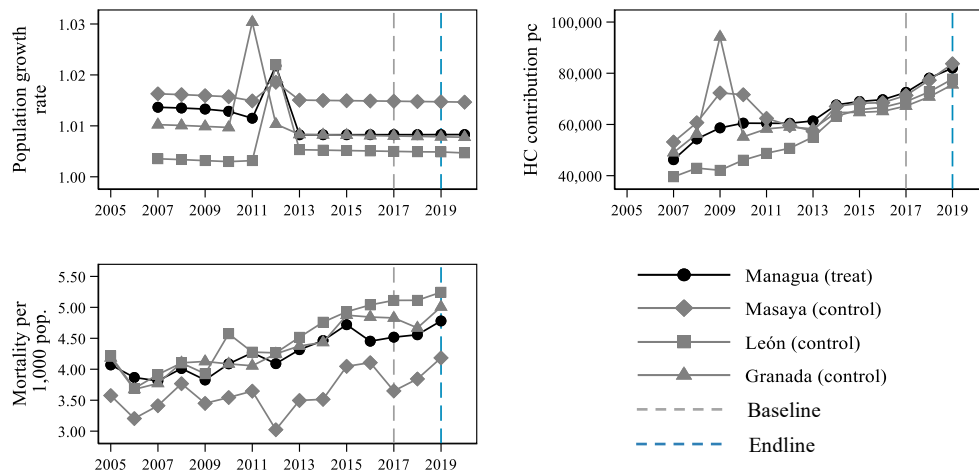
Notes: The graphic displays the variation in waiting time by patients’ age (left) and educational attainment (right). Observations from base- and endline and control and treatment groups are combined. The boxplots indicate the median, 25th and 75th percentile, and lower and upper whisker for males and females. The additional point within each boxplot represents the mean perceived waiting time. Observations with waiting times larger than 1.5 times the interquartile range are not shown.

Figure A11:



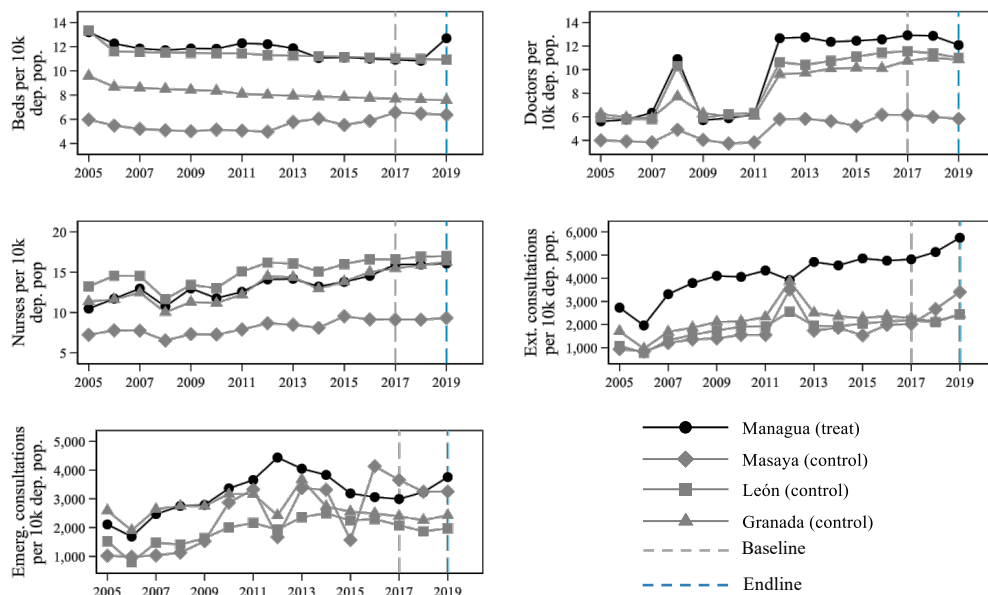
Notes: The graphic displays the nine visit-reason-specific regressions run on subsamples based on the assigned visit category (rows 1 – 9) and all ED patients (last row). The dot represents the coefficient of interest, and the whisker represents the 90% confidence interval of each regression (***) $p < 0.01$, ** $p < 0.05$, * $p < 0.10$).

Figure A12: Trends of sociodemographic indicators.



