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Vaccines and Epidemics : Three Essays on Health Behaviour in Sub-Saharan Africa

Macina El Hadji Moudo

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Vaccines and Epidemics: Three Essays on Health Behaviour in Sub-Saharan Africa

A thesis defended for the degree of

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by

EL HADJI MOUDO MACINA

Thesis Supervisor:

Prof. Dr. Laure Athias
(University of Lausanne, IDHEAP)

Members of the Jury:

Prof. Dr. Mathias Thoenig
(University of Lausanne, HEC)

Prof. Dr. Antonio Estache
(Université Libre de Bruxelles)

Prof. Dr. Yanos Zylberberg
(University of Bristol)

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en administration publique

IMPRIMATUR

Le Décanat de la Faculté de droit, des sciences criminelles et d'administration publique, sur proposition d'un jury formé de la professeure Laure Athias, des professeurs Mathias Thoenig, Antonio Estache, et Yanos Zylberberg, sans se prononcer sur les opinions du candidat, autorise l'impression de la thèse de Monsieur El Hadji Moudo Macina, intitulée :

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Prof. Andreas Ladner
Vice-Doyen de la Faculté de droit,
des sciences criminelles
et d'administration publique

Dédicaces

A toutes les victimes des maladies infectieuses.

A tous les combattants anonymes de l'épidémie de maladie à virus Ebola.

A mon vénéré père Daouda Samba, et à ma tendre mère Marième Kouta.

A mon oncle Amadou Chérif, et ma tante Absa Ndao.

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« La reconnaissance est la mémoire du cœur. »
Hans Christian Anderson

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General Introduction and Overview

Infectious and communicable diseases are widely prevailing in sub-Saharan Africa. Epidemics are responsible for high mortality and morbidity among all sections of the population. For the child population, the most important infections, potentially leading to mortality, are malaria and diarrheal diseases, as well as measles, poliomyelitis, diphtheria, tetanus, and pertussis. Infectious diseases account for half the illnesses in Africa, and the infant mortality rate is, on average, 14 times higher in many countries relative to high-income countries (WHO, 2017). Besides, a range of other infections are equally fatal to the adult population and claim a heavy burden of illness and mortality. Among these are the global pandemic HIV/AIDS, which is responsible for millions of deaths across the continent, or the more recent, highly infectious and deadly Ebola virus disease.

One of the essential and distinguishing features of infectious diseases, in comparison to other endemic chronic diseases of global health concern such as diabetes and cancer, is that most of them are widely preventable with nowadays well-established, accessible, and cost-effective health technology such as vaccines, insecticide-treated nets, water deworming or use of condoms (Dupas, 2011). For example, global immunization campaigns have already succeeded in eradicating one of the historically worst devastating diseases that was smallpox in 1980. This result is described as the world's most triumphant achievement in medicine and public health (Fenner et al., 1988).

Vaccination is commonly viewed as the second most contributing and effective health intervention to the global reduction of mortality and morbidity behind access to safe water and ahead of the discovery of antibiotics (Plotkin et al., 2010). In 2008, distinguished economists from the Copenhagen consensus ranked expanded immunization coverage fourth among the 30 most global welfare-enhancing public interventions. Nevertheless, the still relatively low adoption of what has been arguably identified as one of the most cost-effective preventive health techniques is intriguing, especially for resource-constrained countries and populations in sub-Saharan Africa.. Figure 1 below illustrates the coverage rates of the first dose measles vaccine (MCV1) across a sample of countries in sub-Saharan Africa in 2016. Many countries are lagging far behind the level of guaranteeing herd immunity (95%), which will prevent the resurgence of epidemic outbreaks.

From the traditional economics literature on health in low-income countries, one can identify three types of failures: from the government, markets, and public demand and behaviour for optimal preventive health adoption and infectious disease control. We know from tradi-

tional economic theory that private adoption of preventive health measures such as vaccination or compliance with disease preventive measures generate positive externalities for the society as a whole. Moreover, individuals often face significant asymmetry of information on the benefit of these health technologies, since the latter are imperfectly observable in the short-run. The discrepancy between private and social benefits leads to suboptimal market provision and private underinvestment in preventive health products justifying government intervention.

However, in developing countries, government failures in the provision of primary care services are well-established. The supply-side impediments are related to both access and quality of the health services provided. The health sector is underfunded in low-income countries, 5% of the GDP is spent on health, part of which 60% represent out-of-pocket from private consumers. By comparison, this share represents 10% of the GDP in global health expenditure in rich countries, where public financing, in contrast, reaches 60% (World Bank, 2011). In addition to inadequate funding, public health facilities see high rates of absenteeism from the health workers who also have limited knowledge and training, are prompt to misdiagnosis and prescription of inappropriate treatments, and exert low effort during patient interviews, leading to what is depicted in the literature as a significant "know-do" gap (Das and Hammer, 2014; Dupas and Miguel, 2016). For the sake of illustration, Banerjee et al. (2010) document that 45% of medical staff in charge of immunization are regularly absent from health in rural Udaipur (India). When present, they may also engage in corruption and illegal actions of charging fees for free vaccines services. In Sierra Leone, 65 percent of those immunizing a child reported illegally having to pay for the service in 2008 (IRCBP, 2010).

Alongside the public sector dominating the health system, private providers face higher incentives in supplying costly health services, since insurance is mainly limited to formal sector workers (Kremer and Glennerster, 2011). Das et al. (2013) report in public versus private comparative analysis, that private health providers spend more time with patients and perform more in-depth diagnosis according to guidelines and more frequently prescribe appropriate medication. Nevertheless, private health workers usually have very poor or no-formal training. As standard theory would predict, in the presence of asymmetric information between patients and providers about the quality of care and the appropriate medical treatment (Akerlof, 1970), there exist equilibriums in which only low-quality providers operate. These situations are more likely to occur in the context of limited government monitoring ability and regulatory capacity (Das and Hammer, 2014). Therefore, in such an environment, consumers are less willing to spend more in private health demand leading to the persistence of low-quality equilibriums. Both factors combined, the public and private supply impediments to high-quality health service provision, are documented as significant determinants of low demand for primary care and low public health outcomes. Increasing service reliability in the health facilities (Banerjee et al., 2010) or more powered incentives for public health workers such as pay-for-performance motivating schemes and increasing accountability to patients or

local authorities are among the discussed possibilities for improving the health supply (Das and Hammer, 2014).

From the demand side, an intriguing observation, now supported with striking evidence from field-experiments in the health sector throughout the two last decades in developing countries (Banerjee, Duflo, Kremer, among others), is the incomplete and suboptimal adoption of preventive and cost-effective health technologies with potentially high private life-long return and collective benefits. From the standard human capital, health demand is conceptualized as a human capital investment (Grossman, 2000). Under such a model, rational and intertemporal utility-maximizing individuals invest in preventive or curative health care if the expected discounted private benefit exceeds the private costs. Dupas (2011) introduces a variant of this model to explain household decisions to immunize their children, to seek care from health providers, or buy a prescribed treatment in a developing country setting. The model highlights that the individual's level of health investment is a function of the opportunity cost, the beliefs about the risk of infection, access to financial markets, and the expected future utility of preventive health investment. Given the cost-effectiveness of preventive health techniques under the utility-maximizing assumption, market imperfection in the low-income country setting and notably incomplete information is likely to explain the low adoption of preventive health techniques and behaviour. The author identifies the main explanatory factors through low information and education, constrained financial markets, and time preferences.

The empirical literature investigates the alternative theoretical channels in the field. In a field experiment in Kenya, Dupas (2011) finds that providing information to adolescent girls on their differential risk of HIV infection results in a positive change of their sexual risk-taking behaviour with adult men. The author stresses that not all types of information are useful, and it is effective only when adequately tailored to the recipient. Similar studies also suggest that information effectiveness is sensitive to gender, where women are more responsive to health information than men. However, the evidence also illustrates that lack of information cannot fully explain the low uptake of preventive health techniques or inadequate use of remedial health. Cohen et al. (2011) find that although tested malaria negative, a significant share of patients continue to buy malaria treatment in Kenya. Interestingly, they find that more educated are more skeptical about the information provided and less likely to comply with test results. This literature also highlights the role of social learning and neighbourhood spillovers in determining the adoption of health preventive techniques. For instance, Kremer and Miguel (2007) illustrate free-riding in deworming investment. Other uncovered barriers to the adoption of preventive care are credit constraints and the high price elasticity of demand. Kremer and Gleenerster (2011) suggest an alternative to the standard human capital investment model and suggest a model with present bias where individuals highly discount the future. Dupas and Miguel (2016) suggest that this model could explain why small changes in incentives, such as providing lentils 1kg of lentils per immunization administered (Banerjee et al., 2010), small

financial reward for HIV testing (Thornton, 2008), subsidies for insecticide-treated nets, ITNs (Dupas, 2010), all could result in sensible increase in uptake. Under this model, when faced with imminent risk of severe illness or death, complacency, and delays in preventive behavior adoption are unlikely.

The above literature has outstandingly increased our understanding of barriers to the demand for preventive health and health care in developing countries, and the implications for public health outcomes. However, as Dupas and Miguel (2016, p.36) stress it: "Less research has been carried out on trust and psychological factors directly, although considering those factors is useful for interpreting results of existing experiments that act on the economic environment." In the same vein, Larson et al., (2018, p.1599) conclude to: “a disconnect between the current vaccine hesitancy research and the wider health-related trust literature, a dearth in research on trust in low and middle-income settings, a need for studies on how trust levels change over time and investigations on how resilience to trust-eroding information can be built into trustworthy health system.”

The authors recognize then the potentially important role of trust in health decision-making, especially in an environment of widespread skepticism about public health workers and government intervention due to historical reasons and past state failures, as the history of resistance to preventive health interventions such as vaccination campaigns in Africa (Renne, 2006; Jegede, 2007; Kaler, 2009; Lowes and Monteiro, 2018). The recent experience of widespread mistrust during epidemics, of suspicion towards vaccine trials and resistance to government social-distancing mechanisms during the West African Ebola outbreak, illustrates the importance of trust in health interventions. (Blair et al., 2017; Gonzalez-Torres and Esposito, 2018). This thesis builds on the previous background, consolidated by a similar pattern of population behavior in the ongoing outbreak in Congo (DR) (Vinck et al., 2019). The interesting feature of the Ebola epidemic is the acuteness of the disease, with clear and observable symptoms to populations, which cause immense suffering and immediate risk of death. In this framework, there is, a priori, no asymmetric information between patients and health providers or policymakers on the infection risk, and the complexity of understanding preventive measures is considerably reduced relative to other diseases with more extended incubation periods and more complex clinical symptoms such as HIV. The benefit of preventive measures is likely immediate in the context of the Ebola crisis, probably ruling out time-preferences and present bias.

Moreover, the epidemic saw an impressive international intervention, with a large number of resources mobilized to contain the disease propagation. Health treatments were freely provided, and so was later the participation in vaccine trials. Despite the absence or salience of many identified traditional barriers to preventive health adoption in the case of Ebola disease, the epidemic containment unexpectedly faced a high-level of resistance and widespread distrust. This thesis aims to contribute to filling the gap in the knowledge in understanding the public health demand behaviour in sub-Saharan Africa in the specific context of distrust

in vaccines and the role of social distance in the spread of epidemics. That is, we aim to investigate and assess the potential explanatory power of trust and social interactions on the public health demand behaviour in the adoption of preventive health techniques and the propagation of epidemics in sub-Saharan Africa. More specifically, we will empirically investigate the relative effect of trust on public demand for a standard preventive health technology that is childhood vaccination relative to the traditional determinants of health demand. Next, we admit that communicable disease control and propagation equally depends on the pattern of social interactions at the society level and not only medical health interventions. Thus, we aim to uncover the role of differences in the intensity of social interactions across communities in explaining the pattern of infectious disease spread during epidemics.

