Department of Economics Discussion Papers

ISSN 1473-3307

Vaccines on the Move and the War on Polio

Laura Muñoz-Blanco and Federico Fabio Frattini

Paper number 24/03

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Laura Muñoz-Blanco
University of Exeter

Federico Fabio Frattini
FEEM

26th November, 2024

Abstract

The rising number of refugees and internally displaced people (IDPs) presents new challenges for vaccine distribution and the spread of diseases. How do forcibly displaced population inflows affect infectious diseases incidence in host communities? Can a policy intervention that vaccinates children during their migration mitigate the impacts? To answer these questions, we examine the Pakistani mass internal displacement from the conflict-affected Federally Administered Tribal Areas in 2008. Using a difference-in-differences approach, we compare new polio cases in districts near and far from the conflict zone before and after 2008. The spatial distribution of districts relative to the historical region of Pashtunistan allows us to design a sample of comparable units. We show that a standard deviation increase in predicted IDP inflow leads to a rise in the new polio cases per 100,000 inhabitants. Poorer vaccination levels among IDP compared to native children in host communities are one of the main mechanisms. Implementing a vaccination policy targeting IDP children during their migration journey helps bridge the vaccination gap, with important welfare implications.

Keywords: internal displacement, infectious diseases, vaccines, Pakistan

JEL Classification: D60, I15, O15.

*Laura Muñoz-Blanco, Assistant Professor at University of Exeter, Exeter, United Kingdom. Federico Fabio Frattini, Researcher at FEEM, Milan, Italy.

We thank Martin Suesse for his guidance and time generosity. We thank María Alexandra Castellanos-Vasconez, Naomi Crowther, Lukas Delgado, Mélanie Gittard, Andrea Guariso, Nicola Mastrorocco, Danish Us-Salam, Mirko Vintar, and participants at the SAE 2024, RES 2024, EEA 2024, 3rd Research Conference in Forced Displacement World Bank-UNHCR, II Spanish Workshop in Development Economics, University of Galway, and University of Maynooth for their helpful comments and suggestions. Our special gratitude to the Global Polio Eradication Initiative from the World Health Organization for the data provided. All errors and omissions remain entirely our responsibility.

1 Introduction

The spread of infectious diseases can lock people into poverty, erode human capital, and fracture social cohesion (Correia, Luck, and Verner 2022). Increased human mobility and low vaccination rates exacerbate the spread (Greenwood 2014). Hence, the growing number of refugees and internally displaced people (henceforth referred to as IDPs) can pose new challenges, as operational barriers hinder vaccination efforts. Most of these individuals live in conflict zones with collapsed healthcare systems and face obstacles such as illiteracy, limited access to information in local languages, safety risks, and widespread mistrust of governments (UNHCR 2023). Yet, we have limited knowledge on effective vaccination strategies to reach these hard-to-reach populations.

In this paper, we investigate whether the inflow of IDPs affects the incidence of polio in host communities. Further, we examine whether a policy that vaccinates IDP children during their migration journey can make a difference. To address these questions, we study the mass displacement of the population from the conflict-affected Federally Administered Tribal Areas (FATA) to other districts in Pakistan from 2008 onward. Using a difference-in-differences approach, we compare the new polio cases in districts closer and further away from the FATA border before and after the beginning of the IDP crisis in 2008.

We rely on districts closer to the FATA border receiving more IDPs when the total yearly inflow increases. More formally, as data on migration flows are unavailable at the district level, we construct an annual district measure of predicted IDP inflow. The predicted IDPs measure is based on the interaction of the inverse distance to the FATA's border, and the total yearly IDP flows (Rozo and Sviatschi 2021; Rozo and Vargas 2021). Furthermore, cultural and linguistic barriers led most IDPs to settle in the historical region of Pashtunistan. So, we limit our sample to its districts, enabling comparisons across similar economic, political, and cultural districts.

We find that an increase of one standard deviation in predicted inflow results in 0.00154 additional polio cases per 100,000 inhabitants, corresponding to a 22% of the mean incidence. Why are the main effects meaningful? As at 2022, polio has been eliminated in 193 countries. With the transmission of wild-type polio limited to Afghanistan and Pakistan, an official eradication declaration is in sight. Most host districts had zero or close to zero polio cases before 2008. Ultimately, the estimates we present in this paper capture the impacts of IDP inflow on whether a district has had a new polio case, rather than how many cases.

To support the validity of our results, we show that districts closer and further away from the FATA border possess similar pre-treatment characteristics. Further, a dynamic difference-in-differences specification supports the validity of the parallel trend assumption. We also rule out the existence of confounders' effects deriving from the conflict, such as its direct effects, the arrival of Afghan refugees, international migration outflows, and mistrust towards vaccines. Lastly, we validate our estimates with a series of falsification tests, alternative sample definitions, outcomes, and sets of fixed effects.

We hypothesize that the primary mechanism behind the increase in host districts polio cases is a lower vaccination rate among IDP children.[1] We use individual-level data from the Demographic and Health Survey (DHS) from 1990 to 2017 to assess it. First, we show that children living in host districts born after December 2007 are more likely to be vaccinated than older children. The increase in vaccination levels seems to be driven by a rise in vaccination activities per 100.000 inhabitants from 2008. Crucially for our setting, the vaccination likelihood decreases for IDP children, whose probability of being vaccinated is 17.5% lower than their native counterparts.

Can a vaccine delivery intervention close the vaccination gap between IDP and native children? We evaluate an innovative program launched in April 2012 in districts neighbouring FATA region. The Permanent Transit Point (PTP) program vaccines IDP children during their migration journey, before arriving to host districts. Focusing on a geographical subset of Pashtunistan region near the southern FATA border we evaluate the program. We document that the program effectively targets IDP children, raising their vaccination likelihood by about 12.6%.

The PTP program also brings broader health benefits to IDP children. Our analysis shows that it improves their height-for-age and weight-for-height scores by around 1000 points and body mass index by 185 points. Further, the program reduces the likelihood of exposed IDP children experiencing cough, fever, and diarrhoea by approximately 7%. The results also suggest that the program mitigates the polio incidence in host districts, bringing further credibility to the vaccination gap being an underlying mechanism behind the main results.

Pakistan's challenges mirror a global trend. Since 2022, polio has resurfaced in regions like Malawi, Mozambique, and Gaza—once polio-free but now destabilized by conflict-driven displacements. Effective outreach to IDPs and refugees is also crucial for other diseases as malaria eradication, particularly as Sub-Saharan Africa begins rolling out the malaria vaccine in 2023.

This paper adds to the literature on the consequences of forcibly displaced populations in host communities' health outcomes. Much of this agenda has looked at mortality, children's anthropometrics, and utero conditions (Saarela and Finnäs 2009; Lavy, Schlosser, and Shany

[1] We provide supporting evidence for two alternative mechanisms that complement the immunisation mechanism.

2016; Haukka et al. 2017; Anti and Salemi 2021; Dagnelie, Mayda, and Maystadt 2023).[2] The literature on the impacts of hosting displaced people on the spread of diseases is still limited. Most of the available evidence on the topic is based on cross-country migration (Montalvo and Reynal-Querol 2007; Baez 2011; Ibáñez, Rozo, and Urbina 2021; Ibáñez, Moya, et al. 2023). For instance, Ibáñez, Rozo, and Urbina 2021 find that higher refugee inflow are associated with increments in the incidence of vaccine-preventable diseases, such as chickenpox and tuberculosis, as well as sexually transmitted diseases, namely syphilis. Apart from making refugee inflow measures less challenging, neglecting the impact of IDP inflow risks of obtaining downward biased effects. Unlike refugees, IDPs remain within national borders, often in conflict zones, where health monitoring is limited, enabling disease spread. Our study is among the few to assess the impact of hosting IDPs. Understanding their role in infectious disease transmission is crucial for designing interventions in transit zones and host communities. Papers within the same literature present limited evidence suggesting that the poor conditions, the collapse of fragile health facilities, the overpopulation, and contact with infected migrants in host destinations might be plausible mechanisms (Baez 2011; Ibáñez, Rozo, and Urbina 2021). We also add to this literature by presenting empirical evidence on the vaccination gap between IDP and native children as a major channel.

The role of vaccines in explaining the increase in polio incidence in host communities relates this paper to the research agenda on the determinants of infectious diseases transmission. Most of the existing economic literature has focused on studying the mistrust of vaccines (Martinez-Bravo and Stegmann 2022), the role of trade (Oster 2012), public transportation closure (Adda 2016), and travels (Milusheva 2020). Closer to our paper is Martinez-Bravo and Stegmann 2022, who evaluate the effects of an anti-vaccine propaganda campaign on polio immunization in Pakistan. Here we are interested in the effects of a vaccination policy in the same country, and rule out the potential effect of mistrust in our estimates. Although there is a wide consensus on the importance of vaccines on the spread of infectious diseases (Ward 2014; Herrera-Almanza and Rosales-Rueda 2023; Graff Zivin et al. 2023), no study has documented the effects of a policy designed to vaccinate forcibly displaced children during their migration journey. To the best of our knowledge, we are the first in evaluating a program of this nature.

The rest of the paper is organized as follows. Section 2 provides background information on the conflict, mass migration, and polio in Pakistan. Sections 3 and 4 present the data and identification strategy. Section 5 presents the main results and robustness checks. Section 6 discusses the mechanisms, including the policy evaluation of the PTP program. Section 7 concludes.

[2] See Becker and Ferrara 2019 for an overall review on the forcibly displaced populations literature.

2 Background

2.1 Conflict in FATA Region

Pakistan witnessed a vast surge in violence after the terrorist attack in September 2001 (9/11) in the United States (US). The increase in violence manifested in waves of violent attacks against state institutions and civilians across Pakistan. Terrorists carried out around 1,600 attacks in the pre-9/11 era. However, a significant surge in the number of attacks was observed (around 12,000) in the aftermath of the 9/11 period (GTD 2021). The intensity of such violence was substantial in the Federally Administered Tribal Areas (FATA) when the Tehrik-e-Taliban militants began entering into the region (Malik, Mirza, and Rehman 2023).[3] Figure A1 plots the number of attacks in Pakistan and the FATA region.

FATA was an autonomous tribal region in north-western Pakistan that existed from 1947. FATA merged with the neighbouring province of Khyber Pakhtunkhwa in 2018.[4] FATA were bordered by: Afghanistan to the north and west, Khyber Pakhtunkhwa to the east, and Balochistan to the south. Figure 1 illustrates the three administrative levels of Pakistan.[5] FATA's population was estimated in 2000 to be about 3,341,080 people or roughly 2% of Pakistan's population. FATA is the most rural administrative unit in the country. FATA was located in Pashtunistan (*land of the Pashtuns* in Pashto), a historical pre-colonial region wherein Pashtun culture, the Pashto language, and Pashtun identity have been based.[6]

The acceleration of violence in FATA led to a domestic and international military response. After 9/11, Pakistani and US forces carried out military offensives against alleged sanctuaries of terrorist outfits. On June 19, 2004, the US undertook its first drone strike in Pakistan. Since then, the US has carried out more than 406 drone attacks against alleged Al-Qaeda-linked affiliates in

[3]The Pakistani Taliban, formally called the Tehreek-e-Taliban-e-Pakistan, is an umbrella organisation of various Islamist armed militant groups operating along the Afghan–Pakistani border (Abbas 2008)

[4]From 2018, the administrative units of Pakistan comprise four provinces, one federal territory, and two disputed territories: Punjab, Sindh, Khyber Pakhtunkhwa, and Balochistan; the Islamabad Capital Territory; and the administrative territories of Azad Jammu and Kashmir and Gilgit–Baltistan.

[5]A province (administrative level 1) has different divisions (administrative level 2), and a division is divided into other districts (administrative level 3).

[6]Pashtunistan is a historical region on the Iranian Plateau, inhabited by the indigenous Pashtun people of southern Afghanistan and north-western Pakistan. During British rule in India in 1893, Mortimer Durand drew the Durand Line, fixing the limits of the spheres of influence between the Emirate of Afghanistan and British India and dividing the historical Pashtunistan as a share of two different countries (Bezhan 2014).

Pakistan's North-West. These attacks increased from 2007 and peaked around 2010. 98% of the drone attacks across Pakistan were in FATA. Figure 2 shows the total number of drones from 2001 to 2022 (New-America 2021).

2.2 Forced Displacement within Pakistan

In 2008, 2.3 million people have been displaced driven by the conflict. 98% of the forcibly displaced population migrated within Pakistan (UNHCR 2023). See Figure A2 for a visual representation of the Pakistani forcibly displaced population who migrated inside and outside the country from 2001 to 2022. A concern would be that the decision to migration could be affected by other factors beyond the conflict. In Figure 2, we plot the number of drones and yearly total IDPs from 2001 to 2022. The onset of the IDPs crisis was in 2008, corresponding with a big jump in drone strikes between 2007 and 2008. The fact that the first year the mass displacement corresponds with the first substantial increase in the conflict intensity bring credibility to conflict being the main push factor of the migration. In 2009, the total IDPs reached more than 1.9 million individuals, corresponding to 57% of the FATA's population (UNHCR 2023).[7]

The IDPs came from different FATA districts, but especially from the most affected by the conflict (North Waziristan and South Waziristan, in southern FATA) (UNHCR 2023). In line with the hypothesis of conflict as the main migration-push factor, Figure 3 shows in panel b) the positive correlation between the number of drones and IDPs from a given district. We present the total number of IDPs by origin in Table A1.

Due to cultural and linguistic similarities, most IDPs migrated to relatively safe districts within the historical region of Pashtunistan. We list the total IDPs by host districts in 2008 in Table A2. Many arrived to host districts as cohesive groups (IDMC 2015). IDPs often struggled to integrate in host communities, and they often relied on social networks from their home areas. In specific locations, IDPs were discriminated against by the native population and political leaders whipping up xenophobia against the displaced (Din 2010; IDMC 2015). Most of the affected population has been displaced multiple times, and few have returned to their places of origin (UNHCR 2023).

IDPs usually resided in informal settlements within host communities. They avoided camps for multiple reasons, including the fear of attack by non-state armed groups and lack of private space. The settlements often lack safe drinking water, sanitation, and health care (IDMC 2015).

[7]It exists a later peak in newly IDPs in 2014. Figure A1 shows how the number of terrorists attacks in FATA peaked also in 2014.

2.3 Polio

Polio or Poliomyelitis is a highly infectious viral disease. The virus is transmitted by person-to-person contact. The virus can live in an infected person's intestines or throat for 1–6 weeks. It spreads through contact with an infected person's stool (poop) or, less frequently, droplets from a sneeze. An infected person may spread the virus to others immediately before and up to two weeks after developing symptoms. Infected children can contaminate food and water when they touch them with unwashed hands (CDC 2021).

There is no cure for polio, and it can only be prevented. Two vaccines are available: oral polio (OPV) and inactivated polio (IPV).[8] The OPV is a key tool in humanitarian settings because it's easy to administer and inexpensive. To interrupt polio transmission, at least 90% of all children in every community must be vaccinated at least one OPV dose. Children usually get four doses of the polio vaccine at ages two months, four months, 6–18 months, and 4–6 years (WHO 2022).

Although anyone not fully vaccinated against polio is at risk for polio, polio predominantly affects children under five. Most people who get infected with polio will not have any visible symptoms. About 1 out of 4 people with polio infection will have flu-like symptoms (fever, fatigue, headache, vomiting, stiffness of the neck and pain in the limbs). These symptoms usually last 2 to 5 days. One in 200 infections leads to irreversible paralysis (usually in the legs). Among those paralysed, 5–10% die when their breathing muscles become immobilised (WHO 2022).

Polio case have fallen dramatically over time. In 1988, more than 350,000 cases were reported annually across 125 countries. In 2001, 14 countries reported cases of wild polio. In 2021, the number of cases was down to 649. By 2021 there were only two countries where wild poliovirus cases were recorded: Afghanistan and Pakistan (WHO 2022). The main reason was the increased number of children vaccinated. Globally in 1980, only 22% of one-year-olds were vaccinated against polio, which increased to coverage of 86% of the world's one-year-olds in 2015.[9]

Polio in Pakistan. Since 1994, the Pakistan Polio Eradication Programme (PPEP) has been fighting to end the crippling poliovirus in the country. In 1997, Pakistan reported 1,147 cases, constituting 22% of the cases reported worldwide. Pakistan reduced cases from 20,000 in 1990 to

[8] OPV is administered orally and can be given by volunteers. OPV protects both the individual and the community because it induces gut immunity, which is essential to stopping poliovirus transmission. IPV is given by injection and needs to be administered by a trained health worker. IPV is highly effective in protecting individuals from severe diseases caused by poliovirus. However, it cannot stop the virus's spread in a community.

[9] In 1988, the World Health Assembly created the Global Polio Eradication Initiative to eradicate polio by 2000.

28 in 2005. However, about 100 cases have been reported annually after 2007. Cases steadily rose from 32 in 2007 to 118 in 2008 to 198 in 2011 (WHO 2022).