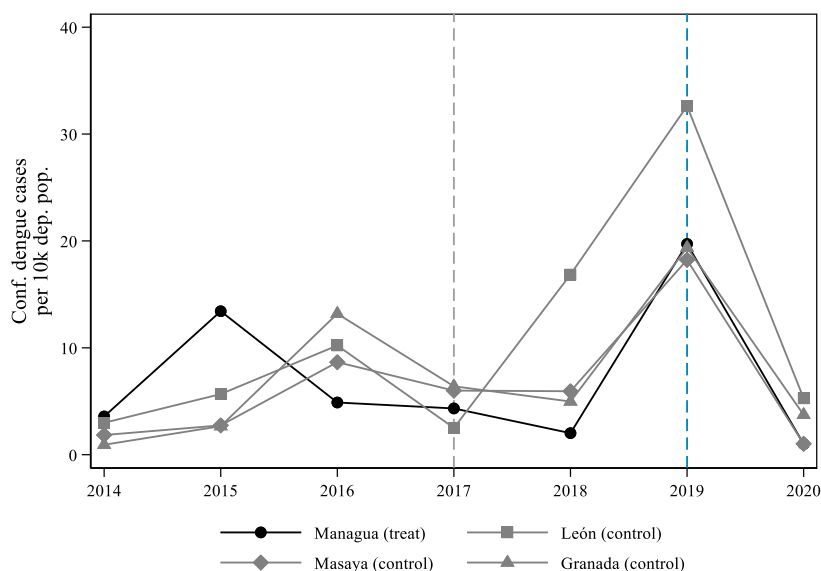
Note: The graphic shows the time trend of several sociodemographic indicators at the department level. Per capita healthcare contribution is calculated as total healthcare contribution divided by the number of insured persons. Own elaboration based on data from INIDE (2019).

Figure A13: Trends of healthcare indicators.



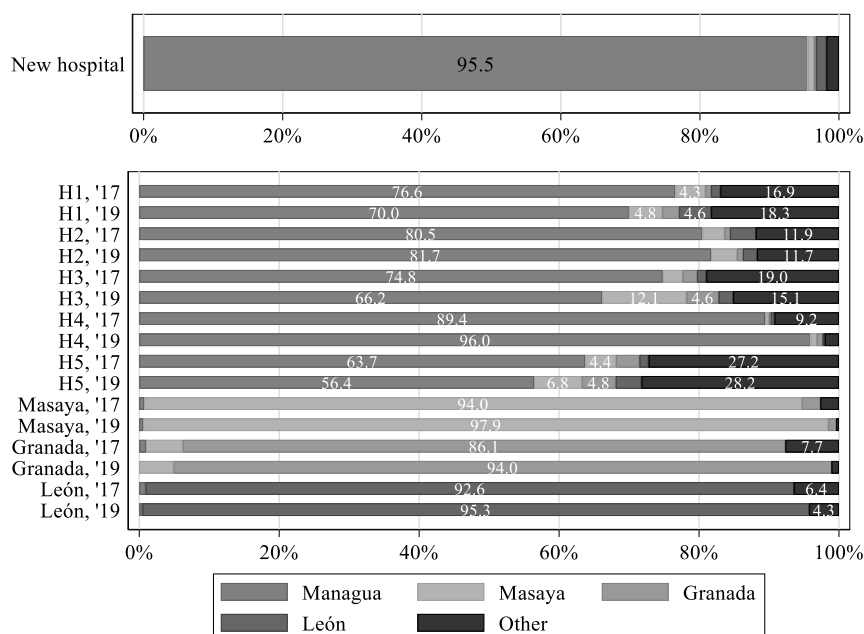
Note: The graphic shows the time trend of several healthcare indicators at the department level. Own elaboration based on data from INIDE (2019) and MINSa (2019).

Figure A14: Confirmed dengue cases over time across departments.



Note: The graphic shows the time trend of confirmed dengue cases at the department level. Own elaboration based on data from PAHO (2022).

Figure A15: Residence of in- and outpatients.



Notes: The graphic shows the patients' residence indicated by participants of an exit-survey conducted with in- and outpatients of the same hospitals during the same impact evaluation. The first bar shows the residence of patients in the new hospital in 2019 and the bars below show the residence of patients in the treatment and control hospitals separated by base- and endline.

Table A1: Variables and data sources.