We claim that this research is valuable for several reasons. Given the severity of infectious and communicable diseases in terms of disease burden, further understanding the determinants of resistance to public health interventions and communicable disease spread has considerable public health implications. Suboptimal uptake of effective preventive medical technologies hampers economic development in the long-run through the potential life-long negative effect of illnesses on child health, education, and expected future economic outcomes.

Understanding the role of trust in public health decisions, its critical dimensions, and the channels through which it impacts public health decisions will have a valuable impact on the public health intervention design and planning. Moreover, understanding how the pattern of social interactions between communities during a health crisis such as epidemics could have a valuable impact on strategic design, planning, and implementation of health interventions during epidemics. More contextually informed and strategic intervention could avoid coercion, resulting in social unrest and resistance, such as those observed in generalized and costly quarantines during the West African Ebola outbreak. The latter could potentially have a long-term damaging consequence of mistrust towards the state and resistance towards future health interventions. Finally, trust induces voluntary cooperation relationships, which imply saving on costly and short-term incentives and effort implemented in the field, such as cash transfer programs to encourage demand for socially beneficial public health behaviour. In the context of the limited state budget, fostering compliance might be more efficient.

Conceptually, this thesis emerges from a long and now well-established economic literature on the role of trust in societies' economic performance. The importance of trust appears in an early observation of Arrow (1972): "Virtually every commercial transaction has within itself an element of trust, certainly any transaction conducted over a period of time. It can be plausibly argued that much of the economic backwardness in the world can be explained by the lack of mutual confidence." Since then, pioneering works from social scientists such as Fukuyuma (1995), Putnam (2000), and later economists such as Guiso et al. (2011) have connected trust to the notion of social capital, defined as "those persistent and shared beliefs and values that help a group overcome the free-rider problem in the pursuit of socially valuable activities" (Guiso et al., 2011). In our context, trust fosters cooperation such as in Berg et al.

(1995) and leads to a higher willingness to uptake preventive behaviour techniques even in an uncertain environment and incomplete information about their safety and effectiveness.

In our thesis, we investigate the two dimensions of trust advanced in the literature. While one dimension of trust, called institutional trust, is relatively volatile and changes quickly according to the contemporaneous political, economic, and social environment, the other dimension, often called cultural trust, is more ingrained and stable over generations and shaped by early family socialization according to expected benefits of future payoffs from trust and cooperative attitude (Bisin and Verdier, 2011). We build particularly from two influential works considering a time-varying measure of trust (Algan and Cahuc, 2010) and an intergenerational and time-persistent transmission of mistrust from the historic adverse effect of the slave trade in sub-Saharan Africa (Nunn and Wantchekon, 2011), to investigate an institutional and cultural dimension of mistrust in the health sector.

We also build from early theoretical insight from social interactions theory which predicts that social interactions are inversely related to social distance between individuals to investigate the role of ethnic distance and pattern of social interactions in the spread of epidemics (Akerlof, 1999). This thesis explicitly acknowledge that the problem of infectious disease transmission and control of epidemics does not solely involve the uptake of vaccines and the adoption of medical health techniques. Because epidemics occur in a social context and social decisions, health intervention preventing disease and spread heavily rely upon strategic control of social interaction and population mobility susceptible to favouring epidemics transmission and spatial transmission.

Why have the issue of trust and social interactions not been provided more in-depth attention before recently, given their arguably relevant impact on public health demand and outcomes? First, the last Ebola crisis has awakened the world's attention to the issue of distrust in preventive health policy. To this situation, we add Western Europe and Northern America crisis of vaccine hesitancy. Second, the data is a significant challenge for whomever ambitions to study trust and health decisions. As an illustration, there is no comprehensive health survey combining the two features, neither the country representative Afrobarometer nor the Demographic Health Survey (DHS). Our thesis ambitions to overcome this issue by exploiting recent and nationally representative social surveys on an individual's trust and attitude on several relevant dimensions. We also exploit the development of rich historical data and empirical strategies from the economics literature to study the effect of different dimensions of trust. Moreover, establishing a causal relationship from observational data is always a daunting enterprise, which explains why many approaches favor field works. We build from recent progress in the study of the effect of trust in economic outcomes and the emergence of rich and precisely geolocated data to address these issues. Finally, the development of spatial econometric models and more refined measurement of ethnic proximity allowed us to advance in the study of spatial spread of epidemics outside the traditional framework of the epidemiology literature.

The thesis purpose is thus to advance the previous literature on the determinants of health demand and behaviour in sub-Saharan Africa. It ambitions to contribute to the literature empirically by identifying the effect of different dimensions of trust and their implications in primary preventive health demand that is child vaccination. It also ambitions to assess the relative importance of trust in comparison to other traditional determinants of vaccine uptake. Finally, this thesis will establish the role of social interactions across communities, through ethnic distance, during a health crisis on the spatial and dynamic spread of epidemics. In doing this, it also investigates the relative importance of the effect of ethnic distance networks in comparison to traditional geographic and socio-economic networks. We do this through three separate and self-contended research articles addressing three overarching research questions that we will subsequently present.

We adopt three different perspectives, at the country, individual and chiefdom level and answer the following research questions:

What is the role of public trust in the government on country-level immunization performance in sub-Saharan Africa?

The first chapter investigates the empirical relationship between variations in public trust in the government and the evolution of vaccination coverage rates in sub-Saharan Africa. It builds from the observation of recurrent and widespread instances of vaccination confidence crisis and resistance to government-sponsored immunization programs across the continent, facing skepticism about their motivations such as sterilization rumors, or securing money from international donors (Gilson, 2003; Jegede, 2007; Kaler, 2009; Blair et al., 2017). The resulting distrust in government is pervasive and persistent even in the presence of acute and deadly health crisis such as the ongoing Ebola in Congo (RDC) (Vinck et al., 2009).

Despite the growing qualitative evidence on the importance of institutional trust in the demand for preventive health, few studies have investigated the empirical relationship, particularly in sub-Saharan Africa, where the expected benefit of adoption preventive health technology in terms of disease burden reduction is much higher (Larson et al., 2018). This work intends to fill this research gap in sub-Saharan Africa, and complement recent empirical studies linking trust in public health authorities and health demand. This literature exploits, for instance, particular shocks in trust in government through information disclosure about public health providers' misbehavior (Alsan and Wanamaker, 2017; Martinez-Bravo and Stegmann, 2019).

We posit that in the presence of uncertainty about government motives and information asymmetry about the safety and effectiveness of vaccines, citizen's vaccination decisions are significantly determined by their level of institutional trust. We build from recent theoretical insights and empirical evidence on the short-term volatility of citizen's beliefs and perceptions towards the state in sub-Saharan (Sanguier and Zylberberg, 2017). We then hypothesize that changes in the level of public trust in the government predict changes in the country-level immunization coverage rates.

To investigate the empirical relationship, we construct a time-varying country-level citizen's trust in the central and the local government officials from the Afrobarometer surveys. The public trust measures are combined with panel data on immunization coverage rates from a baseline sample of 16 sub-Saharan African countries over the period 2002 to 2014. The immunization data are on three uniformly provided essential child vaccines against measles, diphtheria-tetanus-pertussis, and poliomyelitis.

Our empirical approach attempts to address the challenge of establishing a robust causal relationship between public trust in government and country-level immunization. We address omitted variables by controlling for differences in individual characteristics between countries in building our country-level measures of public trust in a first step estimation, and in a second step, by including a rich set of country fixed effects and time-varying factors susceptible to influence both country immunization rates and institutional trust. These include standard economic determinants of immunization coverage rates, such as changes in population demographics, the level of health financing, the evolution in institutional quality and governance, and the overall economic and political cycles. We also attempt to address the primary concern of reverse causality related to the fact that the country's health performance also determines institutional trust by including lagged level of public trust but also performing falsification tests.

We find a positive and significant correlation between changes in public trust in the central government authorities–the head of state and the parliament members–and changes in country-level immunization rates. The positive relationship is not observed for trust in the local government, not in charge of immunization policy, which suggests that we are capturing the effect of trust and not the effect of an unobserved confounding factor affecting positively overall attitude towards the state and immunization performance. The absence of a direct effect of trust in government on child mortality is a piece of supporting evidence suggesting that we capture the behavioural component of trust in the uptake of vaccines, and not overall government quality in implementing health policy or the reverse causal effect of health performance on institutional trust. Investigating the role of shared mandates and decentralized links, we find that the positive effect of trust in the central government is lowered in a more administratively decentralized government. We also find a lower effect of public trust in more ethnically and religiously fractionalized countries, and in those having experienced historically negative adverse shocks on trust, such as the slave trade.

Despite limitations in its empirical strategy to claim a causal effect, this paper establishes a robust and statistically significant relationship between institutional trust and immunization performance accounting for a rich set of standard economic determinants of vaccination demand and coverages rates. Our results suggest that public trust identity is sensitive, and that public attitudes towards the specific authority in charge of immunization intervention could influence uptake. Moreover, trust in the central government has a heterogeneous effect according to the level of decentralization, the adverse historical shocks in trust, or societal

fractionalization. The finding suggests investigating the roots of trust in the medical sector at the society level, by using a research design taking into account the heterogeneity in the individual's personal, cultural, political, and specific local context determining vaccination decisions.

What is the causal effect of mistrust in medicine in the up-take and adoption of preventive health techniques in sub-Saharan Africa?

This chapter relates to the growing strand of literature that attempts to uncover the causal effect of trust in medicine on demand for preventive or curative health. Notable works are from Alsan and Wanamaker (2017) that study the effect of Tuskegee syphilis experiment disclosure in 1972 on black men's contemporaneous demand for health and participation in medical experiments. Martinez-Bravo and Stegmann (2017) study the effect of a more recent CIA vaccination campaign in Pakistan. More related to our work is Lowes and Monteiro (2018) that exploits the effect of colonial medical campaigns in central Africa between 1921 and 1956 to study the effect on today's demand for preventive medicine. Although they use an innovative and robust approach, these studies exploit isolated and geographically limited shocks. In our attempt to uncover the widespread mistrusting behavior in medical interventions in sub-Saharan Africa, we investigate the legacy of a continent-wide adverse shock on trusting norms that is the long history of the transatlantic and Indian Ocean slave trades.

Our work builds from an established conceptual framework from the theory of transmission of cultural norms that predicts that current levels of trust are shaped by both the contemporaneous environment and inherited norms and beliefs from earlier generations such as culture (Bisin and Verdier, 2001). From this background, we build from pioneering work by Nunn and Wantchekon (2011) that demonstrated a negative causal effect of ancestors' past exposure to the slave trade on their current descendent level of interpersonal trust in sub-Saharan Africa. They establish that most of the impact of the slave trade was through internal norms of behavior such as culture rather than institutions. We combine this evidence with insight from Bowless (1998), who predicts that preferences learned under particular circumstances could translate to general rules of behavior in different settings from which they initially occurred. We thus hypothesize that past exposure to the slave trade allows capturing an exogenous source of variation in contemporaneous trust in medicine in sub-Saharan Africa.

In our empirical analysis, we collect a rich set of data on the ethnic groups' past exposure to the slave trade created by Nunn (2008). We use individual-level data from the Demographic Health Survey (DHS) geolocated at the district level (village, town, municipalities) from the most recent and compatible surveys during the period 2010-2014. We have access to a rich sample on the immunization and socio-demographic status of 157,405 children born to 107, 771 adult mothers from 98 different ethnic groups representing at least 5% of their country's population and across a baseline sample of 18 sub-Saharan African countries.