The surge in violence in FATA could be one of the leading reasons of the increase in polio cases in Pakistan (Blattman and E. Miguel 2010; Phadera 2021). Almost 70% of Pakistan's polio cases from 2004 to 2018 were reported in FATA. Poor sanitary conditions with large families living in packed houses could widespread polio transmission. Moreover, the militants carried out propaganda against polio vaccines, increasing vaccine refusal. As the extremists banned polio vaccination, almost 400,000 children could not be vaccinated in FATA during 2010–2011. Even vaccination workers began to be attacked and killed (Mushtaq et al. 2015).

Immunization in Pakistan. Children receive three main vaccines through routine immunisation activities: the poliomyelitis, the DPT (against diphtheria, pertussis, and tetanus), and the measles vaccines. Pakistan follows the recommended vaccination calendar of the World Health Organization, and the first dose of most vaccines is distributed shortly after birth.

As part of the PPEP, Lady Health Workers are responsible for child immunisation. These workers are assigned to a local health facility, each responsible for approximately 1,000 people or 150 homes. In 2014, there were approximately 110,000 Lady Health Workers in Pakistan. They regularly visit households to provide family planning information and immunise children. However, vaccination drives is still the main vaccination strategy through which Pakistani children get immunised. There are national and subnational immunisation days during which vaccinators (typically lady health workers joined by other volunteers) provide vaccines at households' doorstep. They typically last for three days and target all children up to age 5. Since 2010, the provision of public health goods is a provincial responsibility. All the vaccines provided during immunisation drives or at public health facilities are free of charge (Martinez-Bravo and Stegmann 2022).

***Permanent Transit Vaccination* program.** To minimize the risk of spread and provide additional vaccination opportunities, Pakistan launched the *Permanent Transit Vaccination* program in April 2012. The program targets the High-Risk Mobile Populations (e.g., nomads, IDPs, or refugees). The Polio Global Eradication Initiative designed the program. It has been only implemented in Nigeria and Pakistan.

The *Permanent Transit Vaccination* program sets up permanent local vaccination teams to reach the hard-to-reach population. The teams are deployed across all major population transit points. For instance, Permanent Transit Points (henceforth refer as PTPs) are located throughout the routes used by the population coming from or going to the conflict-affected region of FATA. The PTPs' location includes major roads, bridges, ferry crossing points, motorway rest stops, bus stops, Country/Province/District borders, main bus-train stations, major health facilities, religious shrines and other places of the congregation having the possibility of a large number of people gathering. There are around 500 PTPs nationwide.

Permanent Transit teams have at least two members who screen, vaccinate, and record the children vaccinated at the site. There are more than one team in places with high traffic load. Team members belong to the community, are adult males, familiar with the area and transit site, and respect local customs. Each team is trained, and provided with vaccines, cold chain and logistics. In 2018, 1.7 million children have been vaccinated at PTPs (UNICEF 2019).

3 Data

We construct a panel dataset at the district-month level that combines data on conflict, the total forcibly displaced population, polio cases, and the supply-demand for vaccines.

3.1 Conflict data

We use two geo-referenced variables to measure conflict intensity in Pakistan—the number of drone strikes and terrorist attacks at district and monthly levels.

The conflict data on drone strikes comes from the World of Drones Database developed by New America (New-America 2021). New America gathers information on each drone strike's timing (day, month, year), location (latitude and longitude) and total deaths. The information draws upon media reports and other open-source information. The database tracks the countries and non-state actors who have armed drones or are developing them. The information also identifies which actors have used drones in combat and where.

The World of Drones Database has reported 406 drone strikes in Pakistan from 2001 to 2022. The first drone was recorded on June 19, 2004, and the last on July 4, 2018. Only 10 of the 406 drones were located outside FATA. Figure A3 presents in panel a) the spatial distribution of drone strikes in Pakistan. We construct our primary measure of conflict by aggregating the drones that fall in a district monthly. Figure A4 presents the spatial distribution of total deaths by drone strikes in Pakistan.

The data on terrorist attacks against the state and civilians are extracted from the Global

Terrorism Database - GTD (GTD 2021). The GTD provides details on more than 200,000 terrorist incidents worldwide since 1970. For each incident, information is provided on the timing (day, month, and year), location (latitude and longitude), fatalities (wounded and killed), type (assassination, explosion, suicide, hijacking, etc.), target (civilians, businesses, government officials, religious institutions, NGOs, etc.), the terrorist group which carried out the attack, and the motivation of the episode (political or religious).

The GTD reported 13,638 terrorist attacks from 2001, to 2022 in Pakistan. We construct a measure of terrorist attacks at the district-month level by aggregating the number of incidents that fall in a district.

3.2 Forced displacement data

United Nations High Commissioner for Refugees - UNHCR provides the data on forcibly displaced populations (UNHCR 2023). UNHCR 2023 contains information about the countries and provinces of destination and origin, total population, year of arrival, and demographic characteristics (age and gender). This data allows us to quantify the year-level new IDPs, Pakistani new refugees outside Pakistan, and Afghan refugees stock in Pakistan. Figure A2 shows how a large share of the forcibly displaced population remained within Pakistan, refereed as IDPs.

Among the IDPs who fled from FATA, 54% of them are below 18 and 18% below 5. Figure A5 plots the total IDP distribution by age. Moreover, 47% of the IDPs were women or girls. The destination districts were concentrated in Khyber Pakhtunkhwa province, as shown in Figure A6. UNHCR provides also data at the district level for 2008, the first year of the IDP crisis (see Table A2 for the distribution across districts).

3.3 Polio data

We collect data on polio incidence in Pakistan from 2001 to 2022. The data comes from the Polio Eradication Program established by the World Health Organization (WHO). The Polio Eradication Program gathers information on the year-month, district, and the type of virus (wild or circulating vaccine-derived polio) of each polio case.[10] We build our outcome measure on polio incidence by aggregating the number of new polio cases in a given district and month.

[10]In communities with low immunization rates, the virus can spread among unvaccinated children over 12-18 months, mutating into a cVDPV poliovirus (WHO 2022).

The Polio Eradication Program reported 2,080 new polio cases from 2001 to 2022 in Pakistan. As we can see in Figure A7, the cases in the entire country and FATA followed an increasing trend from 2008 onward.

3.4 Vaccination supply and demand

For this project, we also collect data on Pakistan's polio vaccination campaigns between 2001 and 2022. We obtain this data from the Polio Eradication Program. These data contain district-month measures of whether a polio vaccination campaign was conducted, the type of campaign—case response, mop-ups, child health days, sub-national or national immunization days—, the age group targeted, and vaccine type.[11]

We obtain measures of polio immunization at the individual level from the Pakistani Demographic Health Survey (DHS). We use information on the demand for the polio vaccine from the 2012/13 and 2017/18 DHS surveys. We profit from the 2006/07 and 1990/91 DHS surveys to look at the the pre-treatment characteristics.

3.5 Other data

The DHS asks each household member whether the individual was born in the current district of residence and the reason for the migration. We exploit this migration data to build a variable on whether an individual is IDP or native.[12]

The DHS also gathers information on household (e.g., sanitation, overcrowding, house conditions) and individual levels (e.g., date of birth, health-seeking behaviour, labour, and education) characteristics.

For our empirical strategy, we obtain geo-referenced information on the historical pre-colonial region of Pashtunistan. The datasource is the Georeferencing Ethnic Power Relations - GeoEPR 2021 dataset (Vogt et al. 2015). GeoEPR geo-codes politically relevant ethnic groups from the Ethnic Power Relations-Core 2021 dataset.

[11] Mop-ups are polio campaigns targeting areas where a large immunity gap persists. Mop-ups hold between larger-scale national Immunization Days or sub-national Immunization Days. Child Health Days are not specifically polio campaigns, but the polio vaccine is added to Child Health Days alongside other vaccines and health interventions. National Immunization Days are nationwide campaigns targeting all children aged 0-5. Sub-national Immunization Days are vaccination campaigns in key high-risk provinces.

[12] We classify an individual as IDP if they have not born in their village of residents and reports conflict as the primary reason to have migrated.

We use a bunch of district-level covariates to test the validity of our identification strategy. The National Oceanic and Atmospheric Administration (NOAA) processes night light density data. We construct a variable on satellite night light density as a proxy of economic development.[13]

4 Identification Strategy

This paper aims to study the impacts of internally displaced population (IDPs) inflow on the incidence of polio in host districts. For this purpose, we employ a difference-in-difference methodology comparing districts closer and further away from FATA, before and after the beginning of the IDP crises in 2008.

4.1 Sample: Pashtunistan historical region

The decision of where to migrate is a potential endogenous decision (Foged and Peri 2016; Morales 2018; Cengiz and Tekgüç 2022). Additionally, time-varying characteristics in host districts could affect the incidence of polio.[14] For example, if IDPs were to migrate to poor areas closer to their original communities, and we compare poorer and richer districts, we would overestimate the effects.[15] To overcome this challenge, we restrict our sample to a set of districts with similar economic, political, and cultural characteristics. To do so, we exploit the location of districts with respect to the Pashtunistan historical border.

Pashtunistan is a pre-colonial region covering a share of Afghanistan and Pakistan, including FATA (see section 1.1 for more details). Due to cultural and linguistic similarities, most of the IDP families from FATA migrated to other districts within Pashtunistan.[16] Research in the migration literature highlights how cultural and linguistic proximity, as well as the presence of established cultural networks, play a crucial role in shaping migration flows and migrants' decisions about where to settle (Bartel 1989; Adserà and Pytliková 2015).

[13]NOAA uses satellite images collected by the US Air Force Defense Meteorological Satellite Program.

[14]See Verme and Schuettler 2021 for a review focused on IDP.

[15]Low-income households are more likely to be deprived from good sanitation, water, and housing (Dewilde 2021), which can facilitate polio spread.

[16]The main language spoken in the delineated Pashtunistan region is Pashto. The Pashtuns practice Pashtunwali, the indigenous culture of the Pashtuns. Pashtun tribes often disregard administrative borders, historically crossing freely between FATA and neighboring Afghan regions. However, since 2004, military measures have significantly restricted this cross-border movement.

To identify the effects, we restrict our main sample to the districts which territory falls entirely or partially into Pashtunistan. Figure 1 shows in light blue the main sample. The central identifying assumption is that the IDP population mostly moved to Pashtu districts, and non-Pashtu districts had no or negligible presence of IDPs. Although FATA is part of Pashtunistan, we drop it from the sample to avoid potential confounding effects from the conflict.[17]

4.2 Main specification

We estimate the following specification in a panel dataset at Pashtunistan district-month level.

$$Y_{d,tm} = \beta_0 + \beta_1 IDPCrisis_t * PredictedInflow_{d,t} + \beta_2 X_{d,t} + \gamma_d + \delta_{tm} + \epsilon_{d,tm} \quad (1)$$

where d stands for district, t for year and m for month. $Y_{d,tm}$ represents the district-month outcome: the number of new polio cases per 100,000 inhabitants in the year and month tm. We use the population in 2017 to calculate the number of cases per 100,000 inhabitants.[18][19] $IDPCrisis_t$ is a dummy variable that takes the value of one after 2007. $X_{d,t}$ is a matrix of district-year controls. Namely, we control for district-level nightlight intensity as a proxy of economic development (Pérez-Sindín, Chen, and Prishchepov 2021) and the total number of polio vaccination campaigns in a given district-month, which account for the vaccination supply. γ_d and δ_{tm} account for district and year-month fixed effects. The year-month fixed effect accounts for seasonal shocks standard across all districts in Pakistan. District fixed effect controls for time-invariant characteristics within a district. Standard errors are clustered at the district level.

Based on empirical evidence, we rely on districts closer to the FATA border receiving more IDPs when the total yearly inflow of IDPs increase (Calderon-Mejia and Ibañez 2016).[20] Table A2 shows how most of the IDPs displaced in 2008 stayed in the surrounded districts. Figure A6 presents descriptive province-level evidence on how IDPs stayed in Khyber Pakhtunkhwa, one of the closest province to FATA, after 2008. Data on the IDP inflow at the district-year level is not available from 2009 onward. Therefore, we approximate district-year inflow of the IDP population using a predicted inflow measure:

[17] We use an alternative sample definition in the robustness section.

[18] Azad Jammu and Kashmir and Gilgit-Baltistan provinces are not in the 2017 Population census. So, Kargil, Kupwara, Muzaffarabad and Neelum districts drop from the sample.

[19] Table A11 shows that the results hold with an outcome normalised by 100,000 inhabitants in 1998.

[20] Calderon-Mejia and Ibañez 2016 instruments the IDPs inflow with the aggregate number of massacres in city c at time t, weighted by the inverse of the distance to city c.

$$PredictedInflow_{d,t} = IDPinflow_t * \frac{1}{DistFATA_d}$$

where $IDPinflow_t$ stands for the new IDPs registered in Pakistan in each year t. $\frac{1}{DistFATA_d}$ is the inverse Euclidean distance of each centroid district to the closest FATA border.[21] We standardized $PredictedInflow_{d,t}$ to ease the interpretation of our results. This is an accepted procedure in the related literature (Rozo and Sviatschi 2021; Rozo and Vargas 2021). The interaction $IDPCrisis_t * PredictedInflow_{d,t}$ implies that we formally estimate a 2x2 continuous difference-in-differences (DiD). Hence, we compare the new polio cases in districts closer and further away from FATA's border, before and after the IDP crises in 2008.

5 Results

We show the main results in Table 1. Column (3) shows that an increase of one standard deviation in predicted inflow leads to 0.00154 additional polio cases per 100,000 inhabitants. Column (1) presents the estimates without fixed effects and controls. The magnitude of the effects does not substantially change when adding district and year-month fixed effects (column (2)). Column (3) shows that the results hold when controlling for nightlight intensity and total vaccination campaigns.

Why are the main effects meaningful? During the 1990s and 2000s, eradicating polio has been a worldwide effort. Polio has been eliminated in 193 countries, with the transmission of wild-type polio limited to Afghanistan and Pakistan. But, until polio is not worldwide eradicated, all countries remain at risk of imported wild polio. Identifying the determinants of new cases is critical to prevent additional ones. In 2005, 28 cases were reported in Pakistan, compared to the 1,147 cases in 1997. Moreover, most host districts had zero or close to zero polio cases before 2008. Ultimately, the estimates we present in this paper capture how unexpected arival of IDPs or refugees can disrupt the eradication efforts of a disease in a region or a country. We show this to take place via IDPs. Moreover, despite finding estimates with a magnitude quite substantial, a quite high risk of underreporting is present, as 75% of people infected with poliovirus are asymptomatic (WHO 2022). To bring credibility to the main findings, we should observe an increase in the incidence of those diseases. Ideally, we would look at the incidence of other diseases

[21] The results hold when we use distance to the border of each municipality. Figure A10 shows that distance to FATA border is not correlated to nightlight intensity (i.e., a development economics proxy) and political support for Taliban before 2008.

-measles, chickenpox, or malaria- to validate our findings. Unfortunately, data limitations prevent this important analysis, as we could not find comparable data for other diseases.[22]

5.1 Identification threats

Unbalanced pre-treatment characteristics. Table A3 presents summary statistics of key demographics and socioeconomic variables that compare districts with high IDP intensity (closer districts) and districts without or with negligible IDP population (further districts).[23] Closer districts are defined as those whose territory falls entirely in Pashtunistan. Further districts are those with only a share within Pashtunistan. The balancing test in Table A3 does not reveal significant pre-shock differences.[24]

Pre-trends outcomes. The key identifying assumption on the validity of the main results is that treated and control units should evolve similarly regarding the outcome of interest absent the treatment. To overcome the fact that formally our treatment variable is continuous, we still identify treatment exposure comparing districts with high IDP intensity (closer districts), and districts without or with negligible IDP population (further districts). Qualitatively, Figure 3 plots the new polio cases from 2001 to 2022 in closer and furhter districts, suggesting that consistent differences in the pre-treatment period should be minimal. More rigorously, we estimate the following event-study specification,

$$Y_{d,t} = \beta_0 + \sum_{p=-5}^{8} \alpha_p IDPCrisis_{t+p} + \gamma_d + \delta_{tm} + \epsilon_{d,t} \quad (2)$$

where $\sum_{p=-5}^{8} \alpha_p IDPCrisis_{t+p}$ identifies year dummies relative to the start of the IDP crisis (2008) for closer districts. We investigate back to $p = -5$ and up to $p = +8$ years. The omitted year is 2007. Figure A12 reports the results of this exercise, and it is possible to see that closer and further districts do not exhibit statistical differences in the pre-treatment period.

Conflict effect. Conflict can affect the health outcomes of children at an early age (Bundervoet, Verwimp, and Akresh 2009). The conflict is primarily concentrated in FATA, which is not in our

[22]The data available for the other diseases were insufficient to grant a meaningful regression analysis or were unavailable before 2008.

[23]It is worth mentioning that we still restrict the sample to Pashtunistan districts.

[24]The characteristics are district-level and time-invariant, taken in 1998 from the Population Census.

baseline sample. Still, we want to purge our estimates of the indirect effect of conflict on the incidence of polio cases. In Table A4, we report estimates when we control for, respectively, the distance to the latest drone attack and the number of terrorist attacks.[25] 43% of the districts of our sample experienced at least a terrorist attack during our period of analysis. Remarkably, when we control for either of the two, the results remain in line with those of Table 1.