	Variable	Description	Source
<i>Outcome</i>			
	ED waiting time	Time (minutes) between patients arrive and leave the main ED waiting room in the study hospitals. Recorded by enumerators during daytime for a random selection of patients.	Patient survey in EDs, 2017 and 2019, data not publicly available
<i>Explanatory variables</i>			
	Sex	Sex of patients who wait for ED treatment in the study hospitals. Recorded by enumerators during daytime for a random selection of patients.	Patient survey in EDs, 2017 and 2019, data not publicly available
	Age	Age in years of patients who wait for ED treatment in the study hospitals. Recorded by enumerators during daytime for a random selection of patients.	Patient survey in EDs, 2017 and 2019, data not publicly available
	Education	Highest educational level of patients (or their accompanying persons in case of patients aged below 15 years) who wait for ED treatment in the study hospitals. Recorded by enumerators during daytime for a random selection of patients.	Patient survey in EDs, 2017 and 2019, data not publicly available
<i>Complementary data (by observational level)</i>			
<i>Patient</i>	Reason for leaving	Reason why patients leave the main waiting room of the ED. Recorded by enumerators during daytime for a random selection of patients.	Patient survey in EDs, 2017 and 2019, data not publicly available
	Residence	Department of residence of randomly selected in- and outpatients. Recorded by enumerators during daytime for a random selection of patients in the same study hospitals and during the same enumeration period.	Exit-survey, 2017 and 2019, data not publicly available
<i>Facility</i>	Female share	Gender composition of all patients in study hospitals for the months August and September in 2017 and 2019.	MINSa (not publicly available)
	Age distribution	Categorization into infant, child and adult of all patients in study hospitals for the months August and September in 2017 and 2019.	MINSa (not publicly available)

	Beds	Total number of beds in study hospitals for the months August and September in 2017 and 2019.	MINSa (not publicly available)
	Doctors	Total number of doctors in study hospitals for the months August and September in 2017 and 2019.	MINSa (not publicly available)
	Nurses	Total number of nurses in study hospitals for the months August and September in 2017 and 2019.	MINSa (not publicly available)
	Consultations	Total number of consultations divided by external and emergency in study hospitals for the months August and September in 2017 and 2019.	MINSa (not publicly available)
	Km to new hospital	Distance of study hospitals to new hospital in kilometers.	Google Maps
<i>Department</i>	Population	Total population by sex and age group per department and year.	INIDE (Statistical Yearbook)
	Mortality	Total number of deaths per department and year.	INIDE (Statistical Yearbook)
	Health insurance contribution	Annual health insurance contribution per department population. For the calculations, we use the official rate insured have to contribute from their salary within the different insurance regimes, the annual salaries of all insured persons by insurance regime per department, and the number of active insured persons in the different insurance regimes per department and year.	INIDE (Statistical Yearbook)
	Beds in hospitals	Total number of beds in all public hospitals per department and year.	INIDE (Statistical Yearbook)
	Doctors	Total number of doctors per department and year.	INIDE (Statistical Yearbook)
	Nurses	Total number of nurses per department year.	INIDE (Statistical Yearbook)
	Consultations	Annual external and emergency consultations in public hospitals. Data is disaggregated by department as well as patients' sex and age group.	INIDE (Statistical Yearbook)
	Dengue cases	Total number of confirmed dengue cases per department and year.	PAHO (2022)

Note: The table lists the names, description and data source of all variables used for the analysis and argumentation of the paper.

Table A2: ED patient composition of study sample and administrative data.

	Baseline (2017)			Endline (2019)		
	Control Mean (1)	Treatment Mean (2)	Std. Diff (1)-(2) (3)	Control Mean (4)	Treatment Mean (5)	Std. Diff (1)-(2) (6)
<i>Panel A: Study sample</i>						
Female, %	73.60	67.90	0.125	60.24	65.07	-0.100
Age	35.49	30.05	0.265	34.46	31.20	0.161
Infants (< 1), %	2.12	1.89	0.016	0.94	2.87	-0.141
Children (1-15), %	9.25	19.54	-0.296	10.20	20.78	-0.296
Adults (>15), %	88.62	78.57	0.274	88.86	76.35	0.335
Years of schooling	8.11	8.35	-0.054	6.94	8.80	-0.434
No formal education, %	10.36	5.25	0.191	15.76	6.97	0.280
Primary incomplete, %	17.74	16.78	0.025	15.92	9.43	0.196
Primary complete, %	14.60	12.31	0.067	18.59	12.30	0.175
Secondary incomplete, %	19.10	27.37	-0.197	18.35	28.02	-0.231
Secondary complete, %	16.04	23.41	-0.186	23.14	27.55	-0.101
Tertiary incomplete, %	12.99	10.15	0.089	4.24	8.54	-0.177
Tertiary complete and more, %	9.17	4.73	0.175	4.00	7.18	-0.139
<i>Panel B: Administrative data</i>						
Female, %	60.89	66.72	-0.450	58.97	63.07	-0.339
Infants (< 1), %	3.49	5.05	-0.293	4.42	3.53	0.280
Children (1-15), %	20.61	21.36	-0.035	29.34	24.88	0.192
Adults (>15), %	75.90	73.59	0.085	66.24	71.59	-0.203