In order to identify the causal effect of mistrust in medicine, we first establish that descendants of ethnic groups that were more intensely exposed to the slave trade are today signifi-

cantly more likely to hold negative perceptions on the trustworthiness of modern health workers by seeing them as corrupt or lacking attention and respect during last health interaction. Interestingly, this negative perception does apply to more factual dimensions of the quality of health facilities such as cost availability of health supply, absence of doctors, waiting-time, or dirty facilities. We interpret this finding that past exposure to the slave trade did not affect descendants' current trust in medicine through access to health system but only their perception towards health workers. This first evidence rules out bias from the negative effect of the slave on general current economic outcomes. Second, we estimate a reduced form equation linking past exposure to the slave trade to the mother's current child immunization decision, to instrument for the effect of norms of mistrust in medicine and current behavior in the uptake of preventive health techniques. Our identification strategy uses a rich set of controls at the individual, local, and ethnic group levels to ensure that the slave trade satisfies the exclusion restriction. We also exploit variations within localities in a second strategy. Third, we perform a falsification test on alternative preventive health techniques with a different level of uncertainty relative to vaccines to confirm our hypothesized mistrust in the preventive health medicine channel.

We find that a child born to a mother whose ancestors were exposed to the slave trade is today 5 to 9 percentage points less likely to be vaccinated than a similar child whose mother is descendant from a slave-free group. The most conservative estimate predicts an adverse effect of the slave trade that offsets the positive effect of belonging to the wealthiest quintile of the income distribution, but also the positive effect of being born to an employed mother. The negative effect of the slave trade dominates the negative effect of distance to health facilities. Finally, our results predict a sizable impact of the slave trade on the vaccination rate of slave raided groups had they been slave free. Our results predict a 25% increase in coverage rate for the Hausa group in Northern Nigeria, which is equivalent to a 50% drop in measles incidence according to some estimates and more than 10,625 cases avoided each two-years between 2011 and 2014. We also find that in contrast to vaccines, the past exposure to the slave trade had no significant impact on the use of malaria ITN, which arguably does not involve the uncertainty inherent to vaccines. Also, the effect was similarly negative and statistically significant on the likelihood of acceptance of an anaemia test, involving injection such as vaccines. These findings suggest supporting evidence for our causal effect of mistrust in the medicine channel.

In this paper, we claim that we uncover the causal impact of trust in medicine in demand for uncertain preventive health techniques such as immunization in sub-Saharan Africa. We also shed light on the persistence of historical adverse shocks to better understand widespread contemporary mistrusting behavior towards particular health interventions and technology. Our results suggest that the effect of trust as a determinant for health demand is sizable and could potentially dominate other traditional socio-economic determinants of preventive health such as income and employment or perceived distance to health facilities. The paper sheds light on the importance of adequately addressing and managing potential sources of medical risk

and misbehavior to reduce the perceived risk of adoption of cost-effective health techniques in sub-Saharan Africa. Given between-group variations in the rate of adoption of uncertain and risky health technology, based on their current level of trust in medicine, favoring early adopters could be beneficial to leverage the benefits of positive externalities and the feedback effects of social learning. It also highlights that given long-term persistence of norms of mistrust in medicine, solely providing information or education is not always enough to change behavior, interventions considering early life socialization by the parents could potentially change the long-term equilibrium to one in which trusting attitudes leads to a higher payoff.

What is the role of ethnic distance on the spatial and dynamic propagation across Sierra Leone Chiefdoms on the West African Ebola Virus Disease epidemic?

In the third chapter, we investigate whether the spatial propagation of the Ebola Virus Disease (EVD) epidemic across Sierra Leone chiefdoms followed the pattern of social interactions between ethnic groups. This study emerges from the particularity of the West African Ebola outbreak, in which human-to-human transmission of the virus was the unique transmission channel and where physical contact during social interactions was an essential source of contagion and disease propagation. Moreover, despite the massive scale of the outbreak, there was substantial heterogeneity in the spatial distribution of cases even across neighboring chiefdoms. In Sierra Leone, the EVD affected 114 chiefdoms out of 153 and left more than 25% of them free of the epidemic (Fang et al., 2017). Besides, the transmissibility of the epidemic was much lower than initially predicted by traditional forecast. Our study proposes to improve our understanding of the EVD propagation by explicitly investigating the role of social interactions in the spread of the epidemic.

We build from previous evidence that in sub-Saharan Africa, community interactions at the society level are widely determined by co-ethnicity. Therefore, we postulate that ethnic distance, which is the identification in different ethnic groups, by shaping the intensity of social interactions between groups (Gomez, 2017), potentially plays a significant role in the spread of communicable disease across communities.

Theoretically, we build upon a new insight from the social contact network theory of reduced disease transmission in spatially constrained contact structures as developed for Ebola transmission by Kiskowski and Chowell (2016). We hypothesize a mechanism in which ethnic distance generates a spatially constrained social network of chiefdoms within Serra Leone that shapes the spatial diffusion of the epidemics across them. As a consequence, the ethnic distance might beneficially hamper disease propagation across neighboring chiefdoms populated by different but highly ethnically homogenous groups.

Our work relates to different strands of literature that highlight alternative network candidates for explaining the spatial pattern of the EVD epidemic propagation across Sierra Leonean chiefdoms. In addition to the traditional contiguity and geographic distance network, Richards et al. (2014) highlight the role of kinship-based network and inter-ethnic alliances, and the mobility of individuals within this network to attend social events (marriages, patients visit, fu-

nerals) or to seek care from traditional healers. Aker et al. (2014) show the role of co-ethnicity and intra-ethnic exchanges and market interactions, while Oster (2007) uncovers the role of trade routes and exports as a network of interactions and routes of communicable disease spread such as HIV in sub-Saharan Africa.

In our empirical analysis, we use weekly data on the differential incidence of Ebola across Sierra Leone chiefdoms from May 2014 to September 2015. The data was shared by Li-Qung Fang et al. (2015) and collected from the WHO, and the National Ebola Response Center (NERC) records in Sierra Leone. Our sample forms a panel of 153 spatial units observed during all the duration of the epidemic, over 69 weeks. We use Sierra Leone 2004 population and housing census data to identify the composition of the dominant ethnic groups in each chiefdom. We also collect complementary data from different sources to perform our empirical analysis.

In our main empirical strategy, we estimate a spatial and dynamic model of epidemic propagation across Sierra Leone To model spatial interactions between chiefdoms, we define alternative spatial network weights matrices, our baseline ethnic distance matrix, and geographic and contiguity weighting matrices. We estimate both a locality and time-fixed effect variants of our model to account for unobserved heterogeneity susceptible to influence the level of disease incidence and propagation. We also explicitly address the identified issues related to the spatial autoregressive term and the spatial autocorrelation errors following Yu and al. (2008). Next, we test the explanatory power of our ethnic distance network against other potential network candidates for explaining the spatial propagation of the epidemics.

We find that the social network based on chiefdom's ethnic linkages accounts more for the spatial spread of the EVD epidemic in Sierra Leone than the traditional geographic distance and contiguity-based network. Our results are robust to different specifications and sensitivity analysis. The model predictions are in line with specific features of Ebola transmission, as documented by the previous literature. We simultaneously investigate the explanatory power of alternative networks of spatial propagation of communicable diseases against our ethnic distance matrix. We find that higher spatial spillover effects are predicted by the ethnic distance network across chiefdoms in the EVD spread, by contrast to traditional vectors of extensive epidemic propagation such as roads and markets that appeared not having played a significant role in Ebola spread across Sierra Leone chiefdoms.

From a theoretical point of view, this study contributes by proposing a new avenue for modeling communicable disease spatial spread in sub-Saharan Africa by explicitly taking into account social interactions between ethnic groups. Conceptually, we highlight the potential of investigating differential interactions between groups through ethnic distance rather than classical symmetric measures of ethnic diversity or polarization.

Our work has practical implications for strategic policy intervention and control of epidemic spread by improving quarantines, contract tracing, and vaccination. We highlight how better understanding the pattern of social interactions between communities could help to

predict the future potential epidemic spread and avoid costly generalized quarantines through more strategic design. The study suggests potential improvement of contact tracing of the infection transmission chains by considering the knowledge of the relevant social network and ethnic connections. Finally, our study could contribute to modeling the relevant social network for medical interventions such as ring vaccination during epidemics.

The research questions to which the dissertation attempts to answer, the empirical approaches adopted, the data used, and the main results are summarized in the following table.

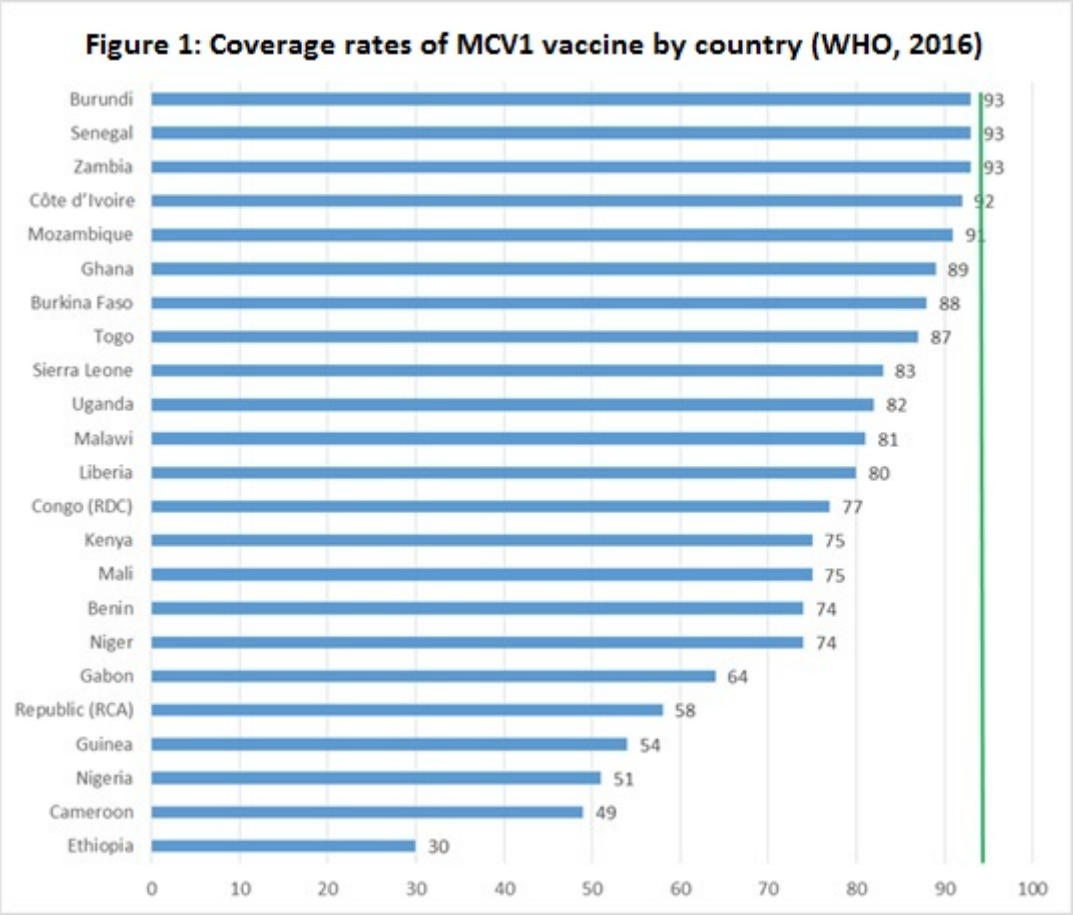

Table I: Summary of research questions, empirical approaches, data and results.