Afghan refugees. Since the late 1970s, Pakistan has been a host country for millions of refugees and some 1.35 million still reside in the country. (UNHCR 2023). Figure A13 shows the evolution of total stock of Afghan refugees in Pakistan from 2001 to 2022. Most refugees are in the Pashtun-dominated areas of Pakistan. This fact is a major problem for our identification, as their presence can bias our estimates. To put up this empirical limitation, we conduct two different exercises in Table A5. In Panel A, we show that the results of Table 1 hold when we control for the total district-year Afghan refugees. In Panel B, we also show evidence that the estimates do not change when we control for the number of refugee camps in a district.[26]

Migration outflows. Although very few Pakistanis migrated internationally, a big jump in the number of Pakistani refugees before and after 2007 could affect our results. Figure A2 helps to remove this concern. The number of Pakistani refugees has been relatively constant from 2000 to 2011, with an increase from 2012. However, the results remain unchanged when we control for the total number of Pakistani refugees abroad interacted with year fixed effects (see Table A6).

Polio vaccine mistrust. After the conflict in FATA, the resistance to foreign interventions has considerably increased across the country. Additionally, the misinformation and vaccines mistrust have also been a barrier to stopping polio eradication in Pakistan. Misconceptions on vaccines' efficacy has been spread across local communities. As documented by Martinez-Bravo and Stegmann 2022, the disclosure of information on July 11th of 2011 describing a fake vaccination roll-out delivered by the Central Intelligence Agency (CIA) accentuated the mistrust on vaccines.[27] As a result, the Taliban initiated an anti-vaccine campaign aimed at discrediting vaccines and

[25] Only five host districts were hit by a drone (10 drones in total). The observations before June 2004 drop from the sample, as there were no drones before, leading to a drop in sample size.

[26] Only 3 out of the 296 camps had IDPs as the targeted population, implying that the refugee camps mainly were for foreign refugees, rather than IDPS.

[27] The CIA wanted to find out if Bin Laden was hiding in Abbottabad, Pakistan. To this end, the CIA organised a fake vaccination ruse. The objective was to obtain DNA samples of children living in the compound and compare them to the DNA of Bin Laden's sister, who had died in Boston in 2010. On July 11th of 2011, the British

vaccination workers. This event is potentially problematic for us, as they may introduce potential bias to our estimates. Following Martinez-Bravo and Stegmann 2022, we retrieve the votes share of the Islamist coalition at the 2008 general elections. We use it as a proxy of ideological affinity to the Taliban.[28] We include this data in our estimating equations interacted with year fixed effects. Table A7 shows that accounting for the political support for Taliban our estimates unchanged.[29]

5.2 Additional robustness tests

We further assess the validity of our results in three ways. First, two falsification tests rule out anticipatory effects and potential reverse causality. Second, we validate the outcome we focus on and the treatment definition using alternative ones. Third, we show that the results hold using additional sets of fixed effects.

Reverse causality. In this project, we look at the impacts of hosting conflict-induced IDPs on polio incidence in host communities. It could be a concern that IDP families chose their host community based on previous or existing polio case numbers. Hence, a potential reverse causality could threaten our identification. Table A9 rules out this hypothesis by showing no correlation between the aggregate district polio cases from 2001 to 2007 and IDP inflow.

Sample definition. The definition of sample relies on the historical border of Pashtunistan. As explained in subsection 4.1, the estimating sample includes the districts whose territory, either totally (closer districts) or partially (further districts), falls within Pashtunistan. As an alternative sample specification, we include non-Pashtunistan districts which are adjacent to the "further districts". They correspond to the most-light-red polygons in Figure A14. In Table A10 we show that the coefficients remain in line with the main results.

Alternative outcomes. We investigate the sensitivity of our results to the use of two different outcomes. These are: the probability of observing in a district d at time tm a new polio case; the number of polio cases per 100,000 inhabitants in 1998, rather than in 2017. Table A11 shows

newspaper *The Guardian* published an article describing the vaccine ruse (Martinez-Bravo and Stegmann 2022).

[28]Districts with higher support for Islamist groups are likely to be more exposed to the antivaccine propaganda campaign, and grant more credibility to their anti-vaccine messages (Martinez-Bravo and Stegmann 2022).

[29]A small drop in sample size in Table A7 is due to the merging with the 2008 electoral data.

that, despite with lower significance, the estimates of the two different outcomes are in line with our preferred outcome.[30]

Alternative specification with different sets of fixed effects. In our baseline specification (equation 1), we control for a year-month fixed effect and a district fixed effect. Polio cases have changed in the country, where the health response is the provincial government's responsibility. Hence, we show that our results are robust to alternative specifications. In Table A12 we further include either provincial (Panel A) or division (Panel B) linear trends to flexibly control for province or division trends not captured by either the district or the year-month fixed effects.[31] Remarkably, the coefficients remain in line with the main results.[32]

6 Mechanisms

The main findings show that the arrival of a large IDP inflow increases polio incidence in host communities. What are the underlying mechanisms behind a polio increase? We document that low vaccination rates among IDP children is the main mechanism behind the results.

6.1 Lower vaccination rates among IDP children

The conflict in FATA have affected routine immunisation, leading to less than 45% of children living in FATA being vaccinated against polio (Hussain et al. 2016). Moreover, the militants carried out continuous propaganda against polio vaccination, translating into increased vaccine refusal (Mushtaq et al. 2015; Rahim, Ahmad, and Abdul-Ghafar 2022). 70% of Pakistan's polio cases from 2004 to 2018 were reported from FATA. As a result, IDP children are more likely to be unvaccinated and, more likely to be or get infected when arriving to host districts.

Does the arrival of IDPs affect the immunization in host districts? Are children born after 2007 less likely to be vaccinated? Are IDP children differently affected than natives? We address these questions by exploiting within-district cohort variation and estimating the following specification.

[30] It is notable the drop in observation for the number of polio cases per 100,000 inhabitants in 1998 (panel B), that is due to the poor coverage of the 1998 census.

[31] It is worth mentioning that divisions are nested within provinces.

[32] The results are not affected by the inclusion of either province * year or division * year fixed effects, allowing to control non-linearities in the above-discussed evolution. Results are available upon request.

$$Y_{i,k,d} = \beta_0 + \beta_1 Cohort_k + \beta_2 X_{i,h,d} + \alpha_d + \epsilon_{i,d} \tag{3}$$

where $Y_{i,k,d}$ is equal to one if child i from the cohort k living in district d received at least one dose of the polio vaccine, zero otherwise.[33] The timing of the treatment is given by the year and month of birth: $Cohort_k$. $Cohort_k$ is one if child i was born after December 2007. We control for covariates $X_{i,h,d}$ at the individual, household and district levels. District-level covariates include nightlight intensity and the number of polio activities in the year of the interview. We include the work status of the head of household, urban location, and gender of the child as individual-level covariates.[34] Additionally, we include district α_d fixed effect, which accounts for districts' changes in immunization supply or social patterns. Standard errors are clustered at the district level.

We find that children in host communities born after the arrival of the IDP population are more likely to be vaccinated than those born before. Panel A of Table 2 shows the results. The IDP inflow seems to increase the probability of immunization in the host districts roughly by 5.7 percentage points (pp) in Column (2), with the estimates being statistically significant at the one per cent level. The magnitude of the effects does not change with covariates. Column (3) shows that the point estimates increase to 6.7 pp when controlling for nightlight intensity and the total vaccination campaigns in a year (significant at the one per cent level). We could be concerned that the employment or socio-demographic characteristics could drive our results. In column (4), we control for the head of household's work status, urban location, and gender of the child. The results hold. The results also hold when we simultaneously control for the covariates of columns (3) and (4) (see column (5)). These findings suggest that the immunization rates did not decrease after the arrival of IDP inflow, they actually increased. The increase in vaccination levels seems to be driven by an increase in vaccines supply. Table A17 shows that an increase of one standard deviation in predicted inflow leads to a rise in vaccination campaigns per 100.000 inhabitants.

Panel B unveils a crucial heterogeneity in vaccination rates between IDP and native children. IDP children are 17.5% less likely to be vaccinated compared to native ones, with the coefficients being stable across columns. Factors influencing both the demand and supply of healthcare ser-

[33] $Y_{i,k,d}$ is equal to one if the parents' child can show vaccination documents proving the vaccination date. The results also hold relaxing the definition (i.e., at least one dose of polio without vaccination documents).

[34] Employment and urban characteristics control for liquidity constrained, and education to process information on the potential returns to various health investments (Dupas and Miguel 2017). The Taliban spread that the polio vaccine was intended to sterilize Muslim girls with potential differential effects on vaccines between boys and girls (Martinez-Bravo and Stegmann 2022).

vices may explain the gap in polio vaccination. One possible explanation for this disparity is the lower demand for healthcare and health products among IDP families, often associated with lower income and educational attainment, as noted by Dupas and Miguel 2017. However, evidence from Panel A of Table A17 does not indicate significant differences in healthcare service use between IDPs and natives.[35] An alternative explanation could be heightened vaccine mistrust among IDPs (Martinez-Bravo and Stegmann 2022). Yet, the findings in Table A7 appear to challenge this hypothesis. Instead, systemic discrimination against IDPs, particularly Pashtuns—often stigmatized as terrorists or Taliban collaborators by government forces—may play a critical role (Defence 2021). This bias could disrupt vaccine supply chains for IDP children, as immunization campaigns depend heavily on governmental Lady Health Workers (LHWs). Furthermore, psychological associations between LHWs and government forces may amplify skepticism and reluctance among IDP families to seek vaccines. Finally, as detailed in Section 2.3, household-based vaccination campaigns remain Pakistan's primary immunization strategy. Reaching IDP children, who often reside in inaccessible slums, presents additional logistical challenges. Unfortunately, the data do not allow for direct testing of the discrimination or accessibility hypotheses.

The gap in immunity between IDP and native children appears to be a critical factor driving the rise in polio cases in host districts following an IDP inflow. However, nationwide immunization rates in Pakistan remain alarmingly low. Before 2008, no host district reported vaccination coverage exceeding 45% (at least one dose), far below the 90% threshold recommended by the World Health Organization to interrupt polio transmission. After 2008, the presence of IDPs slow down this issue, increasing vaccination coverage in host districts to a 48%. Eliminating polio completely requires targeting every child, regardless of their migration status. Addressing these disparities is essential to closing the immunization gap and ensuring broader public health security in host communities.

6.1.1 Permanent Transit Point program evaluation.

The previously discussed results show the importance of vaccinating IDP children to interrupt polio transmission in host communities. How can a policy intervention successfully vaccinate IDP children and close the vaccination gap? How efficient are vaccination programs designed to vaccinate them before arriving to host communities? As presented in the subsection 2.3, Pakistan is one of the two countries implementing a Permanent Transit Point (PTP) program. The PTP

[35] I proxy demand for healthcare services as the demand for prenatal doctor and postnatal doctor assistance.

program was implemented in April 2012 and aims at targeting high-risk mobile population such as IDP children. As part of this project, we evaluate the program.

Despite not having access to the whole country, we digitise Figure 4 and retrieve the number of PTPs at the district level for a subset of the Pashtunistan historical region.[36] The fact that we focus on six out of the 39 baseline districts is a limit of this analysis. However, we argue that this area is the most salient in terms of IDP inflow, given its proximity to Waziristan region, where the conflict intensity was higher.[37] Then, we estimate the following estimating equation,

$$Y_{i,k,d} = \beta_0 + \beta_1 Cohort_k + \beta_2 N\,PTP_d + \beta_3 Cohort_k * N\,PTP_d + \beta_4 X_{i,d} + \alpha_d + \epsilon_{i,d}, \tag{4}$$

where $Y_{i,k,d}$ is still equal to one if child i from the cohort k living in district d received at least one dose of the polio vaccine, zero otherwise. $Cohort_k$ is equal to one if a child i was born after December 2007, that is after the onset of the IDP crisis. $N\,PTP_d$ is the number of PTPs in district d. In line with the previous evidence on children's vaccination, we further augment these interactions by including IDP_i that captures whether a child i is IDP or not. $X_{i,d}$ is still a vector of child i and district d controls. We conclude by including district fixed effects.

We hypothesize that higher the number of PTPs in a district higher the probability of IDPs passing through a PTP, and therefore being vaccinated before arriving to host districts. Table 3 shows the results on the policy evaluation. In Panel A, we replicate Panel B of Table 2 to show that, despite the different samples, we still find similar pattern. Although the interaction between the exposed cohort and the IDP variable is statistically insignificant, the signs of the coefficients are consistent across the two tables. The cohort of children exposed to the treatment are more likely to be vaccinated, while this is not the case for IDP children. It is worth mentioning that, while the un-interacted cohort coefficients show similar magnitude between the two tables, the ones related to the interaction between the cohort and the IDP variable show quite a sizeable difference, with the ones from Table 3 being substantially smaller.[38]

In Panel B of Table 3, we formally evaluate the program. The triple interaction between the exposed cohort, the number of PTPs and the IDP variable, yields positive coefficients, which are remarkably stable across columns. The estimates are statistically significant at the 1% level. An additional PTP increases the likelihood of an exposed IDP child being vaccinated by 12.6% (column

[36] We still exclude FATA from the estimating sample.

[37] Waziristan region is divided into two districts: North Waziristan,and Lower South Waziristan District, and Upper South Waziristan District. From 2001 to 2022, 375 out of the 406 (92%) drones hit Waziristan region.

[38] Only a 1% of the interviewed children classifies as IDP. The sample drops from 13,504 to 1,896 observations, which may explain the smaller estimates.

2). Moreover, the fact that the interaction between exposed cohort and the number of PTPs does not show any statistical significance signals that the PTPs target specifically IDP children. Overall, this empirical exercise supports the effectiveness of the PTP program in increasing vaccination against polio in districts subject to IDP inflow. Despite being limited by the geographical sample available, we argue that this empirical exercise is a robust evaluation of the program.

How does the program impact the share of vaccinated children in host communities? After 2008 and before 2012, the average share of vaccinated children in host districts corresponds to 22%. After the program in 2012, the average increases to 27%. These numbers suggest that vaccinating IDP children is can be a key component to interrupt polio transmission.

Polio cases. If the vaccination gap between IDP and natives is the underlying mechanism behind the polio increase, we should expect that closing the gap would lead to a mitigation effect in polio cases. We attempt to look at polio cases in A13 comparing the new polio cases before and after 2012 (the start of the program) by the number of PTPs. When looking at the coefficients related to the $Post\,2012_t * N.\,PTP_d$ interaction, none of the coefficients are statistically significant. This is true also when looking at the $IDPCrisis_t * PredictedInflow_{d,t}$ interaction. Hence, most likely, we are limited by sample size in terms of data coverage of PTPs. However, it is worth noting that all the coefficients relate to the PTPs interaction are negative, suggesting a polio incidence mitigation effect by the program.

Welfare implications. Vaccines have a critical role in improving child health and their far-reaching social and economic benefit (Nandi and Shet 2020). The PTP program, also, directly impacts IDP children's health outcomes. Vaccinating IDP children leads to an improvement in their anthropometric, body mass, and other diseases.

We find that children in host communities born after the arrival of the IDP population have worst anthropometric measures. Panel A of Table 4 shows a negative effect on height-for-age and weight-for-height scores of the under 5-year-old children, with the estimates being statistically significant at the one per cent level.[39] There is also an increase in the probability of children reporting coughing the week before the interview. These results speak to Baez 2011 and Anti and Salemi 2021, who find a worsening of native children's anthropometrics, an increase in diarrhea and fever over one year after refugees arrived. The welfare impacts hide substancial heterogenity between IDP and native children. IDPs experience an additional adverse effects on height-for-age

[39] There are no anthropometric and BMI measures in the 2006 DHS survey, dropping the sample size.

and weight-for-age scores that correspond to a 38% of the average effects. IDP children come from a conflict-affected region where the health systems collapsed, which could explain the gap in health outcomes.

Do the PTP program impact children health outcomes? We expand the evaluation of the program on these outcomes. Panel B of Table 4 displays the results. Importantly, an additional PTP increases the height-for-age and weight-for-height scores of the under 5-year-old IDP children by around 1,000 scores (columns 1 and 2). The estimates are statistically significant at the one per cent level. The program also seems to increase the body mass index of IDP children by 185 points (column 3). An additional PTP also decreases the likelihood of an exposed IDP child to have a cough, fever, and diarrhea by 8%, 7% and 4%, respectively.

Qualitative discussion of costs and benefits. Large-scale vaccination campaigns in crowded refugee and IDP camps are a common strategy employed by governments and international organizations. These programs have proven effective in reaching forcibly displaced populations concentrated in such settings (Chin, Buckee, and Mahmud 2020). However, an increasingly large number of forcibly displaced populations (FDPs) find refuge in communities or informal settlements rather than camps. This trend, as seen with IDPs in Pakistan, presents significant logistical and financial challenges for vaccination efforts due to the dispersed nature of these populations.