Notes: The table shows summary statistics for patient characteristics collected during base- and endline in Eds of hospitals in Panel A and for total patient composition of observed public hospitals according to administrative data from MINSa in Panel B. Columns (3) and (6) display the standardized differences. Due to incomplete data of MINSa the share of female patients refers to outpatients in the case of treatment hospitals. All values from MINSa are calculated as monthly average over the months August, September, and October from 2017 and 2019 respectively.

Table A3: Change in reason for leaving the ED waiting room.

	Share of patients ...		
	... attended by a doctor	... transferred to other room	... who left without attendance
	(1)	(2)	(3)
treatment * after	0.348 (0.027)*** [0.052]***	-0.315 (0.026)*** [0.050]***	-0.033 (0.011)*** [0.011]***
<i>N</i>	5,078	5,078	5,078
<i>R</i> ²	0.200	0.216	0.023
Facility and Month FE	Yes	Yes	Yes
Sampling weights	Yes	Yes	Yes

Notes: The table shows the estimation results when applying Model I but using the reason for leaving the ED's waiting room as dependent variable. Each cell reports the coefficient of the interaction term *treatment*after*. Robust standard errors are displayed in parentheses and clustered standard errors in squared brackets (*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$).

Table A4: Change in waiting time when controlling for covariates at facility level.

	All emergency patients: asinh(waiting)					
	(1)	(2)	(3)	(4)	(5)	(6)
treatment * after	-0.650 (0.079)*** [0.289]**	-0.670 (0.077)*** [0.253]**	-0.546 (0.078)*** [0.248]*	-0.630 (0.077)*** [0.246]**	-0.634 (0.079)*** [0.270]**	-0.835 (0.079)*** [0.263]***
Beds per 1,000 consultations			-0.365 (0.035)*** [0.121]***			-1.438 (0.060)*** [0.127]***
Doctors per 1,000 consultations				-0.024 (0.041) [0.114]		0.677 (0.059)*** [0.131]***
Nurses per 1,000 consultations					-0.197 (0.037)*** [0.122]	0.641 (0.069)*** [0.160]***
≈ % change	-0.477	-0.488	-0.421	-0.467	-0.469	-0.566
<i>N</i>	4,990	4,990	4,990	4,990	4,990	4,990
<i>R</i> ²	0.343	0.363	0.366	0.343	0.350	0.407
Facility and Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Sampling weights	Yes	Yes	Yes	Yes	Yes	Yes
DOW and arrival FE	No	Yes	No	No	No	No

Notes: The table shows the estimation results when applying Model II and adding additional covariates at the facility level. Each cell reports the coefficient of the interaction term *treatment*after* and of the additional covariates. Robust standard errors are displayed in parentheses and clustered standard errors displayed in squared brackets (*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$).

Table A5: Change in waiting time based on alternative control group compositions.

	All emergency patients: $asinh(waiting)$			
	(1)	(2)	(3)	(4)
treatment * after	-0.650 (0.079)*** [0.284]**	-0.496 (0.086)*** [0.287]	-0.803 (0.101)*** [0.351]**	-0.771 (0.081)*** [0.273]**
≈ % change	-0.477	-0.390	-0.552	-0.537
<i>N</i>	4,990	4,350	3,900	4,320
<i>R</i> ²	0.343	0.349	0.302	0.344
Facility and Month FE	Yes	Yes	Yes	Yes
Sampling weights	Yes	Yes	Yes	Yes
Excl. control hospital	None	Granada	Masaya	León

Notes: The table reports the results when applying Model I. Column (2) excludes observations from the control hospital Granada, column (3) those from the control hospital Masaya, and column (4) those from the control hospital León. The dependent variable is $asinh(waiting)$. Robust standard errors are displayed in parentheses and clustered standard errors displayed in squared brackets (***p* < 0.01, ***p* < 0.05, **p* < 0.10).