	Approach	Sources of data	Main results
Chapter 1 What is the role of public trust in the government on country-level immunization performance in sub-Saharan Africa?	-Construction of time-varying measure of public trust level in the central and local governments. -Estimation of the effect of variations in public trust on variations in country-level immunization coverage rates. (OLS and Panel data Fixed-Effects Estimation)	-Trust data from the Afrobarometer survey. -N= 167,162 -16 countries represented -Period covered: 2002-2014. -Immunization data from the World Health Organization (WHO).	-Trust in the central government have positive effect on country- level immunization coverage rates. -Trust in the local government have no significant effect. -The effect of public trust decreases in more decentralized, fractionalized, slave raided countries.
Chapter 2 What is the causal effect of mistrust in medicine in the up-take and adoption of preventive health techniques in sub-Saharan Africa?	-Investigate the legacy of the slave trade to identify a causal effect of mistrust in medicine in sub-Saharan Africa. -Reduced-form estimation of the effect of ancestor's exposure to the slave trade on the individual's current vaccination decision. (OLS and Linear Probability Model Estimation)	-Slave trade data from Nunn (2008) and Nunn and Wantchekon (2011). -N=98 ethnic groups. -Immunization data from the Demographic Health Survey (DHS) individual-level data geolocated at the district level. -157,405 children -107,771 mothers -18 countries represented. -Period covered: 2010-2014.	-The Slave trade has negative effect on perception of trustworthiness of health workers, no effect on perception of access to physical health supply. -The slave trade, through its impact on mistrust in medicine, has a negative causal effect on child immunization: 5 to 9 points less than slave-free groups. -No effect on use of ITN bed net.
Chapter 3 What is the role of ethnic distance on the spatial and dynamic propagation across Sierra Leone Chiefdoms on the West African Ebola Virus Disease epidemic?	-Construct ethnic distance network spatial weights matrix. - Construct contiguity, geographic distance, roads, market, and health utilities networks. -Estimation of spatial and dynamic epidemic model. (Quasi-Maximum likelihood Estimation)	-Ebola Data from Li-Qung Fang et al. (2015) collected by WHO and National Ebola Response Center (NERC) in Sierra Leone. -N=153 chiefdoms. -Period: May 2014-September 2015. -Ethnic groups data from Sierra Leone 2004 population and housing census. -National Public Services Survey (2008).	-Chiefdoms import more cases from ethnically similar neighbours. -The ethnic distance network accounts more for the spatial spread of Ebola than the geographic distance or contiguity-based networks. -Roads and markets had no significant impact in Ebola spread.

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Overcoming Rumors and Uncertainty: Does Public Trust in Government predict Vaccine Uptake in sub-Saharan Africa?

Moudo Macina

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Abstract

In the context of pervasive rumors and uncertainty about the motivations of immunization interventions and recurrent vaccine confidence crisis, we examine the role of public trust in the government on country-level immunization performance in sub-Saharan Africa. We use data on immunization coverage rates from a baseline sample of 16 sub-Saharan African countries from 2002 to 2014. The immunization data are combined with our constructed time-varying country-level citizen's trust in the central and the local government officials from the Afrobarometer surveys. We find that changes in contemporaneous public trust towards the government are positively and significantly associated with changes in country immunization coverage rates. Moreover, we show that it is trust in the central government that drives the relationship and not trust in the local government. We also document a heterogeneous effect of public trust in more decentralized countries or the intensity of adverse historical shocks such as the slave trade and more fragmented societies. The findings suggest that, if appropriately leveraged, institutional trust could potentially improve immunization services in Africa.

Keywords: public distrust, childhood immunization, vaccine hesitancy, sub-Saharan Africa

Contents

1 Introduction

Immunization is recently facing growing public resistance and concern about its safety. As a result, vaccine hesitancy is identified as one of the top 10 threats to world health in 2019 by the World Health Organization (WHO, 2019). Despite their remarkable success over the last decades, the infectious and communicable diseases they prevent are still widely prevailing.[1] Especially in sub-Saharan Africa, where they account for half of the disease burden.[2]Fortunately, many of these illnesses are nowadays widely preventable by the mean of cost-effective health technologies such as vaccination. However, their uptake remains suboptimal. For instance, around 20 million children under one year did not receive lifesaving vaccines worldwide in 2018. A large share of them lives in sub-Saharan Africa.

The traditional literature usually emphasizes the infrastructure and supply impediments to health services to explain the low access to primary health care in developing countries, such as deprived and under-financed health systems (Estache and Wodon, 2014, Das and Hammer, 2014) on the one side. On the other side, there are constraints from the demand side related to liquidity, low education, and knowledge about the effectiveness and benefits of vaccines, and behavioral limitations such as present bias (Dupas, 2011).

However, government-sponsored immunization programs regularly face a widespread crisis of skepticism and rumors about their motives in the sub-Saharan African context. This observation makes the issue of public trust in government particularly salient for a successful immunization policy. Despite growing qualitative and case studies evidence, discussing the importance of trust in the demand for health, few empirical studies are investigating the relationship between trust and immunization outcomes (Gilson, 2003, 2006; Larson et al., 2010, 2015, 2018; Jamison, 2019).

In sub-Saharan Africa, it is not unusual that the government, when perceived as untrustworthy, faces vaccination resistance due to sterilization and family planning rumors (Kaler, 2009). These rumors are often pervasive and even persist in the presence of deadly epidemics

[1]Immunization is deemed as one of the "low hanging fruit" of global health alongside access to clean water (Kremer and Gleenerster, 2012). Immunization is one of modern medicine's most significant public health success stories, and it has triumphed, achieving smallpox eradication in 1980 (Fenner et al., 1988). Until today, vaccines prevent 2 to 3 million child deaths every year, according to WHO estimates.

[2]In comparison, they are responsible for only 3% of infections in high-income countries according to the World Health Organization (WHO, 2008).

with immediate health threats such as the current Ebola epidemics in Congo (DRC) (Vinck et al., 2019). The resulting suspicious beliefs and non-cooperative attitudes towards the state submit to popular conspiracy theories on government vaccination motivations and accusations of complicity with large pharmaceutical companies and foreign countries (Jolley and Douglass, 2014).

These conspiracy allegations are furthermore perceived as credible in an environment combining particular features: a public authority perceived as corrupt and solely motivated to secure funding from international donors; circumstances in which the government fails to provide primary curative health services, often perceived as more pressing needs by the public, but is eager to implement family planning policies that often involve coercion and costly change in cultural and behavioral norms (Gonzalez-Torres and Esposito, 2018); memories of public health harmful side effects or misbehavior, resulting in vaccine resistance, as the Northern Nigeria boycott of polio-immunization campaign following vaccines adverse effects illustrates (Jegede, 2007).

Why should trust in the government be particularly relevant for immunization programs in Africa? First, because childhood immunization, as provided in sub-Saharan Africa, remains a supply-driven and government-sponsored public health intervention mostly, also widely benefiting from financing and technical support from international health organizations and donors (Khaleghian, 2004). As a result, the service faces serious challenges to stimulate the demand for this preventive health technique, whose benefits are not always easily observed relative to curative primary care (Dupas and Miguel, 2006). Second, the government is a quasi-monopoly provider of essential immunization services, and there remains substantial asymmetry of information and power towards the public on its public health motives and the safety of vaccines. Third, particular features of immunization programs in sub-Saharan Africa make them easily subject to rumors and suspicions. In addition to prevailing uncertainty, Kaler (2009) identifies short term and intensive mobilization during immunization campaigns with unusually zealous health workers, provided with free of charge serums and eager to achieve targeted coverage goals. Often, the aim is reached even at the price of normative pressure and coercion on parents to vaccinate. Vaccination campaigns, through their technical and mastery execution, contrast with other curative primary health services. These differences may highlight the extent of the collapse of routine gov-

ernment health services and raise suspicion and mistrust in front of unfamiliar commitment and goodwill. Moreover, it is not unusual that such campaigns are implemented at the cost of routine health services, mobilizing the essentials of human capital and logistics. Further, people may equally amalgamate vaccination goals with those of the public clinic in charge of fertility control and reproductive health policy, as the latter regularly provides routine child immunization as well.

In this paper, we investigate the role of trust in public authorities and immunization performance. We postulate that citizens who trust more their government are more likely to overcome the uncertainty around government motives, the negative popular beliefs, and exposure to conspiracy theories around sterilization and fertility control, and subsequently more likely to rely upon the argument from authority (Cummings, 2014). As a consequence of holding favorable priors on the trustworthiness of the public authority, trust will translate into vaccination decisions and higher aggregate country performance ceteris paribus.

Across sub-Saharan African countries, government immunization programs take place in an environment and climate that is more or less favorable to the cooperative behavior of citizens towards the state. In this paper, we posit that according to the current state of the world, higher trust in the state triggers favorable priors towards an uncertain and risky health intervention, while conversely a negative state of the world, corresponding to relatively lower trusting environment, triggers negative priors towards the state immunization campaigns and less compliance. In particular, we hypothesize that changes in the level of public trust in the government predict changes in the country-level immunization performance.

Although highly informative and relevant to both scholars and health policy practitioners, it is difficult to establish a causal relationship between public trust in government and country-level immunization. The challenge is even more daunting in the developing country context, where high uncertainty of supply and low predictability of demand behavior characterize the environment in which health services are delivered. Precisely, we face two significant identification challenges. The first is omitted variables, which affect both immunization level and public trust in government. The second is the issue of reverse causality, related to the fact that the country's health performance also determines institutional trust. As a consequence, a traditional cross-section analysis would face severe limitations due to

the inability to account for country-specific confounding factors that codetermine both immunization performance and the level of institutional trust. Moreover, in the absence of any readily available instrument, establishing causality is difficult. Plausible candidates from the literature, such as protest or media coverage of corruption cases, would necessarily violate the exclusion restriction. Since they probably affect immunization performance in a way we could not account for and different from the public trust channel.

Hence, to overcome the above identification issues, we take advantage of the recent Afro- barometer survey series. We construct a panel of time-varying measures of citizens' institutional trust while controlling for differences in individual characteristics between countries since they determine both individual trust in the state and child immunization decision. Subsequently, exploiting the time variations of our trust measures permits accounting for country fixed effects, which means controlling for unobserved time-invariant variables to address the omitted variables bias, but also the possibility to identify the effect of other observed time-varying factors influencing both country immunization rates and institutional trust. Among these time-varying factors are variables capturing the evolution in the country population demographics, changes in the level of health financing, in the governance and institutional quality, and the overall economic and political cycles.

To address reverse causality, we investigate the effect of public trust from past periods on current changes in immunization performance. This approach is meaningful, given the evidence of short-term volatility of citizen's beliefs and perceptions towards the state (Sangnier et Zylberberg, 2017). However, we are aware that identification relies upon the assumption that trust in the past periods is not correlated with unobserved heterogeneity in the current period. This assumption is quite strong, given evidence in the literature on long term persistence and historical roots of heterogeneity in trust and related outcomes. From the literature, variations in public trust are jointly determined by the current environment and historical factors and beliefs from the past such as early childhood socialization and culture (Bisin and Verdier (2001), Tabellini (2008), Algan and Cahuc (2010), Nunn and Wantchekon (2011)). Our objective in this paper is not to disentangle between these two channels but to establish the empirical relationship between changes in beliefs towards the state and subsequent changes in overall uptake of a trust-sensitive primary health service that is child immunization.

We further provide evidence for our conjectured trust channel by performing different empirical exercises. First, we discard the potential interpretation that significant statistical correlation found between trust in the head of state–trust in the president–is driven by the country's overall positive perception towards the government leaders, as a result of better health performance or global political, economic, or social environment. To achieve this objective, in addition to the inclusion of a rich set of controls, we also investigate the impact of public trust in the local government that is not in charge of immunization programs. Indeed, there is much evidence supporting that basic immunization in sub-Saharan Africa is primarily a central government mandate with the collaboration of global health and international donors. We find a positive and significant correlation between public trust in the central government authorities and country-level childhood immunization rates. An increase in public trust in the president is positively and significantly associated with an increase in country-level immunization. This result is supported by trust in the legislative branch of the state, in charge of public budgeting approval, and whose actions may reflect the preferences of the executive branch on public spending and investment. Most importantly, for our identification, the observed positive and significant correlation is not present for trust in the executive local government. We interpret this finding as the first evidence for our interpretation of the trust in the government channel.