Qualitatively discussing the costs and benefits of Pakistan's PTP (Permanent Transit Point) program, establishing permanent vaccination programs at transit points along migration routes offers a highly effective solution. Transit points—border crossings, transportation hubs, and religious sites—act as natural gathering places for FDPs, enabling health workers to reach large numbers of individuals efficiently. Given the mobility and unpredictability of FDPs, transit points provide a rare opportunity to engage with them as they pass through.

Vaccinating at transit points minimizes logistical challenges and reduces the costs associated with reaching dispersed populations in remote areas. These programs can also halt the spread of infectious diseases before they propagate further along migration routes or into host communities. Prevention through vaccination is significantly less costly and logistically easier than responding to outbreaks. By establishing herd immunity in areas with low vaccine coverage, transit-point programs indirectly protect unvaccinated individuals. Additionally, offering vaccines in the local language and cultural context fosters inclusivity and integrates FDPs into broader public health strategies.

Despite their effectiveness, vaccination programs at transit points face substantial logistical and coordination challenges. These include extra investments in refrigeration equipment for cold chains, training health workers, and securing necessary supplies such as vaccines, syringes, and personal protective equipment. Setting up makeshift vaccination stations and ensuring the safety of both health teams and FDPs at each permanent transit point can be costly and complex. Furthermore, collaboration among governments, humanitarian organizations, and local authorities is essential, yet resource-intensive and time-consuming. Transit points also pose challenges for follow-up care and administering booster doses, as FDPs may not return to the same location.

While these programs require significant upfront investment, their long-term benefits outweigh the costs. By preventing disease outbreaks and improving health outcomes, vaccination efforts at transit points enhance the well-being of forcibly displaced populations and strengthen public health security for host communities.

6.2 Other mechanisms

We also study two alternative mechanisms that complement the immunization channel. First, the arrival of IDPs in overcrowded households, where polio can quickly spread. Second, a sudden increase in the demand for health services causes congestion in the local healthcare system, with just a partial response in the supply. Appendix C provides empirical evidence suggesting that the alternative mechanisms could also have a role in the increase in polio incidence in host districts.

7 Conclusion

This paper demonstrates that communities receiving internally displaced persons (IDPs) experienced a notable increase in new polio cases per 100,000 inhabitants. We analysed the mass displacement of 57% of the population from the conflict-affected Federally Administered Tribal Areas (FATA) to other districts in Pakistan between 2008 and 2022. Using a difference-in-differences approach, we compared the incidence of new polio cases in districts closer to and farther from the FATA border before and after 2008.

Our findings indicate that the surge in polio cases in host communities was driven by the arrival of poorly immunized children, whose vaccination schedules were disrupted by the conflict. Refugees and IDPs face significant barriers to accessing immunization services.

We show that targeted vaccination policies for IDP children during their migration journey can be a successful vaccination policy. The Permanent Transit Point program effectively reached IDP children affected by the post-2008 crisis, significantly increasing their likelihood of being vaccinated against polio. Prioritizing the immunization of hard-to-reach populations, such as IDP and refugee children, is essential for public health. Vaccinating the hard to reach as IDPs bring further impact on greater antropometric measures and lower incidence for other diseases. Vaccinated children are more likely to thrive, succeed in education, and lead healthy lives (UNICEF 2023).

Pakistan's situation is not unique. Since 2022, polio outbreaks have re-emerged in places like Malawi, Mozambique, and Gaza—regions that had been polio-free for decades but are now grappling with new displacements due to ongoing conflicts. Our findings extend to other infectious diseases as well. For instance, reaching IDPs and refugees will be essential for malaria eradication efforts, especially with the roll-out of the malaria vaccine in Sub-Saharan Africa beginning in 2023.

Finally, the low vaccination rates among IDP children may stem from various factors, such as inadequate vaccine delivery in conflict zones or low demand from IDP families. The success of the Permanent Transit Point program suggests that increasing vaccine supply enhances the likelihood of IDP children being vaccinated. However, our data does not allow us to assess the program's impact on institutional trust. Future research should explore whether vaccination programs discriminate against IDPs and how these experiences influence IDPs' national identity and trust in government, as well as the potential for rebuilding that trust.

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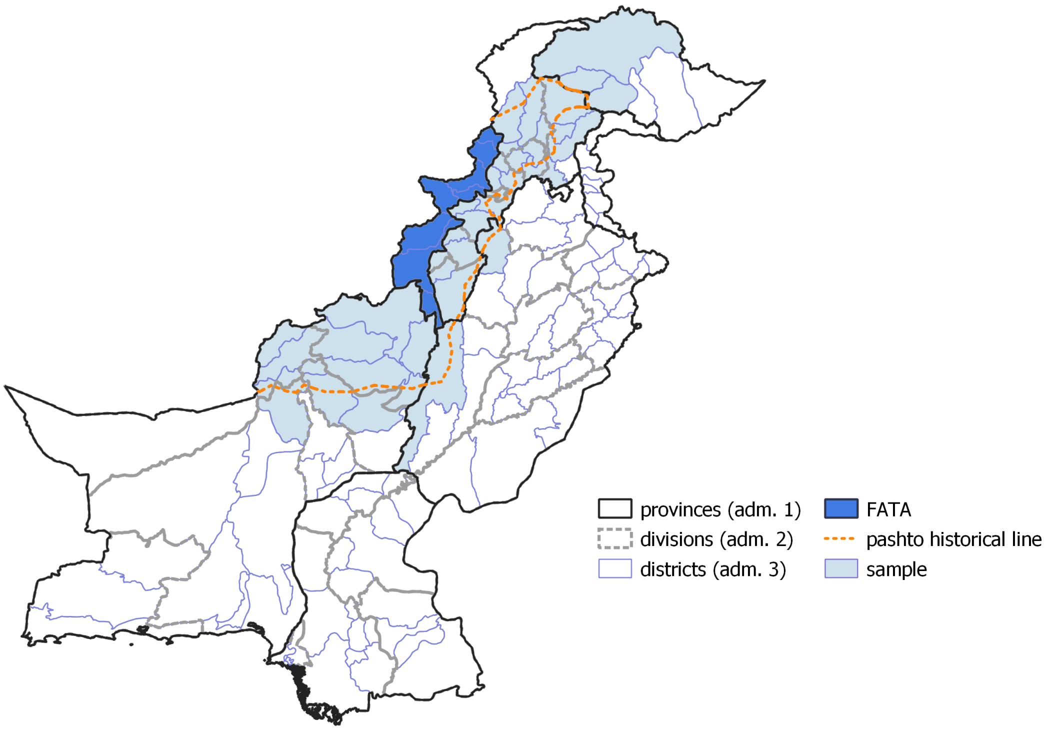
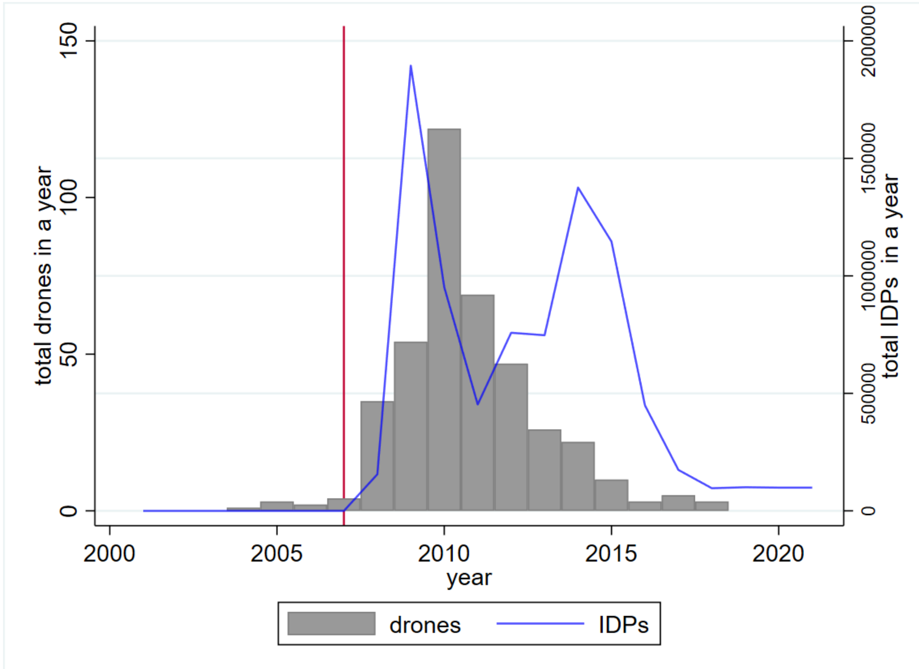
Figures and Tables

Figure 1: Sample districts



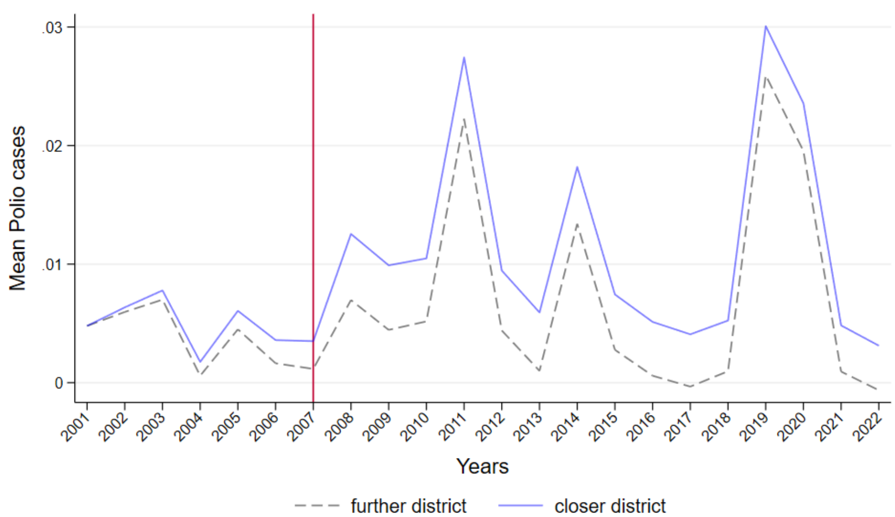
Note: This figure shows the spatial distribution of the main sample. In light blue, we show the districts within the baseline sample. The sample includes the districts that entirely or partially fall within Pashtunistan and that received the internally displaced population (IDPs) from the Federally Administered Tribal Areas (FATA). The region of FATA is in dark blue. The orange line illustrates the pre-colonial region of Pashtunistan. The black line corresponds to the provinces (the first administrative division in Pakistan). The grey line corresponds to division (the second administrative division). The white polygons with purple lines are the districts (the third administrative division).

Figure 2: Total drones strikes and IDP population (2001-2022)



Note: This figure shows the yearly number of drones and internally displaced persons (IDPs) from 2001 to 2022. The grey bars show the number of drones and the blue line the new IDPs. The vertical red line corresponds to 2007.

Figure 3: Polio cases (2001-2022)



Note: this Figure plots the mean polio cases per 100,000 inhabitants in districts closer and further from FATA border, before and after 2008. Closer and further districts are part of the pre-colonial region of Pashtunistan. The red line signals the offset of the IDP crisis.

Figure 4: Permanent Transit Points (PTPs) to vaccinate children on the move

Number of Functional Transit Points bordering NWA			
Province	District	Tehsil	Total
FATA	FR Bannu	FR Bannu	6
FATA	FR D I Khan	FR D.I Khan	2
FATA	FR Tank	FR Tank	2
FATA	Kurram Agency	Central Kurram	2
FATA	Kurram Agency	Lower Kurran	4
KP	Bannu	Bannu	14
KP	D I Khan	D I Khan	11
KP	D I Khan	Daraban	1
KP	D I Khan	Kulachi	1
KP	D I Khan	Paharpur	1
KP	D I Khan	Pariva	1
KP	Hangu	Hangu	6
KP	Hangu	Thall	10
KP	Karak	B D Shah	2
KP	Karak	Karak	5
KP	Karak	Takht e Nasrati	1
KP	Lakki Marwat	Lakki Marwat	6
KP	Lakki Marwat	Sarai Naurang	12
KP	Tank	Tank	9
Total			96

Note: This figure illustrates the functional Permanent Transit Vaccination Points in districts bordering the North Waziristan district. The Pakistan Polio Eradication Programme vaccinates children passing through the Permanent Transit Points (PTPs). There are 500 PTPs across all major transit points nationwide. These PTPs are set up along the country's district borders and other essential transit points such as railway stations, bus stops, and highways. The picture shows the functioning PTPs in blue points in six districts. Source. World Health Organization.

Table 1: Effect of IDP inflow on new polio cases per 100,000 inhabitants

	(1)	(2)	(3)
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.00139**	0.00156***	0.00154**
	(0.00061)	(0.00055)	(0.00058)
N	8713	8713	8713
District FE	No	Yes	Yes
Year FE	No	Yes	Yes
Controls	No	No	Yes
N. of districts	34	34	34
Mean Y	0.007	0.007	0.007

Notes: this Table presents the impacts of the IDP inflows on new polio cases per 100,000 inhabitants (in 2017) in districts closer and further from FATA border, before and after 2008. Districts whose territory falls within the pre-colonial region of *Pashtunistan* are part of the sample. The treatment timing starts in 2008. Observations are at the district and month level from 2001 to 2022. The baseline specification is presented in equation (1). Column (1) presents the results without district, year-month fixed effects and covariates. Column (2) includes district and year-month fixed effects. Column (3) controls for nightlight intensity and total vaccination campaigns. Robust standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table 2: Effect of IDP inflow on vaccination against polio

	(1)	(2)	(3)	(4)	(5)
		Panel A: Cohort specification			
$Cohort_{08}$	0.05028*	0.05668***	0.06659***	0.05376***	0.06179***
	(0.02534)	(0.01831)	(0.01730)	(0.01789)	(0.01674)
		Panel B: Cohort specification, IDP heterogeneity			
$Cohort_{08}$	0.05150*	0.05854***	0.06780***	0.05565***	0.06302***
	(0.02545)	(0.01834)	(0.01716)	(0.01792)	(0.01658)
*$Cohort_{08}$ * IDP*	-0.18126***	-0.17568***	-0.16955***	-0.17523***	-0.17063***
	(0.03580)	(0.03277)	(0.03306)	(0.03350)	(0.03317)
N	13504	13504	13504	13504	13504
District FE	No	Yes	Yes	Yes	Yes
DHS controls	No	No	No	Yes	Yes
Controls	No	No	Yes	No	Yes
N. of districts	38	38	38	38	38
Mean Y	0.219	0.219	0.219	0.219	0.219

Notes: this Table presents the impacts of the IDP inflows on vaccination behaviours at individual level. The dependent variable is a binary variable for being vaccinated, coded to one if the children is vaccinated. In Panel A, we use the date of birth from the Demographic and Health Survey (DHS) from 1998 to 2017 to define an alternative treatment. Children born from January 2008 are exposed to the treatment. Panel B investigates the heterogeneity between native and IDP children. The specification related to panel A and B is presented in equation 3. Column (1) presents the results without covariates and fixed effects; column (2) includes district fixed effects; column (3) controls for nightlight intensity and total vaccination campaigns; columns (4) controls for the head of household, urban location, and gender of the child; column (5) control for the full set of covariates included in columns (3) and (4). Robust standard errors are clustered at the district level. *** p. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Number of PTPs and polio vaccination

	(1)	(2)	(3)	(4)	(5)
Panel A: Cohort specification, IDP heterogeneity					
$Cohort_{08}$	0.07465***	0.08357***	0.08218***	0.08321***	0.06712**
	(0.01701)	(0.01759)	(0.02867)	(0.01751)	(0.02818)
$Cohort_{08}$ * IDP_i	-0.00890	-0.02423	-0.02634	-0.01962	-0.02057
	(0.08347)	(0.08460)	(0.08446)	(0.08218)	(0.08209)
Panel B: PTP and polio vaccination, IDP heterogeneity					
$Cohort_{08}$ * $N.\ PTP_d$	-0.00158	0.00262	0.00300	-0.00104	0.00092
	(0.00549)	(0.00573)	(0.00633)	(0.00587)	(0.00638)
$Cohort_{08}$ * $N.\ PTP_d$ * IDP_i	0.12430***	0.12648***	0.12676***	0.12360***	0.12259***
	(0.03244)	(0.03315)	(0.03322)	(0.03170)	(0.03178)
N	1896	1896	1896	1895	1895
District FE	No	Yes	Yes	Yes	Yes
DHS controls	No	No	No	Yes	Yes
Controls	No	No	Yes	No	Yes
N. of districts	6	6	6	6	6
Mean Y	0.148	0.148	0.148	0.148	0.148