Table A6: Change in waiting time when controlling for covariates at department level.

	All emergency patients: $asinh(waiting)$				
	(1)	(2)	(3)	(4)	(5)
treatment * after	-0.650 (0.079)*** [0.284]**	-0.663 (0.087)*** [0.306]**	-0.950 (0.131)*** [0.414]**	-0.700 (0.079)*** [0.284]**	-1.861 (0.161)*** [0.366]***
Ln(population in 10,000)		-3.349 (6.976) [16.296]			81.878 (15.217)*** [26.752]*
Annual nom. revenue growth			-0.015 (0.005)** [0.013]		-0.079 (0.011)*** [0.019]***
Dengue cases per 10,000 dep. pop.				-0.024 (0.005)*** [0.008]***	-0.000 (0.000) [0.000]
≈ % change	-0.477	-0.484	-0.613	-0.472	-0.844
<i>N</i>	4,990	4,990	4,990	4,990	4,990
<i>R</i> ²	0.343	0.343	0.345	0.348	0.349
Facility and Month FE	Yes	Yes	Yes	Yes	Yes
Sampling weights	Yes	Yes	Yes	Yes	Yes

Notes: The table shows the estimation results when applying Model II and adding additional covariates at the department level. Each cell reports the coefficient of the interaction term *treatment*after* and of the additional covariates. Robust standard errors are displayed in parentheses and clustered standard errors displayed in squared brackets (***p* < 0.01, ***p* < 0.05, **p* < 0.10).

Table A7: Change in waiting time with alternative treatment definitions.

	All emergency patients: $\text{asinh}(\text{waiting})$		
	(1)	(2)	(3)
treatment * after	-0.650 (0.079)*** [0.289]**		
distance (km) * after		0.007 (0.002)*** [0.005]	
treatment (individual) * after			-0.517 (0.080)*** [0.317]
\approx % change	-0.477	0.007	-0.403
<i>N</i>	4,990	4,990	5,363
<i>R</i> ²	0.343	0.334	0.059
Obs from new hospital	Excluded	Excluded	Included
Facility FE	Yes	Yes	Yes
Sampling weights	Yes	Yes	Yes

Notes: The table shows the estimation results when applying Model I and alternative treatment definitions. Column (2) uses distance in kilometers to the new hospital, and column (3) uses patients' department of residency as treatment definition. The dependent variable is $\text{asinh}(\text{waiting})$. Robust standard errors are displayed in parentheses and clustered standard errors displayed in squared brackets (***) $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A8: Change in waiting time after excluding outlier observations.

	All emergency patients: $\text{asinh}(\text{waiting})$				
	Baseline specification (1)	Facility-specific		Facility-wave-specific	
		Excl. ± 3.0 (2)	Excl. ± 2.5 (3)	Excl. ± 3.0 (4)	Excl. ± 2.5 (5)
treatment * after	-0.650 (0.079)*** [0.284]**	-0.656 (0.078)*** [0.284]**	-0.626 (0.077)*** [0.284]**	-0.678 (0.078)*** [0.285]**	-0.667 (0.077)*** [0.285]**
\approx % change	-0.477	-0.481	-0.465	-0.493	-0.487
<i>N</i>	4,990	4,970	4,945	4,970	4,937
<i>R</i> ²	0.343	0.356	0.371	0.355	0.369
Facility FE	Yes	Yes	Yes	Yes	Yes
Sampling weights	Yes	Yes	Yes	Yes	Yes

Notes: Each cell reports the estimation coefficient for the interaction term $\text{treatment}^*\text{after}$ when applying regression Model I. Columns (2) and (4) restrict the samples to observations with waiting time ranging within ± 3 standard deviations, columns (3) and (5) to those ranging within ± 2.5 standard deviations from the facility-specific or facility-wave-specific mean waiting time, respectively. The dependent variable is $\text{asinh}(\text{waiting})$. Robust standard errors are displayed in parentheses and clustered standard errors displayed in squared brackets (***) $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.