Second, to further confirm our hypothesized trust mechanism, we perform a placebo test by looking at the effect of public trust on a more general health outcome that should also reflect overall government performance. The identification hypothesis is that, had our results been driven by unobserved confounding factors and reverse causation from government health performance to trust in government (Rockers et al., 2012), the relationship between trust in the head of state and child mortality rate should pick-up both effects. We do not find any evidence of a significant correlation between trust in the head of state on infant and neonatal mortality rates as we did for immunization. A finding we interpret as a supporting evidence of the behavioral component of trust in government that we capture and not the overall government quality in implementing health policy.

Third, we acknowledge that our national coverage rates data and the country-level approach do not enable us to take into account within-country regional specificities and variations in vaccination attitudes and outcomes. Only observing mean country coverage rates

mask potentially much heterogeneity within a country in vaccination performance, determined by local specificities, public health services, and the cultural attitudes towards vaccination. In particular, the absence of evidence for the effect of trust in local government raises the issue of the effect of administrative and fiscal decentralization in the provision of public services, which has public good dimension. By solely observing national average measures of trust in local government, we do not capture all the complexities of shared mandates between the central and local governments. In line with addressing these limitations, we operate two exercises. First, we investigate the issue of the heterogeneous effect of trust in the head of state according to the level of political and fiscal decentralization. Second, we further investigate the heterogeneous effect of trust in the state as a function of the historical and social fragmentation at the country level, which allows preliminary investigation of within-country disparities. The impact of negative past historical shocks has been proven to shape inherited interpersonal trust within societies sub-Saharan Africa context through past exposure to the slave trade (Nunn and Wantchekon, 2011), and other variables such as ethnolinguistic and religious fractionalization (Alesina et al., 2003). These variables have been shown in the pioneering literature as potential determinants of both institutional trust in the local government, provision of public goods, and overall economic outcomes in sub-Saharan Africa.

We find that the interaction effect of trust in the central government head of state is negative in more administratively decentralized countries. The interaction with fiscal decentralization was not statistically significant, although it had a negative sign. These results suggest that public attitude towards the central government has less impact in more decentralized countries. One plausible interpretation of the result is that the central state is less influential in shaping local health attitudes in more decentralized settings. As a result, overall attitudes may have less impact, in particular, when preferences and objectives are diverging. We also tested the heterogeneous effect of trust in local government, one could have expected a significant effect for more autonomous localities, but we found no significant effect, confirming the relative stronghold of the central state in immunization services.

We investigate the effect of public trust interacted with historical and sociocultural fractionalization and found a negative effect of the slave trade, ethnolinguistic, and religious

fractionalization. One could have expected public trust towards the central government to be more valuable in more fractionalized societies, but the findings suggest that social cohesion and public trust are a complement. A possible alternative interpretation is this result illustrates the historical and cultural dimensions shaping institutional trust (Algan and Cahuc, 2010, for a review). Thus, our findings call for further investigating the roots of trust at the society level and research design that take into account heterogeneity in the individual, cultural, and local context at which the vaccination decisions are made.

Conceptually, our work sheds light on the different dynamics of institutional trust. We show that public trust has a short-term volatile component, fluctuating over time within and between countries. This time-varying feature is essential since it confirms some degree of adjustment and update of citizens' beliefs and attitudes towards the state and suggest the scope for public intervention.

The remainder of this paper is organized as follows. In section 2, we discuss the related literature to our work. In section 3, we provide the background on rumors and distrust in vaccination and government in sub-Saharan Africa and the conceptual framework on which we build to study the effect of trust in government in immunization. In section 4, we present the data. The estimation strategy is specified in section 5 with some basic resulting descriptive statistics. The main results are shown in section 6 and discussed in section 7. Finally, section 8 concludes.

2 Related Literature

The novelty of this work is in providing direct empirical evidence on the effect of changes in public trust across time and vaccination coverage rates. The paper contributes to a growing literature on institutional trust and vaccines, until now mainly focused in high-income countries, and has remained widely anecdotal and mostly based on qualitative evidence (Blair et al., 2017). We explicitly operationalize quantitatively public trust using responses to nationally representative surveys. We exploit access to longitudinal survey data on public trust in comparison to the majority of the public health literature on trust in the health sector. The latter generally rely either upon qualitative analysis on a small sample or context-specific case study design with mixed-method (exploratory interviews, focus-group, and in depth-

interview) (Larson et al., 2018, Jamison et al., 2019). The strength of their approach is that they allow in-depth and detailed documentation and understanding of the potential link between different factors and dimensions of trust and vaccination intention or uptake.

Nevertheless, they fall short of addressing the inherent limitations of case studies, which are context-specific and raises external validity issues regarding the possible generalization of the findings. Moreover, establishing causal inference is out the scope of these studies. To our knowledge, this is the first study with a panel approach linking public trust in government and vaccine coverages rate in sub-Saharan Africa.

In particular, this work contributes to recent and burgeoning research on vaccine hesitancy and trust in vaccination that attempts to measure and understand the determinants and dynamics of vaccine confidence for global public health (Larson et al., 2015, 2018). Larson et al. (2018) systematically and extensively surveys the literature that explicitly refers to trust and confidence in vaccines in their research questions and objective. They find that, although this literature covers different dimensions of trust, it often implicitly refers to trust and the majority lack of formal definition of trust. They conclude to: "a disconnect between the current vaccine hesitancy research and the wider health-related trust literature, a dearth in research on trust in low and middle-income settings, a need for studies on how trust levels change over time and investigations on how resilience to trust-eroding information can be built into trustworthy health system." Our work echoes this call and attempts to address this knowledge gap. We also speak to the specific public health literature investigating the role of differential trust in government and racial disparities in demand for vaccines (Gilles et al., 2011; Freimuth et al.,2017; Jamison et al., 2017). For instance, Jamison et al. (2017) study the relationship between trust in federal government and health institutions and influenza vaccine uptake between African Americans and Whites. They show that African Americans were less likely to trust the government and more skeptical about its motivations regarding vaccines. In focus group interviews, some African American non-vaccine takers declared: "You don't trust a government vaccine!... I don't trust the government for nothing they are mixed-up". Our research attempts to put quantitative evidence on these qualitative and anecdotal narratives.

A more conceptually supporting and contextually close to our work studies protests and citizens' trust in the state in sub-Saharan Africa (Sangnier et Zylberberg, 2017). The

authors show that after a recent protest, citizens update their beliefs as captured by a sizable decrease in their level of trust in the state leaders and public officials. They document the link between negative changes of perception after protests and declared intentions for future civic behavior such as abstaining from voting in the next elections or voting for opposition parties. In our work, we were not able to distinguish the particular driver of the negative or positive shock to trust towards the state, but we could identify its effect across a more extended period and its aggregate effect on subsequent health outcome sponsored by the government and calling for trust, compliance and cooperative attitude.

Particularly closer to our topic an using the same quantitative approach is recent literature investigating how short term adverse shocks of disclosed information, misinformation, and rumors raising doubts on the motivations and trustworthiness of the government or health workers might undermine public trust. This growing skepticism leads to lower demand for immunization and health services. In recent work, Martinez-Bravo and Stegmann (2019) study the impact of disclosure of the 2011 American CIA fake vaccination campaign in Pakistan and its subsequent negative impact on trust in vaccines and on demand for modern health services, after Taliban anti-vaccination propaganda. The strength of their approach is that they focus on clearly identified information disclosure campaign and exploit a difference-in-differences strategy to identify the effect of a negative shock to public trust in vaccination behavior. However, one potential limitation of their work is that it might fail to discriminate between distrust and coercion due to intimidation effect from the Taliban propaganda. Parents living in areas under Taliban influence may be under threat, and thus involuntarily withdraw their children from vaccination.

Related literature studies the impact of institutional trust and misinformation during public health crises such as containment of epidemics in Africa (Blair et al., 2017 in Monrovia (Liberia) and Vinck et al., 2019). They find that respondents expressing low trust in government and holding misinformed beliefs and rumors were less likely to accept Ebola vaccines, to adopt the government health directives and precautions such as preventive behaviors, or to comply with social distancing measures such as quarantine. They show that even respondents trusting independent non-governmental organizations (INGOs) were not more compliant conditional on not trusting the government, leading them to the conclusion that INGOs cannot substitute for government institutions. This result is related to our

findings on the distinctive effect of trust in the central and the local government and the importance of identity in trusting attitudes.

Moreover, forthcoming literature in epidemic outcomes studies the relationship between institutional trust in government, misinformation during the Ebola crisis in sub-Saharan Africa, and epidemic containment. Gonzalez-Torres and Esposito (2018) show that public health intervention to stop the disease propagation in West-Africa generated conflict in areas where the citizens highly mistrusted the government.

Our work is also related to a more pioneering research about the disclosure of Tuskegee Syphilis study, a 40 year (1932 to 1972) government study where 399 black men from Macon County (Alabama) were purposely denied adequate treatment for Syphilis, allegedly in the scientific objective to understand the natural history of the infection (Gamble, 1997). The authors document how this event led to a considerable drop of African American trust in the federal government and health institutions and discouraging participation in clinical trials and organ donation. In a follow-up study, Alsan and Wanamaker (2017) quantitatively show that black men living nowadays closer to the Tuskegee location have lower trust in health care institutions.

In this context, an emerging literature studies beliefs in conspiracy theories and the psychological roots of anti-vaccination attitudes (Jolley and Douglass, 2014; Hornsey et al., 2018). They find that people endorsing conspiracy beliefs around the US government and the 9/11 attacks, or the death of Princess Diana, were also more likely to hold conspiracy beliefs around the Big Pharma, the link between vaccines and autism and subsequent anti-vaccination attitudes.

Another strand of literature implements randomized-control-trials (RCTs) and identifies barriers to preventive health demand such as liquidity constraints, time preference, and the psychological costs of difficult access to health care (See Dupas, 2011 and Dupas and Miguel, 2017 for a review).

Finally, this paper is broadly related to an extensive literature on the determinants of health demand and vaccine uptake in low-income countries. Political stability, gender equality, and smaller land surface are associated with higher and more equal vaccination coverage rates at the country-level (Arsenault et al., 2017). Other researchers study the effects of social norms such as gender inequities; relationship to power (Antai, 2012); parents'

preferences (Ozawa, 2018); mother's social engagement, vaccine availability, vaccine safety concerns, mothers' low education and imperfect information (Adeloye et al., 2016).

3 Background on vaccination and conceptual framework

3.1 Background on vaccination rumors and public distrust in sub-Saharan Africa

In sub-Saharan Africa, vaccines have drastically reduced the burden of infectious and communicable diseases by reducing disease morbidity and related mortality. Despite their achievements and effectiveness as a health strategy, immunization intervention is still facing the challenges of skepticism, which translates into frequent and regular confidence and resistance crisis (Kaler, 2009). Many events across the continent account for this trust crisis. One classical episodic widely studied and discussed in the literature is related to Nigeria, the most populated country in the continent. In August 2003, four northern Nigerian states boycotted the polio immunization campaign launched earlier in the vague of the WHO's 1998 Polio Eradication Campaign.

As a consequence of previous low participation, the country accounted for 45% of polio cases worldwide, and 80 % of cases reported from the African region in 2003 (Renne, 2006). The campaign failure was a consequence of widespread rumors and public distrust towards government vaccination programs and foreign intervention in general, in what is a majority Muslim area. Local politicians and religious leaders called parents to resist the immunization program. They suspected vaccines were contaminated with anti-fertility (estradiol hormone), HIV, and cancerous agents (Jegede, 2007).