Notes: this Table presents the impact of the Permanent Transit Point program on the probability of vaccinated with polio at individual level. The dependent variable is a binary variable for being vaccinated, coded to one if the child is vaccinated. We measure the impact of the program by counting the number of PTPs in a district. In Panel A, we use the date of birth from the Demographic and Health Survey (DHS) from 1998 to 2017 to define exposure to treatment. Children born from January 2008 are exposed to the treatment. This exposure is interacted with a dummy that captures whether a child is IDP. Panel B investigates the heterogeneity between exposed cohorts and PTPs and IDP children. The specification related to panel A and B is presented in equation 4. Column (1) presents the results without covariates and fixed effects; column (2) includes district fixed effects; column (3) controls for nightlight intensity and total vaccination campaigns; columns (4) controls for the head of household, urban location, and gender of the child; column (5) control for the full set of covariates included in columns (3) and (4). Robust standard errors in parantheses. *** p<0.01, ** p<0.05, * p<0.1

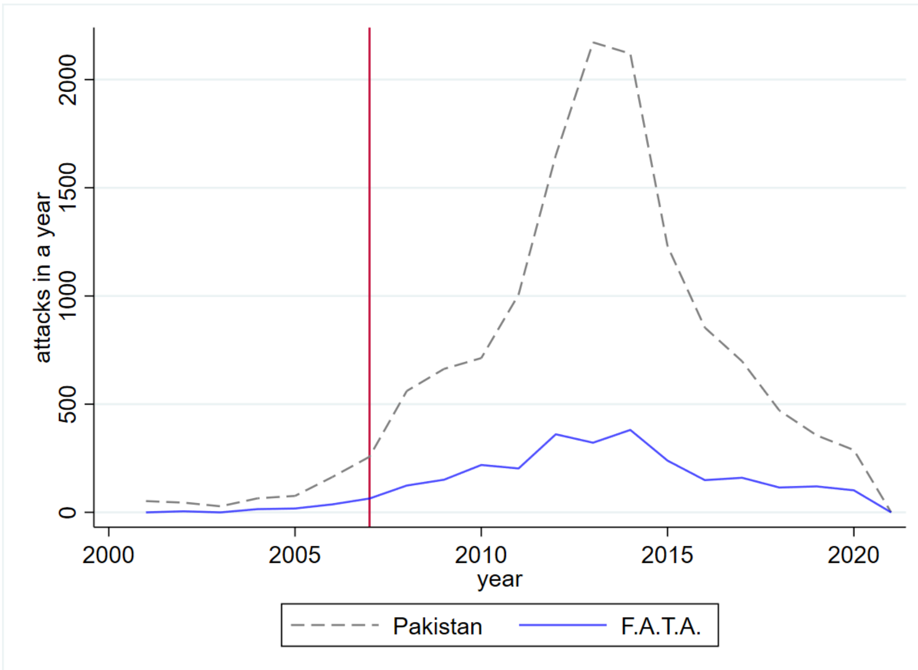
Table 4: Number of PTPs and welfare outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
	Height	Weight	BMI	Cough	Fever	Diarrhea
Panel A: Cohort specification, IDP heterogeneity						
$Cohort_{08}$	-4123.366***	-4236.659***	3284.206***	0.050	-0.011	0.019
	(561.858)	(542.307)	(599.723)	(0.032)	(0.032)	(0.028)
$Cohort_{08}$ * IDP_i	-1570.101**	-1644.537**	-1139.357	-0.030	-0.027	-0.006
	(786.025)	(781.762)	(1725.046)	(0.094)	(0.093)	(0.083)
Panel B: PTP and welfare outcomes, IDP heterogeneity						
$Cohort_{08}$ * $N.\ PTP_d$	-68.446	-56.250	6.197	0.020**	0.011	0.018**
	(143.607)	(141.780)	(298.336)	(0.008)	(0.008)	(0.007)
$Cohort_{08}$ * $N.\ PTP_d$ * IDP_i	991.303***	1003.678***	163.458**	-0.086***	-0.075**	-0.042*
	(167.551)	(165.547)	(75.053)	(0.031)	(0.030)	(0.022)
N	755	755	602	1895	1895	1895
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
N. of districts	6	6	6	6	6	6
Mean Y	0.148	0.148	0.148	0.148	0.148	0.148

Notes: this Table presents the impacts of the number of PTPs on welfare variables at individual level. The dependent variables are: height; weight; Body Mass Index (BMI); dummy if child had cough/fever/diarrhea in the past week. In Panel A, we use the date of birth from the Demographic and Health Survey (DHS) from 1998 to 2017 to define exposure to treatment. Children born from January 2008 are exposed to the treatment. This exposure is interacted with a dummy that captures whether a child is IDP. Panel B investigates the heterogeneity between native and PTPs and IDP children. The specification related to panel A and B is presented in equation 4. Each columns focuses on a specific outcome. Robust standard errors in parantheses. *** p<0.01, ** p<0.05, * p<0.1

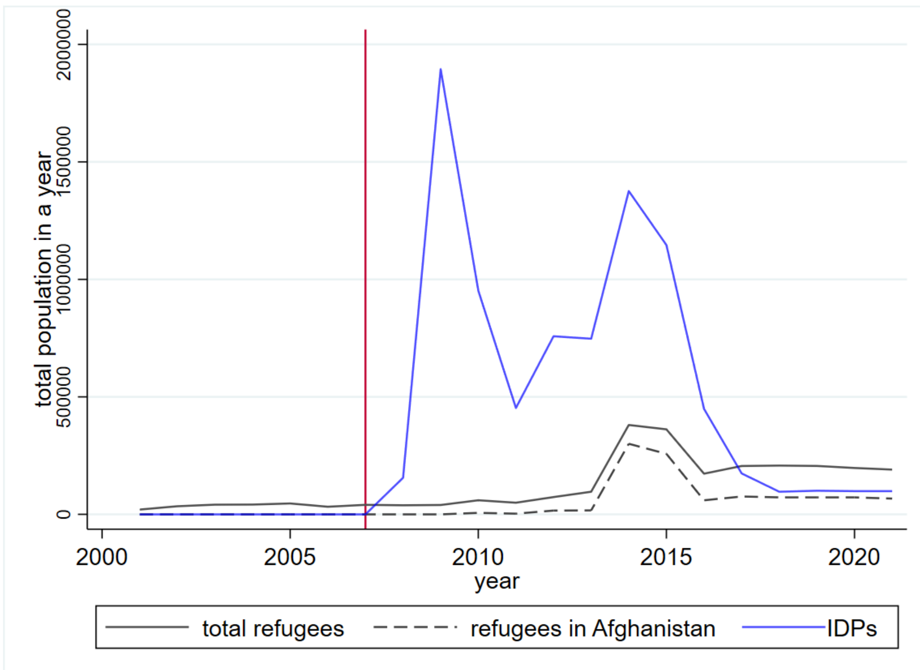
A Additional Figures

Figure A1: Terrorist attacks (2001-2022)



Note: This figure shows the yearly number of terrorist attacks from 2001 to 2022. The grey dashed line for Pakistan and the blue line for FATA The vertical red line corresponds to 2007. Source. The Global Terrorism Database (GTD 2021).

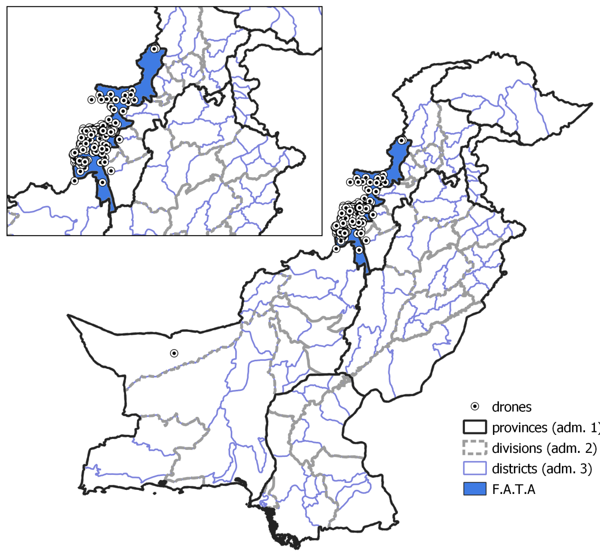
Figure A2: Forcibly displaced population within and outside Pakistan (2001-2022)



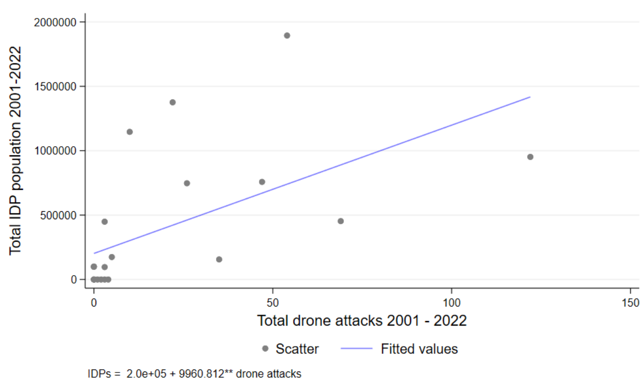
Note: This figure shows the yearly displaced population from Pakistan from 2001 to 2022. The blue line corresponds to the internally displaced persons (IDP). The black line shows the number of Pakistani refugees worldwide. And the black dashed line of the Pakistani refugees in Afghanistan. The vertical red line corresponds to 2007. Source. The United Nations High Commissioner for Refugees (UNHCR 2023).

Figure A3: Drones as a migration push factor

a) Drone strikes locations

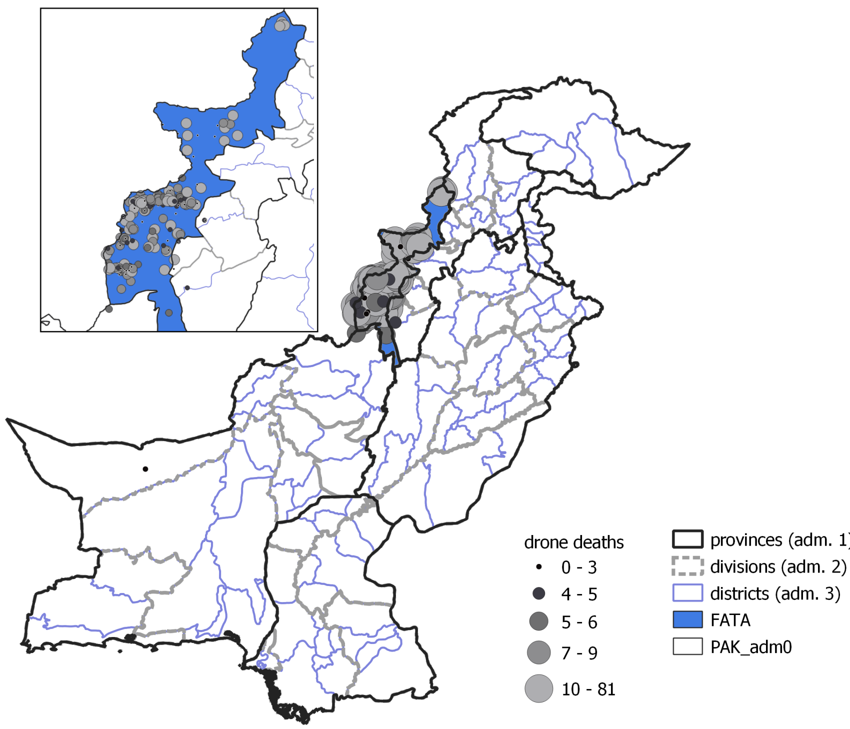


b) Correlation between the number of drones and IDPs



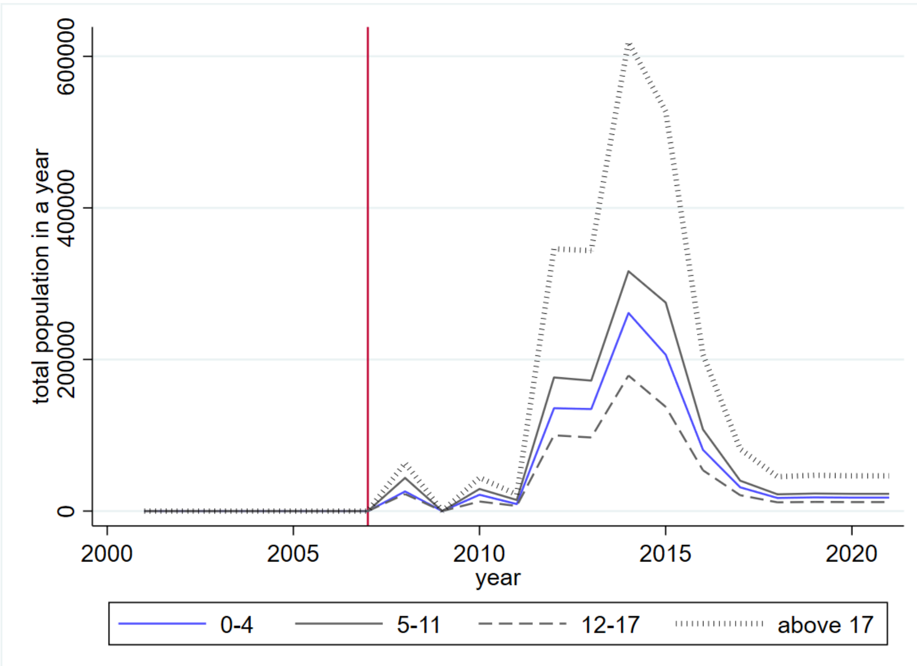
Note: This figure shows the relationship between the intensity of drone strikes and migration. Figure A illustrates the spatial distribution of drones from 2001 to 2022 in Pakistan. The blue polygons correspond to the Federally Administered Tribal Areas (FATA) region. Figure B plots the correlation between the aggregate number of drone attacks and the aggregate IDPs from 2001 to 2022.

Figure A4: Total deaths by drones (2001-2022)



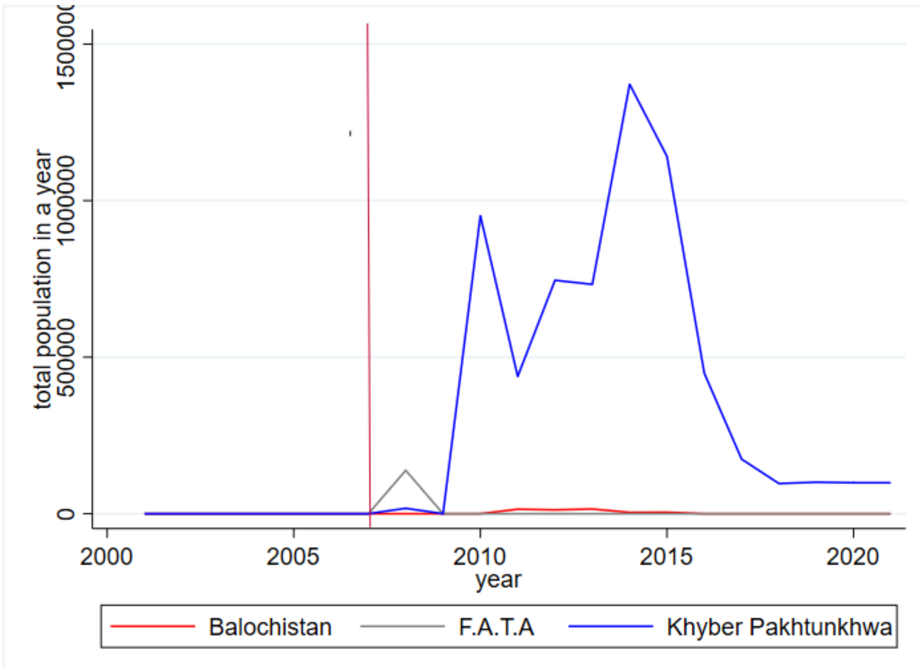
Note: This figure shows the spatial distribution of deaths associated with each drone strike from 2001 to 2022. The higher the dot higher is the total number of deaths. Source. The World of Drones Database developed by New America (New-America 2021).

Figure A5: Internally Displaced Persons by age (2001-2022)



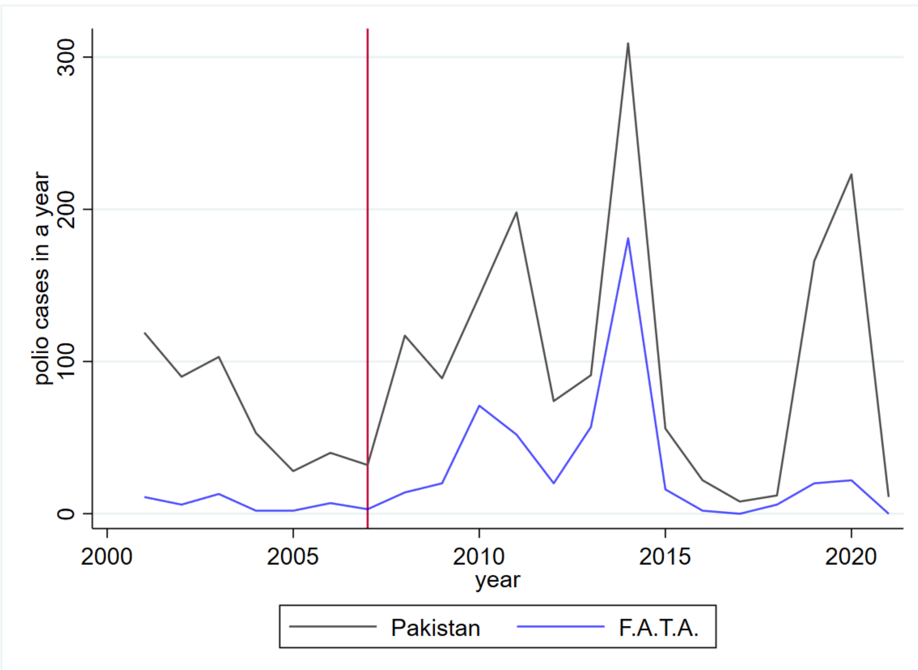
Note: This figure shows the yearly new internally displaced population by age from 2001 to 2022. The blue line corresponds to the ages 0-4, the black line to the ages 5-11, the black dashed line to the ages 12-17 and the black pointed line to the ages above 17. The vertical red line corresponds to 2007. Source. The United Nations High Commissioner for Refugees (UNHCR 2023).