Historically, the region experienced government population control in the 1980s while the country was under military rule and experienced successive political turmoil. This experience also led the population to connect vaccination with the federal government's willingness to control the fertility rate and willingness to sterilize children. Later, in 1996, the region experienced a vaccine trial lead by the American drug producer Pfizer. The trial was suspected of having provoked the death of 11 children, and to ethical misbehavior (Jegede,

2007). In particular, the 2003 campaign took place during the United-States war in Iraq after September 11th. A favorable context for conspiracy theories around Muslim population control spreading in grassroots communities. The political context led Muslim communities in the North to be suspicious of any "western world" initiated public intervention in majority Muslim regions. Throughout this narrative, one can understand how the combination of sterility rumors, a succession of past government failures, religious beliefs, and political influence generated an environment of suspicion and distrust in front of any attempt from the government to implement immunization intervention.

Earlier in 1990, the anti-tetanus campaign faced the same rumors of sterilization of schooling girls in western Cameroon. Feldman-Savelsberg et al. (2000) and Kaler (2009) document how a history of resistance to the central government, coincidence with government family planning and contraceptive promotion, and rumors of ethnic population control motivations triggered fierce population rejection of the tetanus toxoid vaccines. The opposition and suspicion culminated after the murder of a priest advocating anti-vaccination. Protests and public discontents pressured the government ultimately to abandon the intervention.

In Uganda, Lucy Gilson (2003) survey trust and its impact on the development of health care. In the period between the 1970s and 1980s, Uganda went through a political crisis, causing the collapse of the national economy and public expenditure in the health system. This situation resulted in a weakened public health system. Health workers lost motivation after many health professionals left the country and a surge of low quality alternative private formal and informal health suppliers (Birungi,1998). As Gilson wrote: "The resulting distrust of immunization services provided through government facilities was rooted in patient's concern for their own safety. It led people to own their own syringes; then could either opt to be given an injection by a friend or relative or insist on their own equipment being used when attending a government health facility." This latest narrative conveys an understanding of how failure to adequately provide health services through lack of funding translate into the negative perception of citizens on the quality of public health systems and ultimately result in the decision not to use the government health facilities or follow its medical advice. Trust in government and subsequent cooperative behavior might also be driven by citizen's confidence in government performance and trustworthiness. For our empirical investigation, the practical implication is to duly account for the quality of the

supply side of vaccines, namely the health system, and the quality of the country's institutional framework.

3.2 Conceptual framework

From a conceptual point of view, country immunization rates are the result of the interaction between the supply and the demand for vaccines. We postulate that the potential size of the market is determined by the estimated target population as captured by the evolution of the country's population demographic structure. The level of vaccine supply is determined by the level of investment in the health system as captured by the level of domestic government investment in the preventive health sector, and the level of funding from international donors (health system financing). We assume the objective quality of vaccines is exogenous and determined by foreign industrial producers.

The demand for vaccines is determined by the individual socio-demographic characteristics (age, education, gender, income, urbanization) susceptible to influence their opportunity cost and their knowledge and preferences for preventive measures. We assume that in the presence of uncertainty about government motives and information asymmetry about the safety and effectiveness of vaccines, citizen's vaccination decision is significantly determined by their level of institutional trust in the government.

Additionally, the level of institutional trust in the government is shaped by two main distinct factors: the institutional performance (perceived government effectiveness, quality of governance, level of control of corruption, political, social and economic environment) and the cultural background from early socialization (ethnicity, inherited norms of trust) (Bisin and Verdier, 2001; Bisin et al., 2004; Guiso et al., 2008; Tabellini, 2008; Algan and Cahuc, 2010; Nunn and Wantchekon, 2010; Rockers et al., 2012; Godefroidt et al., 2017; Foster and Friedan, 2017).

We posit that citizens who trust the government are more likely to hold favorable beliefs that the government is willing to take the right course of action and "do what is perceived as fair" (Easton, 1965). As a consequence, they are more likely to rely upon "the argument from authority" when deliberating upon their child vaccination decision (Cummings, 2014). Identification of the behavioral component of trust in the public authority requires

appropriately controlling for the potential confounding factors associated with the standard economic and social dimensions.

4 Data

The individual-level data on trust in public institutions are from four consecutive rounds of the Afrobarometer surveys. These survey series are nationally representative and based on interviews conducted in the local languages of a random sample of either 1,200 or 2,400 individuals of voting age in each country.[3] Our baseline sample includes a total of 16 sub-Saharan African countries: Botswana, Cabo Verde, Ghana, Kenya, Lesotho, Malawi, Mali, Mozambique, Namibia, Nigeria, Senegal, South Africa, Tanzania, Uganda, Zambia, and Zimbabwe. Across all survey rounds and countries, we have a potential sample of 167,162 respondents.

The respondents reported on their level of trust in the public officials: the president, the parliament, and the local council. They answered literally to the question: "How much do you trust each of the following, or haven't you heard about them to say: the president ?" (the parliament ? or the local council ?). The answer takes four possible values of 0, 1, 2, or 3 : 0 corresponding to the response "not at all"; 1 to "just a little"; 2 "to somewhat"; and 3 to the response "a lot." In this work, we distinguish between trust in the two institutional levels as trust in the central government (trust in the president, trust in the parliament) and trust in the local government (trust in the local council).

The data on vaccine coverage rates measures the proportion of children immunized with each vaccine at one year of age. They were obtained from the WHO statistics. We collected data on coverage rates for the three uniformly provided basic vaccines according to the WHO immunization schedule: measles vaccine (MCV1), a single vaccine usually admin-

[3] The data were collected in the period 2002 and 2014 and included all respondents countries from the 2nd to the 5th survey round. The 2nd round surveys took place between the year 2002 and 2003, the 3rd round between 2005-2006, the 4th round data collected between 2008 and 2009 and finally the 5th survey round data collected between 2011 and 2013.

istered at around 9 months of age, DTP1 and DPT3 vaccine, the first and third dose of a three vaccine series against diphtheria, pertussis (whooping cough) and tetanus that is usually administered at around 10–16 weeks of age and the third dose of poliomyelitis vaccine administered generally after 14 Weeks. The data covers 12 years over the period 2002 to 2014.[4]

Given that the period spanned by our vaccination panel is longer than our trust measure by one year, we match our panel of public trust data to the country-level data on immunization coverage rates. We assign our country-level trust measures as measured from 2002 to 2013 from the Afrobarometer survey to match the period 2002-2014 of the vaccine data. The country-level trust reported in public authorities for the period 2002-2003 (corresponding to survey round 2) is extended to the period 2002-2004. Following a similar logic, public trust from 2005-2006 (round 3) is extended to 2005-2007; public trust in 2008-2009 (round 4) is extended to the period 2008-2010; and finally, the public trust of 2011-2013 (round 5) is extended to the period 2011-2014. In summary, for each survey round, we had a one-year extension. To make our matching of coverage rate to the timing of trust measure by the Afro-barometer more consistent, we take the average immunization coverage rate over the period in which public trust is surveyed in the country.[5] Table 1 below, split in Panel A and Panel B, provides a full and self-contained presentation of all variables, their short description, and the data source.

[4] According to WHO estimates, in 2014, more than 18.7 million infants worldwide were not reached with routine immunization services such as DTP3. In the same year, 114,900 measles deaths were reported globally, corresponding to 314 deaths every day or 13 child deaths every hour. For poliomyelitis, the WHO official assessment illustrates the challenge: "Failure to eradicate polio from these last remaining strongholds could result in as many as 200 000 new cases every year, within ten years, all over the world."

[5] In practice, many children complete their immunization schedule in more than one year since many catch-ups over several campaigns later than the initial schedule. Taking the average over two to three years period might better reflect the time-span of the decision. It also addresses the issues of missing observations and measurement errors and delays in reporting on the yearly panel.

***Table 1-Panel A* Variable description and data source**

Variables	Description	Source
Health system performance		
Vaccine coverage rate	Yearly vaccine coverage rate : DTP1,DTP3,MCV1,Pol3	World Health Organization
Infant mortality rate	Probability of dying between birth and age 1 per 1000 live births	World Health Organization
Neonatal mortality rate	Probability of dying per 1000 live births	World Health Organization
Under-five mortality rate	Probability of dying by age 5 per 1000 live births	World Health Organization
Institutional trust		
Trust in the president	Response to the trust in President question	Round 2 to 5 of the Afrobarometer survey
Trust in parliament	Response to the trust in Parliament question	Round 2 to 5 of the Afrobarometer survey
Trust in local council	Response to the trust in Local council question	Round 2 to 5 of the Afrobarometer survey
Population demographics		
Total population	Population, total	United Nations, Population Division (2015).
Pop. Less than 5 years	Pop. less than 5 years	United Nations, Population Division (2015).
Pop. Less than 15 years	Pop. less than 15 years	United Nations, Population Division (2015).
Female 15-49 years	Female 15-49 years	United Nations, Population Division (2015).
Pop. Density	Population density (people per sq. km of land area)	World Bank (2015)

***Table 1 (Continued)-Panel B* Variable description and data source**

Health financing		
GDP per capita	GDP per capita (current US$)	World Bank and OECD
Health Expenditure	Current health expenditure (CHE) as % of GDP	World Health Organization
Health Expenditure	Current health expenditure (CHE) per capita in PPP int$	World Health Organization
Health Expenditure	Domestic general government health expenditure (GGHE-D) per capita in PPP int$	World Health Organization
Health Expenditure	Domestic private health expenditure (PVT-D) per capita in PPP int$	World Health Organization
Health Expenditure	External health expenditure (EXT) per capita in PPP int$	World Health Organization
Health Expenditure	Out-of-pocket expenditure (OOP) per capita in PPP int$	World Health Organization
Governance and Institutional performance		
Decentralization	Decentralization Index	The World Bank (2015)
Accountability	ranges -2.5 (weak) to 2.5 (strong) governance performance	WGI, The World Bank (2015)
Political Stability	ranges -2.5 (weak) to 2.5 (strong) governance performance	WGI, The World Bank (2015)
Government Effectiveness	ranges -2.5 (weak) to 2.5 (strong) governance performance	WGI, The World Bank (2015)
Rule of law	ranges -2.5 (weak) to 2.5 (strong) governance performance	WGI, The World Bank (2015)
Corruption	ranges -2.5 (weak) to 2.5 (strong) governance performance	WGI, The World Bank (2015)
Regulatory quality	ranges -2.5 (weak) to 2.5 (strong) governance performance	WGI, The World Bank (2015)
Institutional quality	Aggregated scores on the six above institutional quality dimensions	WGI, The World Bank (2015)
Electoral Cycle	Time distance to electoral year	Database of Political Institutions
Sociocultural		
Ethnicity	Ethnic fractionalization index	Encyclopedia Britannica Book of the Year 2001
Language	Language fractionalization index	Encyclopedia Britannica Book of the Year 2001
Religion	Religion fractionalization index	Encyclopedia Britannica Book of the Year 2001
History	Number of slaves exported by country normalized by population	Nunn (2008)

5 Estimation strategy

In this section, we first present our two-step estimation method to build a time-varying measure of country-level public trust from the individual respondents to survey questionnaires, and next estimate the effect of changes in public trust on changes in immunization coverage rates. Second, we present some basic descriptive statistics of our the resulting main dependent and independent variables used in this study.

5.1 First-step: estimating country contemporaneous level of public trust

In a first step, we follow our methodology by estimating an average measure of public trust across country and survey periods controlling for individual characteristics of the respondents. The rationale behind this two-step estimation follows from the above discussion that the individual characteristics determine institutional trust and immunization, although our immunization data are aggregated at the country level. In this first step, we can extract an average and comparable measure of public trust against the same baseline controlling for heterogeneities in respondents' similar observable characteristics across the country and survey rounds. We estimate the relationship between an individual's reported trust level in public officials and a dummy for her current country of the location to capture the country fixed-effects:

$$TRUST_{i,c,t} = \alpha_0 + C_c\alpha_{ct} + X_{i,c,t}\gamma + \varepsilon_{i,c,t} \qquad (1)$$

where $TRUST_{i,c,t}$ stands for reported trust level of individual i, living in country c at survey period t corresponding to each of our four survey rounds. The variable $TRUST_{i,c,t}$ denotes one of our three measures of public trust that are: trust in the president (the head of state), trust in the parliament, and trust in the local council changing across individuals in the same country and surveyed in the same period. C_c is a vector of country dummy variables across different survey rounds where Senegal is our reference country, and α_{ct} denotes by construction a country contemporaneous fixed effects of reported public trust.