Figure A6: Internally Displaced Population by province



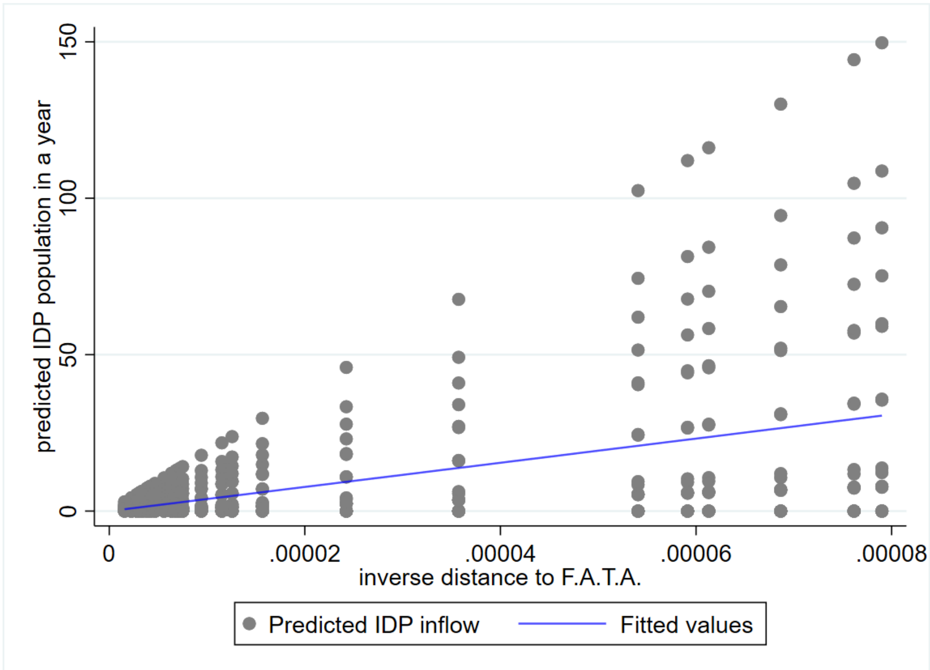
Note: This figure shows the yearly new internally displaced population by province from 2001 to 2022. The red line corresponds to the province of Balochistan, border to Southern FATA. The grey line are the IDPs in FATA The blue line corresponds to Khyber Pakhtunkhwa province. Khyber Pakhtunkhwa is the border of the Eastern and Northern FATA The vertical red line corresponds to 2007. Source. The United Nations High Commissioner for Refugees (UNHCR 2023).

Figure A7: Polio cases in Pakistan and FATA (2001-2022)



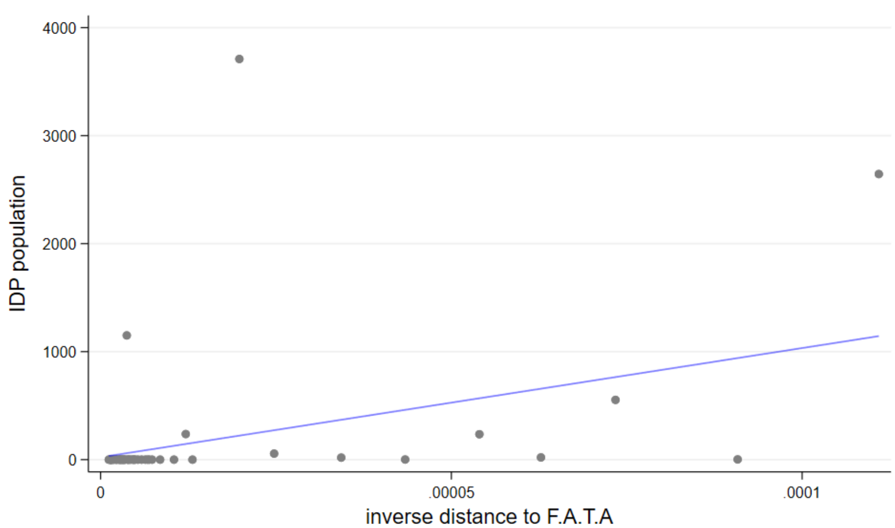
Note: This figure plots the yearly polio cases in Pakistan and FATA. Source. The Polio Eradication Program established by the World Health Organization (WHO).

Figure A8: Inverse distance and predicted inflow



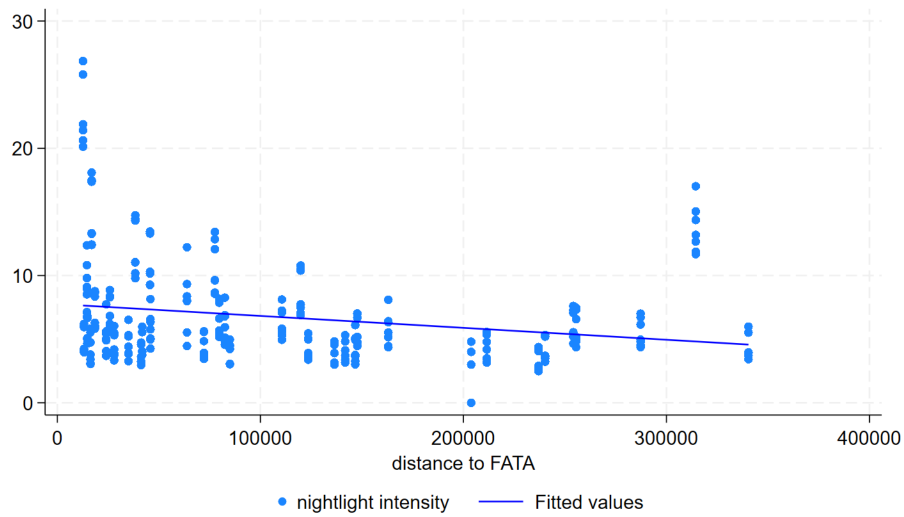
Note: This figure shows the correlation between the predicted inflow measure and the inverse Euclidean distance to the closest FATA border. The predicted inflow measure is equal to the interaction of the inverse distance of each district to the nearest FATA border (district variation) and the total new yearly number of IDP population (annual variation).

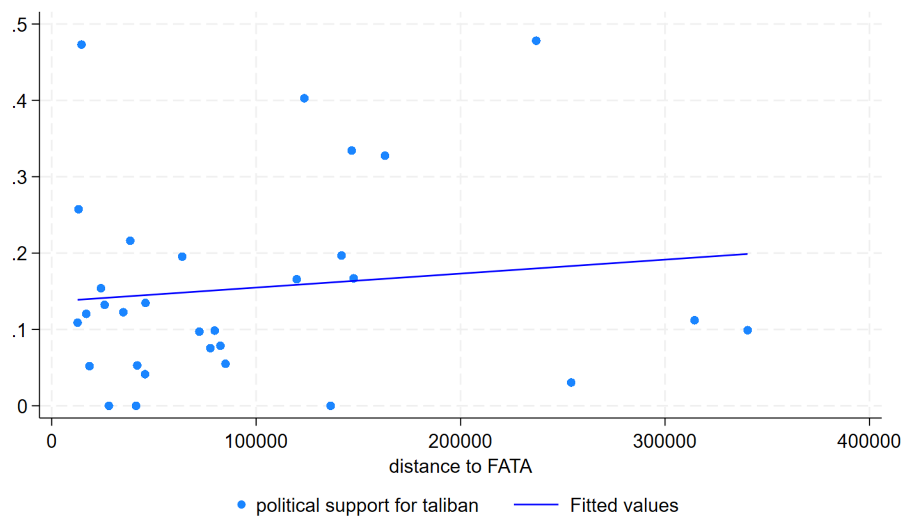
Figure A9: Inversed distance and reported IDPs



Note: This figure shows the correlation between the actual IDP inflow in a district in 2008 and the inverse Euclidean distance to the closest FATA border. The IDP information comes from the United Nations High Commissioner for Refugees - UNHCR (UNHCR 2023).

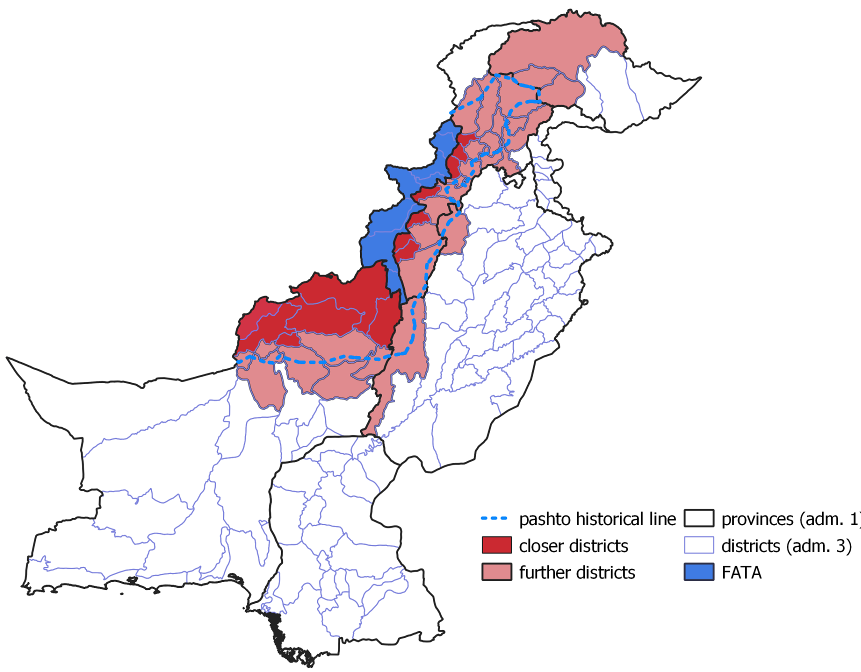
Figure A10: Economic and political characteristics along distance to FATA





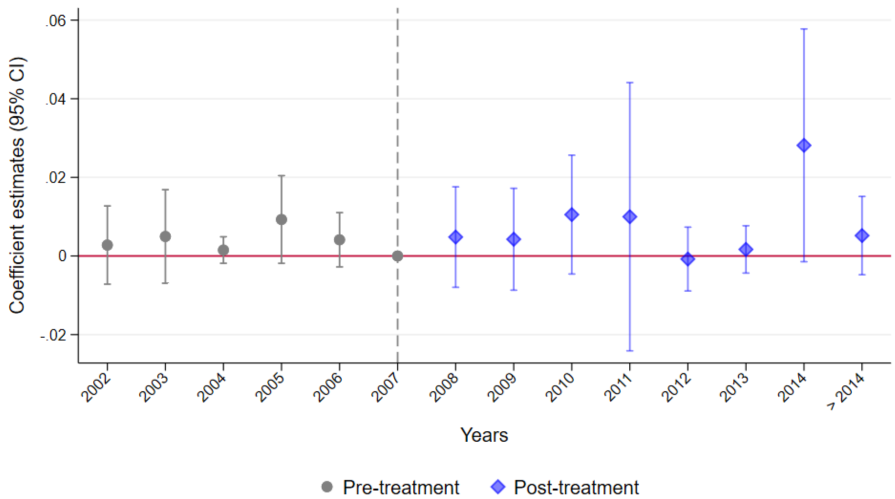
Note: This figure shows the correlation between distance to FATA (in meters) and some sociodemographic characteristics. In the first figure, we plot nightlight intensity from 2000 to 2007. In the second figure we plot the political support for taliban at the national election in 2008.

Figure A11: Closer and Further districts



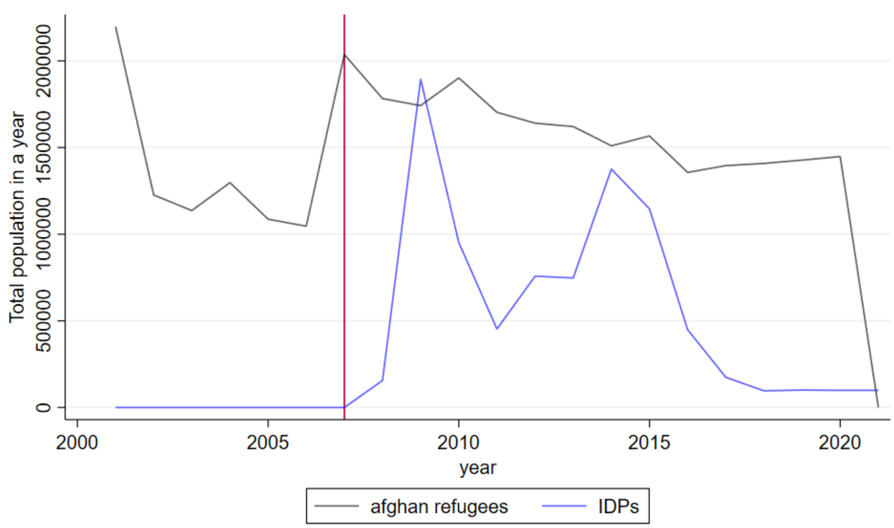
Note: This figure shows treated (host) and control (non-host) districts. To define them, we use the spatial distribution of districts relative to the pre-colonial region of Pashtunistan. The red line corresponds to the Pashtunistan's border. Districts whose territory falls within the pre-colonial region of Pashtunistan are host districts. Non-host districts are those whose territory is outside Pashtunistan but adjacent to the historical border.

Figure A12: Event study



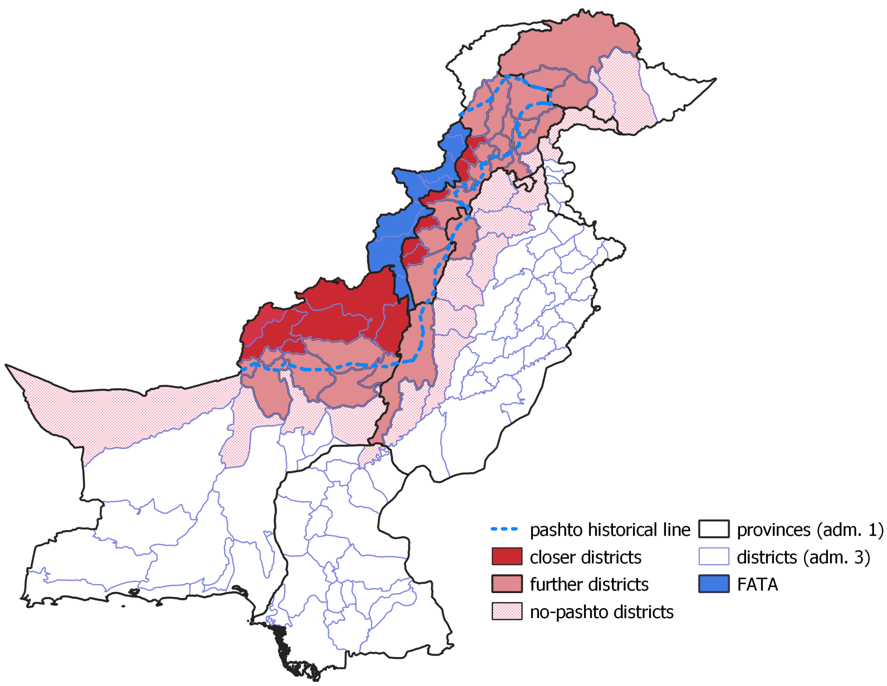
Note: the figure shows the coefficients estimates resulting from the event-study specification in Equation 2. The confidence intervals are 95%. The omitted year is 2007, which is a year before the beginning of the IDP crisis. The dataset is in a year-district panel format. The vertically dotted grey line at the year 2007 signals the start of the IDP crisis.

Figure A13: Afghan refugees (2001-2022)



Note: This figure shows the yearly new IDPs and Afghan refugees in Pakistan from 2001 to 2022. The blue line corresponds to the IDPs. The black line indicates the number of Afghan refugees in Pakistan. The vertical red line corresponds to 2007. Source. The United Nations High Commissioner for Refugees (UNHCR 2023).

Figure A14: Alternative treated and control districts



Note: This figure shows the districts partially within Pashtunistan. To define them, we use the spatial distribution of districts relative to the pre-colonial region of Pashtunistan. The red line corresponds to the Pashtunistan's border. The districts overlapping the border are the red dashed polygons, with only a share of the territory is in Pashtunistan. Districts whose territory falls within the pre-colonial region of Pashtunistan are host districts. Non-host districts are those whose territory is outside Pashtunistan but adjacent to the historical border.

B Additional Tables

Table A1: Aggregate IDPs by district of origin (2001-2022)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Province and Division	Position	District	IDP families	IDP individuals	Drones	Total deaths
F.A.T.A	Southern	North Waziristan	108,149	648,894	291	2003
F.A.T.A	Southern	South Waziristan	71,124	426,744	84	678
F.A.T.A	Southern	Largha Shirani	0	0	1	6
F.A.T.A	Northern	Bajaur	72,895	437,370	4	128
F.A.T.A		Khyber	91,689	550,134	6	61
F.A.T.A		Kurram	33,024	198,144	9	83
F.A.T.A		Mohmand	36,759	220,554	0	0
F.A.T.A		Orakzai	35,823	214,938	1	13
N.W.F.P.	Southern	Tank	2,256	13,536	1	5
TOTAL			451,719	2,710,314	396	2,971

Note: This Table shows the aggregate number of internally displaced persons (IDP) from 2001 to 2022 by district of origin. The IDP data source is UNHCR 2023. Columns (6) and (7) present the aggregate number of drones and the number of deaths created from 2001 to 2022 from New-America 2021.

Table A2: Total IDPs by district of destination in 2008

(1)	(2)	(3)	(4)
Province	District	2008	share
Khyber Pakhtunkhwa (NWFP)	Adam Khel	1168	0.007
Khyber Pakhtunkhwa (NWFP)	Charsadda	187	0.001
Khyber Pakhtunkhwa (NWFP)	Dir	190	0.001
Khyber Pakhtunkhwa (NWFP)	Hangu	63	0.000
Khyber Pakhtunkhwa (NWFP)	Kohat	1237	0.008
Khyber Pakhtunkhwa (NWFP)	Peshawar	21	0.000
Khyber Pakhtunkhwa (NWFP)	Swat	15639	0.100
Khyber Pakhtunkhwa (FATA)	Bajaur	114717	0.736
Khyber Pakhtunkhwa (FATA)	Khyber	110	0.001
Khyber Pakhtunkhwa (FATA)	Kurram	5275	0.034
Khyber Pakhtunkhwa (FATA)	Mohmand	15516	0.100
Khyber Pakhtunkhwa (FATA)	N. Waziristan	11	0.000
Khyber Pakhtunkhwa (FATA)	Orakzai	1632	0.010
Khyber Pakhtunkhwa (FATA)	S. Waziristan	43	0.000
TOTAL		155809	

Note: This Table shows the total number of internally displaced persons (IDP) from 2008 to 2015 by district of destination. The IDP data source is UNHCR 2023. There are no data for 2009 and after 2015.

Table A3: Pre-treatment characteristics in 1998, closer vs further districts

Variable	(1) Furhter	(2) Closer	(3) Diff. (1)-(2)
Monthly new polio cases (2001-2007, 100'000 inh.)	0.004	0.005	0.002
	(0.029)	(0.035)	(0.002)
Monthly polio campaigns	0.702	0.702	0.000
	(0.458)	(0.457)	(0.000)
Night light intensity	6.518	7.831	1.313
	(3.119)	(5.841)	(1.759)
Area (km^2)	4229.935	4528.833	298.898
	(2461.401)	(5472.389)	(1687.938)
Avg. household size (1998)	7.750	8.346	0.596
	(0.975)	(1.098)	(0.384)
Growth rate (1998-1981)	2.726	2.576	-0.150
	(0.918)	(1.040)	(0.363)
Literacy Ratio (1998)	31.865	30.452	-1.412
	(12.674)	(8.863)	(3.774)
Pop. density (1998)	245.394	379.288	133.893
	(215.432)	(475.386)	(146.778)
Population (1981)	399391.125	348773.656	-50617.465
	(241097.875)	(305426.750)	(103478.500)
Population (1998)	650961.188	578396.375	-72564.805
	(374339.781)	(561508.562)	(183186.297)
Sex ratio (1998)	107.291	110.121	2.829
	(7.903)	(6.374)	(2.531)
Houses with electricity (1998)	62.952	75.681	12.729
	(25.168)	(20.595)	(8.123)
Houses with piped water (1998)	27.981	29.165	1.184
	(15.540)	(12.594)	(4.989)
Houses using gas for cooking (1998)	8.314	7.969	-0.345
	(16.118)	(12.263)	(5.004)
Rural population (1998)	84.060	83.247	-0.813
	(15.105)	(12.792)	(4.970)
Urban population (1998)	15.191	16.604	1.413
	(15.434)	(12.837)	(5.026)
Observations	1849	1008	2857

Notes: this Table reports a balancing test on a series of district characteristics of the sample considered in the main analysis. The balancing test covers the 34 districts in the sample. Pre-treatment characteristics are from the 1998 Population Census and the polio cases and campaigns from the Polio Eradication Program from 2001 to 2007. District clustered standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table A4: ffect of IDP inflow on new polio cases per 100,000 inhabitants

	(1)	(2)	(3)
Panel A: controlling for terrorist attacks			
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.00095	0.00120**	0.00119**
	(0.00060)	(0.00049)	(0.00052)
Panel B: controlling for distance to the latest drone attack			
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.00201***	0.00171***	0.00167***
	(0.00072)	(0.00058)	(0.00061)
N	7359	7359	7359
District FE	No	Yes	Yes
Year FE	No	Yes	Yes
Controls	No	No	Yes
N. of districts	34	34	34
Mean Y	0.008	0.008	0.008

Notes: this Table presents the impacts of the IDP inflows on new polio cases per 100,000 inhabitants (in 2017) in districts closer and further from FATA border, before and after 2008. Districts whose territory falls within the pre-colonial region of *Pashtunistan* are part of the sample. The treatment timing starts in 2008. Observations are at the district and month level from 2001 to 2022. The baseline specification is presented in equation (1). Column (1) presents the results without district, year-month fixed effects and covariates. Column (2) includes district and year-month fixed effects. Column (3) controls for nightlight intensity and total vaccination campaigns. Panel A controls for the number of terrorist attacks, while Panel B controls for the distance to the latest drone attack. Robust standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table A5: Potential Afghan refugees effect

	(1)	(2)	(3)
Panel A: controlling for total afghan refugees			
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.00139*	0.00159***	0.00157**
	(0.00071)	(0.00056)	(0.00059)
Panel B: number of refugee camps fixed effects			
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.00139**	0.00156***	0.00154**
	(0.00061)	(0.00055)	(0.00058)
N	8713	8713	8713
District FE	No	Yes	Yes
Year FE	No	Yes	Yes
Controls	No	No	Yes
N. of districts	34	34	34
Mean Y	0.007	0.007	0.007

Notes: this Table presents the impacts of the IDP inflows on new polio cases per 100,000 inhabitants (in 2017) in districts closer and further from FATA border, before and after 2008. Districts whose territory falls within the pre-colonial region of *Pashtunistan* are part of the sample. The treatment timing starts in 2008. Observations are at the district and month level from 2001 to 2022. The baseline specification is presented in equation (1). Column (1) presents the results without district, year-month fixed effects and covariates. Column (2) includes district and year-month fixed effects. Column (3) controls for nightlight intensity and total vaccination campaigns. Panel A controls for the number of total afghan refugees in a district year-month, while Panel B includes the number of refugees camps fixed effects. Robust standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table A6: Potential international migration effects

	(1)	(2)	(3)
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.00197**	0.00156***	0.00154**
	(0.00076)	(0.00055)	(0.00058)
N	8713	8713	8713
District FE	No	Yes	Yes
Year FE	No	Yes	Yes
Controls	No	No	Yes
N. of districts	34	34	34
Mean Y	0.007	0.007	0.007

Notes. This Table presents the impacts of the IDP inflows on new polio cases per 100,000 inhabitants (in 2017) in districts closer and further from FATA border, before and after 2008. Districts whose territory falls within the pre-colonial region of *Pashtunistan* are part of the sample. The treatment timing starts in 2008. Observations are at the district and month level from 2001 to 2022. The baseline specification is presented in equation (1). Column (1) presents the results without district, year-month fixed effects and covariates. Column (2) includes district and year-month fixed effects. Column (3) controls for nightlight intensity and total vaccination campaigns. Controls include the total number of new Pakistani refugees abroad interacted with year fixed effects. Robust standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table A7: Potential Taliban support effects

	(1)	(2)	(3)
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.00278***	0.00163***	0.00162***
	(0.00088)	(0.00055)	(0.00058)
N	8185	8185	8185
District FE	No	Yes	Yes
Year FE	No	Yes	Yes
Controls	No	No	Yes
N. of districts	34	34	34
Mean Y	0.007	0.007	0.007

Notes: this Table presents the impacts of the IDP inflows on new polio cases per 100,000 inhabitants (in 2017) in districts closer and further from FATA border, before and after 2008. Districts whose territory falls within the pre-colonial region of *Pashtunistan* are part of the sample. The treatment timing starts in 2008. Observations are at the district and month level from 2001 to 2022. The baseline specification is presented in equation (1). Column (1) presents the results without district, year-month fixed effects and covariates. Column (2) includes district and year-month fixed effects. Column (3) controls for nightlight intensity and total vaccination campaigns. All columns control for the votes share of the Islamist coalition in a district in the 2008 elections, interacted with year dummies. Robust standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table A8: Falsification test: effects one year before treatment

	(1)	(2)	(3)
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.00014	0.00000	-0.00013
	(0.00031)	(0.00013)	(0.00017)
N	8713	8713	8713
Division FE	No	Yes	Yes
Year-month FE	No	Yes	Yes
Controls	No	No	Yes
N. of districts	34	34	34
Mean Y	0.007	0.007	0.007

Notes: this Table presents the impacts of the IDP inflows on the average new polio cases per 100,000 inhabitants before 2008 in districts closer and further from FATA border, before and after 2008. Districts whose territory falls within the pre-colonial region of *Pashtunistan* are part of the sample. The treatment timing starts in 2008. Observations are at the district and month level from 2001 to 2022. The baseline specification is presented in equation (1). Column (1) presents the results without district, year-month fixed effects and covariates. Column (2) includes district and year-month fixed effects. Column (3) controls for nightlight intensity and total vaccination campaigns. Robust standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table A9: Potential reverse causality: post-crisis predicted inflow and pre-crisis yearly polio cases

	(1)	(2)	(3)
$Polio\ Cases_{d,tm\text{-}2001\text{-}2007}$	0.01711	0.01532	-0.01845
	(0.02595)	(0.02286)	(0.02311)
N	7020	7020	7020
Division FE	No	Yes	Yes
Year-month FE	No	Yes	Yes
Controls	No	No	Yes
N. of divisions	14	14	14
Mean Y	0.009	0.009	0.009

Notes: this Table presents the relationship between $IDP\ Crisis_t$ * $Predicted\ Inflow_{d,t}$ and the number of polio cases in district d, before the IDP crisis kicked in. Districts whose territory falls within the pre-colonial region of *Pashtunistan* are part of the sample. The treatment timing starts in 2008. Observations are at the district and month level from 2008 to 2022. The baseline specification is presented in equation (1). Column (1) presents the results without division, year-month fixed effects and covariates. Column (2) includes division and year-month fixed effects. Column (3) controls for nightlight intensity and total vaccination campaigns. Robust standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table A10: Alternative sample definition

	(1)	(2)	(3)
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.00175***	0.00148***	0.00148**
	(0.00061)	(0.00053)	(0.00056)
N	12673	12673	12673
District FE	No	Yes	Yes
Year-month FE	No	Yes	Yes
Controls	No	No	Yes
N. of districts	48	48	48
Mean Y	0.006	0.006	0.006'

Notes: this Table presents the impacts of the IDP inflows on new polio cases per 100,000 inhabitants (in 2017) in districts closer and further from FATA border, before and after 2008. The alternative sample definition consist in districts whose territory falls either within or those adjacent to outside the pre-colonial region of *Pashtunistan*. The treatment timing starts in 2008. Observations are at the district and month level from 2001 to 2022. The baseline specification is presented in equation (1). Column (1) presents the results without district, year-month fixed effects and covariates. Column (2) includes district and year-month fixed effects. Column (3) controls for nightlight intensity and total vaccination campaigns. Robust standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table A11: Alternative outcomes

	(1)	(2)	(3)
	Panel A: *Pr(new polio case) = 1*		
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.02199*	0.01599*	0.01641*
	(0.01092)	(0.00907)	(0.00947)
N	8713	8713	8713
	Panel B: polio cases per 100,000 inhabitants (1998)		
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.00247*	0.00252*	0.00254
	(0.00111)	(0.00130)	(0.00147)
N	2904	2904	2904
District FE	No	Yes	Yes
Year FE	No	Yes	Yes
Controls	No	No	Yes
N. of districts	34	34	34
Mean Y	0.010	0.010	0.010

Notes: this Table presents the impacts of the IDP inflows on: the probability of observing a new polio case in a district and year-month; the new polio cases per 100,000 inhabitants (in 1998); in districts closer and further from FATA border, before and after 2008. Districts whose territory falls within the pre-colonial region of *Pashtunistan* are part of the sample. The treatment timing starts in 2008. Observations are at the district and month level from 2001 to 2022. The baseline specification is presented in equation (1). Column (1) presents the results without district, year-month fixed effects and covariates. Column (2) includes district and year-month fixed effects. Column (3) controls for nightlight intensity and total vaccination campaigns. Robust standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table A12: Additional set of fixed effects

	(1)	(2)	(3)
Panel A: province linear trends			
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.00139**	0.00150**	0.00150**
	(0.00061)	(0.00056)	(0.00059)
Prov. lin. trends FE	No	Yes	Yes
Panel B: division linear trends			
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.00139**	0.00137**	0.00137**
	(0.00061)	(0.00063)	(0.00064)
N	8713	8713	8713
Dist. lin. trends FE	No	Yes	Yes
District FE	No	Yes	Yes
Year-month FE	No	Yes	Yes
Controls	No	No	Yes
N. of districts	34	34	34
Mean Y	0.007	0.007	0.007

Notes: this Table presents the impacts of the IDP inflows on new polio cases per 100,000 inhabitants (in 2017) in districts closer and further from FATA border, before and after 2008. Districts whose territory falls within the pre-colonial region of *Pashtunistan* are part of the sample. The treatment timing starts in 2008. Observations are at the district and month level from 2001 to 2022. The baseline specification is presented in equation (1). Column (1) presents the results without district, year-month fixed effects and covariates. Column (2) includes district and year-month fixed effects. Column (3) controls for nightlight intensity and total vaccination campaigns. Panel A includes province linear trends, Panel B includes division linear trends and Panel C includes district linear trends. Robust standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table A13: Effect of PTPs on new polio cases per 100,000 inhabitants

	(1)	(2)	(3)
*IDP Crisis$_t$ * Predicted Inflow$_{d,t}$*	0.00159	0.00623	0.00611
	(0.00080)	(0.00399)	(0.00424)
*Post 2012$_t$ * N. PTP$_d$*	-0.00026	-0.00044	-0.00048
	(0.00028)	(0.00039)	(0.00039)
N	1584	1584	1584
District FE	No	Yes	Yes
Year FE	No	Yes	Yes
Controls	No	No	Yes
N. of districts	34	34	34
Mean Y	0.015	0.015	0.015

Notes. This Table presents the impacts of the PTP policy on new polio cases per 100,000 inhabitants (in 2017) in districts closer and further from FATA border, before and after 2008. Districts whose territory falls within the pre-colonial region of *Pashtunistan* are part of the sample. The treatment timing starts in 2012. Observations are at the district and month level from 2001 to 2022. The baseline specification is presented in equation (1). Column (1) presents the results without district, year-month fixed effects and covariates. Column (2) includes district and year-month fixed effects. Column (3) controls for nightlight intensity and total vaccination campaigns. Robust standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

C Additional Mechanisms

Household Conditions in Overcrowded Communities. Most IDP families migrated to informal settlements, Pashtun slums, or into squeezed houses of friends or relatives. Access to safe drinking water and hygiene was a major problem for them. Appropriate facilities for bathing, doing laundry or keeping personal hygiene were not always available, facilitating the transmission of polio (IDMC 2015).

One crucial question is whether IDPs settle in poorer locations or if the living conditions get worse with the sudden arrival of IDPs. The balancing exercise of Table A14 suggests that IDP population does not necessarily move to the poorest locations, but to more overcrowded settings. Table A14 also shows how the number of household members and children under five was higher in host districts closer to the FATA border before 2008. Moreover, Table A14 presents evidence that households in closer districts were also more likely to have toilet and television, and children are more likely to have a fever in the last week of the interview and less likely to be a girl. These pre-treatment characteristics may be a key channel behind the main results and, as well, a vital identification threat. Even if we control for local economic development, we cannot ensure that our estimates capture the actual impact of IDP inflow rather than the pre-treatment differences in disadvantages characteristics. Nonetheless, what is certain is that crowded households cannot respond efficiently to an IDP inflow (Brotherhood et al. 2022). As a result, crowded families are systematically more affected by the waves of displaced persons. Keeping this limitation in mind, how does the arrival of IDPs affect socio-demographic health conditions? To shed light on this question, we estimate Equation 3 on six outcomes related to household conditions in host communities: access to drinkable water, access to a toilet, floor quality, number of children under five, household members, and head of the household's working status. We also look at whether exposed cohorts had higher likelihood of being sick, by inspecting two more variables: the probability of either having fever of diarrhea in the past week.