The coefficient α_{ct} is, therefore, our proxy for the average trust of individuals who live in a country c at period t (Algan and Cahuc, 2010). The constructed country-level measure of public trust has the advantage of providing a comparative measure of trust across time, controlling for differences in individual-level characteristics across survey rounds. Those variables are included in $X_{i,c,t}$ such as age, gender, education, income, employment status that are all susceptible to influence trust in the state.

The country-level of public trust $\mathrm{PublicTRUST}_{c,t}$ is constructed relative to Senegal for each survey round, which is the omitted country in the vector of country dummies. The coefficients of interest α_{ct} is then an adjustment of public trust level against our baseline country and capture the variations of country-level public trust relative to Senegal.

We choose Senegal as a reference country for several reasons. First, the country is reputed to be one of the most stable democracies in sub-Saharan Africa and depicted as an example of political and social stability in the region. Second, its citizens report a relatively high level of trust in their public officials. Third, the country has known a long period of peaceful state with no ethnic, religious, or civic conflict compared to its neighbors, especially during the survey period, where it experienced two peaceful democratic transitions. Moreover, the country did not experience a significant health crisis during the survey period, and there is a long tradition of modern public health since the early colonial period. As an illustration, it was the only sub-Saharan African country that experienced and controlled Ebola spread despite recording an imported case from Guinea, successfully managed it, and the patient recovered. So we choose a relatively stable country as a benchmark to minimize the chances that relative changes in public trust across time are driven by unobserved and confounding factors in the benchmark. A positive and significant coefficient for a country dummy in a given survey period means that its citizens reported, on average, a significantly higher level of trust towards the public official of interest relative to Senegalese citizens. The detailed results for this first step are reported in Appendix A.

5.2 Second-step: Modeling the effect of changes in public trust on changes in immunization coverage rate.

The changes in contemporaneous public trust are measured by the change in the value of the country of origin fixed effects in separate regressions of the trust question for the successive survey rounds, as estimated in equation(1).

In this second step, we study the effect of changes in our measure of country-level public trust on changes in immunization coverage rates by estimating the following equation:

$$\Delta VaccineCoverageRate_{ct} = VCR_{ct} = \beta_0 + \beta \Delta PublicTRUST_{ct} + \Gamma \Delta X_{ct} + F_c + \nu_{ct} \qquad (2)$$

Where $\Delta VaccineCoverageRate_{ct}$ is the change in immunization coverage in country c at survey period t relative to the country of reference Senegal. $\Delta PublicTRUST_{ct}$ is the change in the average measure level of public trust in country c relative to Senegal as obtained from the estimation of equation (1) above. ΔX_{ct} is a set of time-varying control variables susceptible to predict country immunization coverage rates, as discussed in our conceptual framework. It includes controls for population demographics including population size, population density, population less than five years, the share of the female of reproductive age 15-49 years among others, and obtained from the UN Population Division and the World Bank. These variables capture the classical potential level of demand for the vaccine. Control variables for health financing are from the WHO, including the amount of domestic general government health expenditure per capita, the external health expenditure per capita from foreign institutions, the share of out-of-pocket health expenditure directly from private households. We included governance and institutional quality controls for political stability, accountability, government effectiveness, control for corruption, regulatory quality retrieved, the rule of law from the Worldwide Governance Indicators (WGIs). Additional controls for the general economic and political cycle included a variable for GDP per capita from the World Bank and a variable for the time distance to electoral period obtained from the Database of Political Institutions. These variables control the general country's economic outlook and potential strategic improvement in public spending in the health sector due to electoral motives. F_c is a vector of country fixed-effects capturing time-invariant country characteristics such as ethnolinguistic and religious fractionaliza-

tion, past historical shocks such as the influence of slave trade, past institutions such as colonial rules susceptible to shape institutional trust.

This specification has both conceptual and technical advantages. First, it permits a dependent variable consistent with our public trust independent variables measuring the changes in the value of the country public trust relative to our baseline country. Second, taking the difference relative to Senegal rather than the level of coverage rate allows normalization of the dependent variable around zero, which accounts for increasing marginal difficulty to improve vaccine coverage rates.

The country fixed effects control for unobserved time-invariant heterogeneity across countries that would affect immunization coverage rate. Including time fixed effect would control for common trends on immunization coverage rate, but since our dependent variable captures a difference relative to the same country of reference for each survey round, which removes common trend by construction.[6] Besides, taking the difference also address the bounded nature of immunization coverage rates (here, the risk of predicting coverage rate higher than 100 or lower than 0).

5.3 Descriptive statistics

We provide basic descriptive statistics of the variations of our main independent variable, measuring the country's time-varying public trust as a result of our first-step estimation. In Table 2 below, we show summary statistics of the measure of contemporaneous public trust in the president, trust in the parliament, and the local council as measured in eq. (1). The negative sign of the mean is consistent with the observation that the reference country displayed an average higher level of trust. The most important feature for our empirical investigation is that there are significant variations both within and between countries as captured by the standard deviations that equal to more than two to three times the mean. Also, these variations are consistent across both trust in the central government public officials (the head of state and the parliament members) and the local government (local coun-

[6] See Dell et al. (2014) for a conceptual discussion of different empirical specifications in panel data estimation.

cilors). The within standard deviation is as high as 0.36 for trust in the president, 0.32 for trust in the parliament, 0.38 for trust in the local council. These variations support our empirical strategy that exploits fluctuations in trust towards the state. Figure 1A in Appendix graphically illustrates using box plots the variations of public trust over time in our baseline sample of 16 countries discussed.[7]

Table 2: **Summary statistics for country-level measure of public trust coefficients**

Variable	sample	Mean	Std. Dev.	Min	Max
Trust in the president	overall	-0.14	0.48	-1.38	1.03
	between		0.37	-1.08	0.41
	within		0.36	-0.89	0.77
Trust in the parliament	overall	-0.05	0.45	-1.20	1.11
	between		0.37	-0.97	0.50
	within		0.32	-0.71	0.67
Trust in the local council	overall	-0.14	0.51	-1.16	2.78
	between		0.38	-0.91	0.66
	within		0.38	-1.13	1.98

Source: Data are from the Afrobarometer survey

Table 3 below shows a summary of the descriptive statistics of our main dependent variables corresponding to country vaccination coverage rates (MCV1, DTP1, DTP3, Polio3) and their changes during the observation period 2002-2014. By looking at the mean, one can see that, on average, the sub-Saharan African countries did not reach the herd immunity level across the three vaccines (95% according to the WHO definition). For example, the average measles vaccine coverage is 79.6% in our sample, but there are a lot of variations between countries, ranging from 26 to 99% and a standard deviation of 15.7 percentage points. The

[7] We can distinguish that variations exist across all countries and measures of public trust. However, some clusters of countries emerge, systematically low-trusting countries relative to Senegal, such as Nigeria, South Africa, and Zimbabwe (fixed effects below zero). Another cluster of, on average, more fluctuating countries are Botswana, Malawi, Ghana. These countries fall above or below the country of reference during the survey period. Finally, there is a cluster of relatively high public trusting countries such as Namibia in the South-West and Tanzania in the Eastern region of the continent.

decrease (nearly 8 points) in the average coverage rate between the first dose of DTP1 and the third dose of DTP3–completing the full sequence is needed for the effectiveness of the vaccine–illustrates the challenge of child dropout throughout the immunization schedule. The Polio vaccine remains a challenge, despite the continent's success to stop the propagation of what used to be in the last century a highly infectious and child disabling disease. The lowest national coverage rates are observed in polio-endemic countries such as Nigeria, where 3 million children are unprotected (WHO, 2019). This situation makes eradication very challenging since Nigeria is also the most populated country in the region and regularly exports cases of infections abroad. Fluctuations in the country's performance in immunization occur both within countries across time but also between countries. Standard deviations might be as high as 16 percentage points and above 10 percentage points both between and within countries. Immunization rates have improved throughout the continent, but have stagnated during the last decade, while fertility rates remain high. Moreover, a particularly challenging feature of immunization is that performance and high coverage rate needs to be sustained every year to stop epidemic resurgence and expect eradication.[8]

[8] In practice, countries might improve performance or backslide over time according to complacency towards infection risks, deprived health system, conflict, social crisis, or trust crisis in vaccines (WHO, 2019).

Table 3: **Summary statistics for country variations in immunization coverage rate**

Variable	Sample	Mean	Std. Dev.	Min	Max
MCV1	overall	79.60	15.70	26.00	99.00
	between		9.67	64.59	96.18
	within		12.50	28.84	100.00
DTP1	overall	90.09	12.18	20.00	99.00
	between		6.79	68.42	98.27
	within		10.26	24.16	100.00
DTP3	overall	82.28	16.17	19.00	99.00
	between		10.02	56.23	97.65
	within		12.96	35.16	100.00
Pol3	overall	81.47	16.42	19.00	99.00
	between		10.45	56.15	97.65
	within		12.92	34.94	100.00
Diff_MCV1	overall	10.51	15.64	-36.00	50.00
	between		9.84	-6.08	27.29
	within		12.33	-25.84	44.75
Diff_DTP1	overall	0.29	13.05	-59.00	29.00
	between		7.25	-24.27	9.21
	within		11.04	-54.63	31.79
Diff_DTP3	overall	5.47	16.15	-56.00	47.00
	between		10.33	-25.00	21.12
	within		12.75	-39.65	43.11
Diff_Polio3	overall	6.87	16.72	-54.00	50.00
	between		10.67	-22.46	23.29
	within		13.19	-36.95	44.75

Data source are from WHO (2015)

6 Results

6.1 Main Results

Table 4 below summarizes our baseline estimates of the effect of changes in public trust on changes in vaccine coverage rates using average time data on our baseline panel of 16 countries observed during 4 periods. The results are in line with our hypothesized positive

relationship that increase in trust in government officials is positively and significantly associated with an increase in immunization coverage rates within-country over time. The estimates are positive, statistically significant, and consistent across all the three basic vaccines (MCV1, DTP1 and DTP3, and Polio3). The first line of Table 4 confirms our hypothesis that trust in the central executive branch, as represented by the president, is positively correlated with country immunization performance. Supporting evidence are found from the similarly positive effect of trust in the central government monitoring institutions, as the parliament, which is generally controlled by the government in sub-Saharan Africa and responsible for public budget approval. As illustrated by the highly correlated level of trust reported between the two institutions.[9]

A first major identification threat is an observed relationship merely driven by overall positive perception towards the political leaders–due to a favorable climate– that we fail to control in some way. The absence of a significant correlation between trust in local governments and immunization rates, in the third line of Table 4, suggests discarding this possibility. Additionally, this finding is consistent across all vaccines and sequences. This result is consistent with our interpretation that public trust is identity-sensitive, and citizens, at least to some extent, can adapt their behavior according to the relevant public authority.

Quantitatively, the estimated effect of the positive shocks on public trust on the increase in coverage rates is sizable. We find that for the first dose of measles vaccine, MCV1: a 1 unit increase (nearly two standard deviations) in country-level citizens' trust in the president relative to Senegal is associated with 23 percentage points increase in immunization coverage rates in that country. The coefficients are similarly sizable and significant for DTP1, DTP3, and Polio3 vaccines and correspond to 19, 16, and 13 percentage points, respectively.