Table A14: Pre-treatment individual characteristics, closer vs further districts

	(1)	(2)	(3)
	Further	Closer	Diff
polio vaccine	0.182	0.210	0.011
	(0.386)	(0.407)	(0.044)
doctor prenatal	0.208	0.256	0.044
	(0.406)	(0.436)	(0.050)
doctor assistance	0.161	0.214	0.049
	(0.368)	(0.411)	(0.035)
diarrhea	0.137	0.146	0.017
	(0.344)	(0.353)	(0.021)
fever	0.219	0.252	0.034*
	(0.414)	(0.434)	(0.019)
water piped	0.522	0.615	0.094
	(0.500)	(0.487)	(0.067)
toilet	0.311	0.456	0.158**
	(0.463)	(0.498)	(0.064)
floor	0.313	0.390	0.079
	(0.464)	(0.488)	(0.073)
television	0.352	0.485	0.139**
	(0.478)	(0.500)	(0.066)
watch tv every week	0.261	0.425	0.181**
	(0.439)	(0.495)	(0.072)
radio	0.437	0.488	0.040
	(0.496)	(0.500)	(0.039)
n. number children under 5	2.597	3.073	0.467***
	(1.538)	(2.045)	(0.118)
n. number household members	9.890	11.309	1.493**
	(5.442)	(6.494)	(0.685)
mother education level	0.302	0.374	0.091
	(0.713)	(0.785)	(0.082)
head working	0.112	0.072	-0.010
	(0.315)	(0.258)	(0.018)
head women	0.076	0.033	-0.049***
	(0.265)	(0.178)	(0.017)
urban	0.382	0.544	0.161
	(0.486)	(0.498)	(0.149)
girl	0.493	0.471	-0.027**
	(0.500)	(0.499)	(0.013)
pashtu	0.677	0.886	0.147
	(0.468)	(0.318)	(0.103)
Observations	4,043	2,290	6,333

Note: This table reports descriptive statistics for the main variables and sample considered in the baseline analysis. The analysis covers 39 district from 2001 to 2007 at the monthly level. Pretreatment characteristics are from the 1991-1992 and 2006-2007 Demographic and Health Survey (DHS).

Table A15: Effect of IDP inflow on household's conditions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Water	Toilet	Floor	N. children	N. members	Fever	Diarrhea
Panel A: Cohort specification							
$Cohort_{08}$	-0.18960***	0.34788***	-0.11047**	-0.08845	-0.04376	0.10224***	0.03796
	(0.04391)	(0.04732)	(0.05293)	(0.08981)	(0.37481)	(0.02466)	(0.02600)
Panel B: Cohort specification, IDP heterogeneity							
$Cohort_{08}$	-0.18834***	0.34904***	-0.10961**	-0.10106	-0.10160	0.10364***	0.03841
	(0.04399)	(0.04656)	(0.05243)	(0.08893)	(0.37299)	(0.02462)	(0.02606)
$Cohort_{08}$ * IDP	-0.15579**	0.03560	-0.00109	0.80749	4.50835***	-0.07048	0.03577
	(0.06821)	(0.13249)	(0.15995)	(0.49851)	(0.79413)	(0.06229)	(0.03926)
N	13504	13504	9548	13504	13504	13504	13504
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DHS controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N. of districts	38	38	38	38	38	38	38

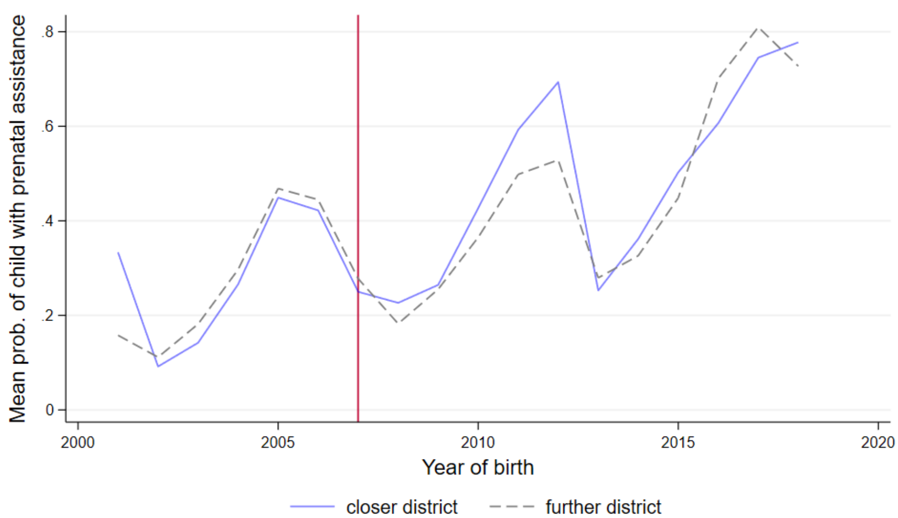
Notes: This Table presents the impacts of the IDP inflows on household characteristics. There are seven different dependent variables: access to drinkable water (column 1), access to a toilet (column 2), floor quality (column 3), number of children under five (column 4), households member (column 5), fever in the last week (column 6), diarrhea in the last week (column 7). The dependent variables are a binary, coded to one if the household has a certain characteristic. In Panel A, we use the date of birth from the Demographic and Health Survey (DHS) from 1998 to 2017 to define an alternative treatment. Children born from January 2008 are exposed to the treatment. Panel B investigates the heterogeneity between native and IDP children. The specification related to panel A and B is presented in equation in Equation 3. Standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Table A15 in Panel A shows that children exposed to the IDP crisis live in a household with less likely access to drinkable water, more likely access to a toilet with lower floor quality, and more likely to have fever in the last week. No effect is found concerning the number of children, members within the household and the likelihood of having diarrhea. Panel B investigate heterogeneous effects between native and IDP children. Notably, we find that IDP children have a lower likelihood of having access to drinkable water and live in households with more members. Specifically to this last result, IDP children live in households with roughly 4.5 additional members if compared to native children. Ending up in overcrowded households can be a vehicle for the spread of the polio virus.

Congestion of Health Services. The sudden arrival of IDP families could create logistical hurdles in health service delivery. The increased demand for healthcare services could have caused additional strain on the local infrastructure, which was often hardly adequate even for the needs of the local population (Din 2010). Host districts with an unstable access to health services could affect the incidence of polio.

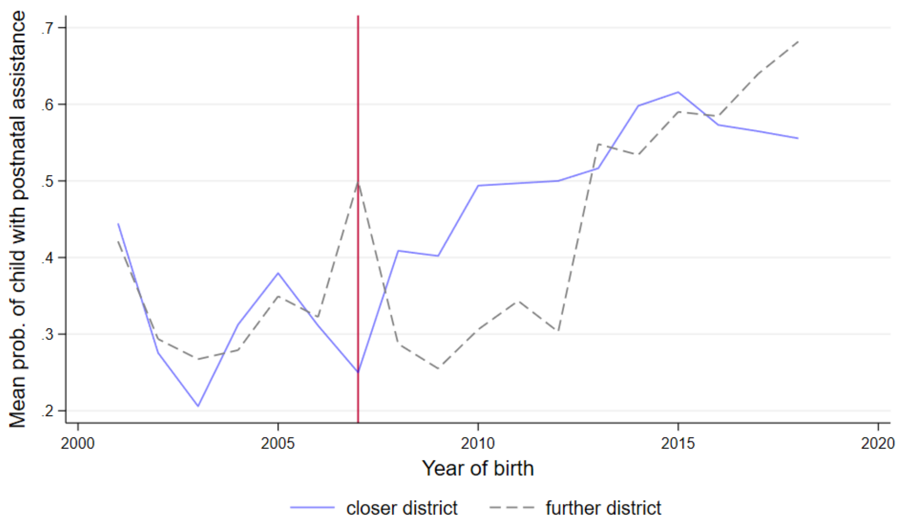
Having data on the aggregate demand for health services would enable us to shed some light on the potential changes created by IDP inflow. Unfortunately, this information is not available. We can only capture the individual demand by using individual-level data on prenatal and postnatal doctor assistance from the DHS. Figure A15 and Figure A16 illustrate an increase in the share of children with both prenatal and postnatal assistance after 2007 in closer districts relative to further ones. To complement the descriptive analysis, we repeat Equation 3 with the prenatal and postnatal doctor assistance outcomes. Results in Table A16 point out that children exposed to the IDP crisis have a higher likelihood of needing pre- and post-natal assistance. There are no heterogeneous effects between IDP and native children (see columns 2 and 4).

Figure A15: Probability of children with prenatal assistance



Note: This figure plots the mean probability of having a child with prenatal assistance in treated and control districts by the year of birth cohort. Treated districts are the host districts and control districts are the non-host districts. Districts whose territory falls within the pre-colonial region of Pashtunistan are host districts. Non-host districts are those whose part is outside Pashtunistan but adjacent to the historical border. The vertical red line corresponds to 2007. Source. Demographic and Health Survey (DHS).

Figure A16: Probability of children with postnatal assistance



Note: This figure plots the mean probability of having a child with postnatal assistance in treated and control districts by the year of birth cohort. Treated districts are the host districts and control districts are the non-host districts. Districts whose territory falls within the pre-colonial region of Pashtunistan are host districts. Non-host districts are those whose part is outside Pashtunistan but adjacent to the historical border. The vertical red line corresponds to December 2007. Source. Demographic and Health Survey (DHS).

Table A16: Effect of IDP inflow on the demand of health services

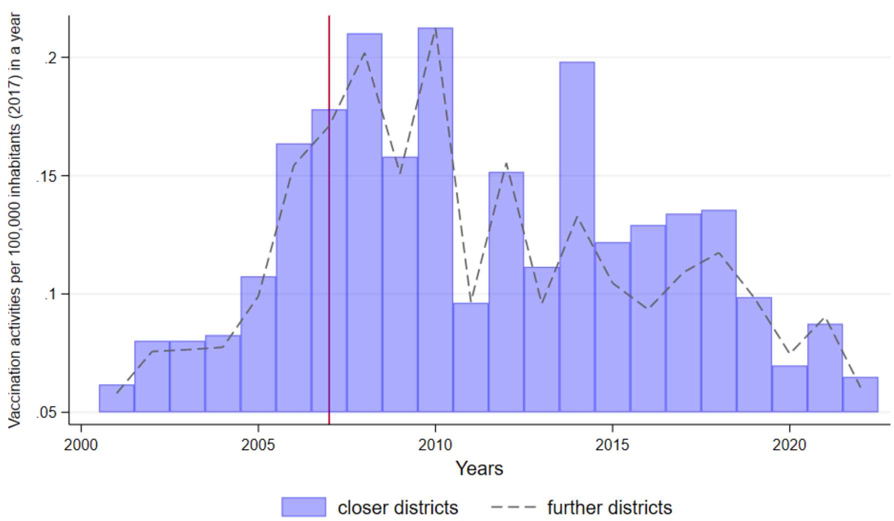
	(1)	(2)	(3)	(4)
	Pre-natal assistance		Post-natal assistance	
$Cohort_{08}$	0.21796***	0.21797***	0.28672***	0.28649***
	(0.02397)	(0.02411)	(0.01551)	(0.01538)
$Cohort_{08}$ * IDP		-0.02068		0.01068
		(0.05164)		(0.05928)
District FE	Yes	Yes	Yes	Yes
DHS controls	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
N. of districts	38	38	38	38

Notes: This Table presents the impacts of the IDP inflows on the demand of health services. There are two different dependent variables: the need of pre-natal assistance (columns 1 and 2), the need of post-natal assistance (column 3 and 4). The dependent variables are a binary, coded to one if child i was in need of either service. We use the date of birth from the Demographic and Health Survey (DHS) from 1998 to 2017 to define an alternative treatment. Children born from January 2008 are exposed to the treatment. Columns (2) and (4) investigate the heterogeneity between native and IDP children. The specification related to this tables is presented in equation in Equation 3. Standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1

Did the healthcare supply respond to an increase in the demand for health services? Ideally, we would like to study this question using district-level data on health service delivery (health centres and workforce). Unfortunately, we could not get this data. To address this limitation, we proxy health services supply with district-level data on polio vaccination campaigns from the Polio Eradication Program. In Pakistan, health is primarily the responsibility of the provincial government. Therefore, the central assumption is that the supply of health services follows the same pattern as the polio vaccination campaigns. Figure A17 shows how the total vaccination activities per 100.000 inhabitants increased in 2008 in host districts with respect to 2007.[40]

Results of Table A17, which exploits Equation 1 using as an outcome the polio vaccination campaigns, support the idea of a responsive supply. However, we can not disentangle if the increase in the supply is high enough to meet the demand for formal health services.

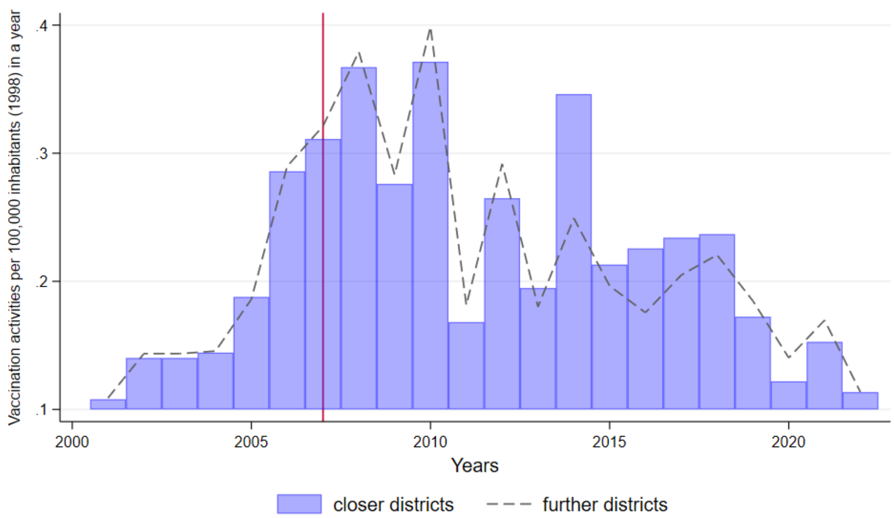
Figure A17: Polio campaigns per 100,000 inhabitants



Note: This figure plots the number of vaccination campaigns against polio per 100,000 inhabitants in treated and control districts from 2001 to 2022. We calculate the campaigns per 100,000 inhabitants relative to the population in 2017 from the 2017 population census. The blue bars show the campaigns in treated districts, and the grey dashed line in control districts. Treated districts are the host districts and control districts are the non-host districts. Districts whose territory falls within the pre-colonial region of Pashtunistan are host districts. Non-host districts are those whose part is outside Pashtunistan but adjacent to the historical border. The vertical red line corresponds to December 2007. Source. The Polio Eradication Program from the World Health Organization (WHO).

[40] We use the 2017 Population Census to construct Figure A17. We obtain a similar graph using the 1998 Population Census (see Figure A18).

Figure A18: Polio campaigns per 100,000 inhabitants in 1998 (2001-2022)



Note: This figure plots the number of vaccination campaigns against polio per 100,000 inhabitants in treated and control districts from 2001 to 2022. We calculate the campaigns per 100,000 inhabitants relative to the population in 1998 from the 1998 population census. The blue bars show the campaigns in treated districts, and the grey dashed line in control districts. Treated districts are the host districts and control districts are the non-host districts. Districts whose territory falls within the pre-colonial region of Pashtunistan are host districts. Non-host districts are those whose part is outside Pashtunistan but adjacent to the historical border. The vertical red line corresponds to December 2007. Source. The Polio Eradication Program from the World Health Organization (WHO).

Table A17: Effect of IDP inflow on new supply of health services

	(1)	(2)	(3)
IDP Crisis$_t$ * *Predicted Inflow*$_{d,t}$	0.14559***	0.06056***	0.05783***
	(0.02092)	(0.01572)	(0.01421)
N	8713	8713	8713
District FE	No	Yes	Yes
Year FE	No	Yes	Yes
Controls	No	No	Yes
N. of districts	34	34	34

Notes: this Table presents the impacts of the IDP inflows on the supply of health services in districts closer and further from FATA border, before and after 2008. Districts whose territory falls within the pre-colonial region of *Pashtunistan* are part of the sample. The treatment timing starts in 2008. Observations are at the district and month level from 2001 to 2022. The baseline specification is presented in equation (1). Column (1) presents the results without district, year-month fixed effects and covariates. Column (2) includes district and year-month fixed effects. Column (3) controls for nightlight intensity. Robust standard errors are clustered at the district level. *** p<0.01, ** p<0.05, * p<0.1