The sign and the size of the estimates are stable for trust in parliament members. We conjecture that this result might capture citizens' trust in the ability of the parliament members to monitor the executive branch and promote legislation for safety and effective immunization. Intuitively, one could discuss the different sizes of the effect across the first and third doses of vaccines sequence. Within our public trust framework, one should expect a higher effect of trust for the first-dose rather than the third dose of a sequence, this way capturing the "psychological cost of the first move." Coverage rates in DTP3 and Polio3 as the result of

[9]Correlation between trust in the president and trust in the parliament is 0.92, while the coefficient is 0.61 for local government.

three consecutively administered vaccines may reflect more routine vaccination and overall functioning of the health system (Khaleghian, 2002) and involve other behavioral determinants of uptake such as convenience, time-consistency, and commitment not to drop out. As a consequence, the single vaccines such as the single-dose of measles, also frequently administered through immunization campaigns, could capture and support more our trust interpretation.

Table 4: **The effect of public trust on immunization coverage rate: summary of main baseline estimates**

	(1) Diff. MCV1	(2) Diff.DTP1	(3) Diff.DTP3	(4) Diff.Polio3
Within estimates: Fixed-effects model				
Trust in the president	23.057***	19.045**	16.992*	13.354**
	(6.840)	(8.189)	(9.343)	(6.256)
Trust in parliament	23.675**	20.521***	15.990*	14.843**
	(9.975)	(6.593)	(8.558)	(7.352)
Trust in local council	-0.822	1.228	-1.056	-0.687
	(15.765)	(19.872)	(30.279)	(14.279)
Population demographics	Yes	Yes	Yes	Yes
Health financing	Yes	Yes	Yes	Yes
Quality of Governance	Yes	Yes	Yes	Yes
Country Fixed-effects	Yes	Yes	Yes	Yes
Observations	64	64	64	64
N countries	16	16	16	16
T periods	4	4	4	4
Adj.R^2	0.486	0.450	0.475	0.503

The table reports within-country fixed-effects estimates. Standard errors are bootstrapped with 50 replications. Population demographics controls include changes in total population, population less than 5 years, population less than 15 years, the female population between 15-49 years, population density. Health financing controls include changes in the share of health expenditure out of GDP, domestic general government health expenditure per capita, domestic private health expenditure per capita, external health expenditure per capita, out-of-pocket expenditure per capita. Quality of governance control includes government accountability, political stability, government effectiveness, the rule of law, and regulatory quality. Additional controls include changes in GDP per capita and time distance to the electoral period.

$^{*}p<0.10,^{**}p<0.05,^{***}p<0.01$

Source: World Health Organization (WHO) and Afrobarometer survey

6.2 Robustness checks

To provide further supporting evidence for our hypothesized changes in contemporaneous trust channel, we perform different robustness checks. We first investigate whether our findings are robust to alternative empirical specifications and explanatory channels in Table 5 below. In panel A of Table 5, we first test the simultaneous effect of the current period and lagged level of public trust on current vaccination coverage rates. We find any evidence of significant persistence of the previous changes in public trust in the president on today's increase in vaccination rates. Moreover, the coefficients capturing the effects of the current level of public trust in immunization remain stable and robust in sign, size, and significance across vaccines in this alternative specification. They are even close to similarity with our baseline estimates.

Next, we investigate the speed citizens directly update their beliefs towards the head of state and the resulting subsequent attitudes by looking at the direct effect of public trust in the previous period on current changes in immunization coverage. Panel B in Table 5 shows it has a non-significant effect on the current changes in vaccination coverage rates. We interpret this result as supporting our claim that our research design captures a dynamic component of public trust that adjusts according to the perceived trustworthiness of the government and subsequently influence behavior towards the state intervention. Interestingly, the model specification with public trust from the past periods could potentially mitigate, at least partially, the particular identification issue associated to reverse causality between health performance and trust in the state authorities. However, this approach relies on the assumption that the lagged level of trust is uncorrelated with unobserved heterogeneity in the current period. Given the evidence from the literature on the persistence of even institutional trust, associated in recent literature to factors such as national and ethnic identification in Africa (Godefroidt, 2017), one should look for additional and more consistent evidence.

Table 5: **Robustness-checks: The effect of public trust on immunization coverage rate: summary of main estimates**

	(1) Diff. MCV1	(2) Diff.DTP1	(3) Diff.DTP3	(4) Diff.Polio3
Panel A				
Long term effect of trust in period (t-1)				
Trust in the president	22.490**	19.318***	16.799**	12.417**
	(9.299)	(7.186)	(7.538)	(5.981)
Trust in the president(t-1)	8.979	11.366	4.370	10.679
	(18.686)	(14.421)	(15.056)	(12.090)
Panel B				
Lagged coverage rate (period t-1)				
Trust in the president(t-1)	12.016	11.309	6.639	12.356
	(12.238)	(39.847)	(15.309)	(14.295)
Controls				
Population demographics	Yes	Yes	Yes	Yes
Health financing	Yes	Yes	Yes	Yes
Quality of Governance	Yes	Yes	Yes	Yes
Country Fixed-effects	Yes	Yes	Yes	Yes
Observations	64	64	64	64
N countries	16	16	16	16
T periods	4	4	4	4

The table reports within-country fixed-effects estimates. Standard errors are bootstrapped with 50 replications. Population demographics controls include changes in total population, population less than 5 years, population less than 15 years, the female population between 15-49 years, population density. Health financing controls include changes in the share of health expenditure out of GDP, domestic general government health expenditure per capita, domestic private health expenditure per capita, external health expenditure per capita, out-of-pocket expenditure per capita. Quality of governance control includes government accountability, political stability, government effectiveness, the rule of law, and regulatory quality. Additional controls include changes in GDP per capita and time distance to the electoral period.

$^{*}p<0.10,^{**}p<0.05,^{***}p<0.01$

Source: World Health Organization (WHO) and Afrobarometer survey

6.3 Using infant and child mortality as a placebo

Our preferred exercise performs a placebo test using infant and neonatal mortality rates that are more general national health outcomes susceptible to also government performance. The rationale and identification hypothesis of our test are that, if the empirical relationship between trust in the president and immunization merely reflects the results of omitted confounding factor or reverse causation from government health performance, the relation to child mortality should equally pick-up this effect. From now, we focus on trust in the pres-

ident and the outcome on the single dose of measles for reasons introduced earlier. We run the placebo regressions on the country's infant, neonatal, and children (under five years) mortality outcomes, as shown in Table 6. Through all three measures of child mortality, we do not find any significant direct relationship between trust in the president and the level of mortality. Given that child mortality reflects overall health and public service performance, such as access to clean drinking water limiting child deaths from diarrheal disease or malaria infection control, we interpret such absence of relationship as additional evidence that for vaccines, we capture the behavioral component of trust in government.[10]

Table 6: **Public trust and overall child health performance: Placebo with Child mortality**

	(1)	(2)	(3)
	Infant mortality	Neonatal mortality	Under 5 years mortality
Trust in the president	2.946	0.070	1.557
	(3.296)	(1.029)	(6.202)
Population demographics	Yes	Yes	Yes
Health financing	Yes	Yes	Yes
Quality of Governance	Yes	Yes	Yes
Country Fixed-effects	Yes	Yes	Yes
Observations	64	64	64
N countries	16	16	16
T periods	4	4	4
Adj.R^2	0.844	0.887	0.847

The table reports within-country fixed-effects estimates. Standard errors are bootstrapped with 50 replications. Population demographics controls include changes in total population, population less than 5 years, population less than 15 years, the female population between 15-49 years, population density. Health financing controls include changes in the share of health expenditure out of GDP, domestic general government health expenditure per capita, domestic private health expenditure per capita, external health expenditure per capita, out-of-pocket expenditure per capita. Quality of governance control includes government accountability, political stability, government effectiveness, the rule of law, and regulatory quality. Additional controls include changes in GDP per capita and time distance to the electoral period.

$^{*}p<0.10,^{**}p<0.05,^{***}p<0.01$

Source: World Health Organization (WHO) and Afrobarometer survey

[10] Less information imperfect preventive technologies are ITN bed net and water deworming or provision of clean water, see Dupas (2011).

6.4 Heterogeneous effects

In this section, we explore heterogeneous effects alongside two dimensions: we further explore the absence of significant effect of trust in the local government by investigating the role of shared mandates between the central government and the local government, after we explore the interplay between historical and fractionalization factors and institutional trust in the state. We seek to gain more insights into the specificities of the regional and local context in which the vaccination decisions are undertaken.

During the 1990s, many sub-Saharan African countries went through decentralization reforms resulting in heterogeneous–although more or less effective–fiscal and administrative local autonomy. Some literature has investigated the role of decentralization on the delivery of health services with public good dimension such as immunization (Khalegian, 2004). The theoretical predictions are ambiguous about the potential direct effect of decentralization in the provision of immunization health services. The literature predicts that decentralization may be beneficial if the positive effect of increased information and adaptation of the service to the local context outweigh the potential adverse effect of lower governance capacity, free-riding between jurisdictions in the presence of positive externalities, or conflicting objectives and preferences between the central and local government. For the particular interaction effect with public trust, we hypothesize that more fiscally decentralized sub-Saharan African countries, defined as the rate of presence of taxation and free public spending, such as Nigeria, could experience less influence of the central state. As a consequence, low trust in the central government combined with a negative local attitude towards vaccines might end with diverting public funds away from preventive and often less popular services such as immunization towards more curative services. A higher level of administrative decentralization, defined as the empowerment of local government and freedom to employ and contract out and build partnerships, provides more autonomy to the local government from the central state. So that, even overall positive attitude towards the central state does not directly influence the behavior at the local level in the provision of health services and could undermine it in case of conflicting objectives.

Our results from this exploratory analysis are in Table 7 below. We find a negative interaction effect between public trust in the president and administrative decentralization on the changes in immunization coverage (Ivanyna and Shah, 2012, Index 2005, measured

from Worldwide Indicators on Localization and Decentralization in 2005, The World Bank, March 2012). Although the interaction effect was only statistically significant under robust standard errors.[11]This finding suggests that more administratively decentralized countries may experience less influence of the central state so that trust in the central state have relatively less effect on regional or local vaccination outcomes. Our earlier discussion from case studies in Northern Nigeria supports this interpretation.

Second, we further examine the heterogeneous effect of trust in the state interacted with a measure of the country's historical exposure to the slave trade. This variable has been demonstrated to shape interpersonal trust in sub-Saharan Africa and trust in the local government (Nunn and Wantchekon, 2011). We also study the interaction effect with other measures of the societal fragmentation potentially interacting with institutional trust by subsequently exploring the impact of ethnolinguistic and religious fractionalization (Alesina et al., 2003). As shown in Table 8 below, the estimated interaction effect is negative for all the variables. Institutional trust has a weaker effect in countries that were more exposed to the slave trade and in more ethnically, linguistically, and religiously fractionalized countries. Although the estimates were not significant for the latter. Similarly, the statistical significance is not robust to the bootstrapped standard errors as reported in Appendix Table A4.[12] These results, although still approximate and with limited robustness to inference, are in line with some previous findings on the persistence of the negative effect of the slave trade as a historical shock on trusting attitudes in Africa. Moreover, combined with estimates from the adverse effects of societal fractionalization, we conjecture that trust in institutions and interpersonal trust are complementary rather than substitutes. Indeed, one could have expected that the positive effect of trust in the state to be higher in more fractionalized states, but the current estimates do not support this interpretation. In principle, this exer-

[11]The interaction effect for fiscal decentralization was not statistically significant, although it had the expected negative sign (not reported). We have also tested the interaction between trust in the local government and administrative decentralization and did not find any significant effect. The absence of a significant coefficient of the interaction with fiscal decentralization may reflect the domination of central government over funding of immunization and as the main channel for international donor's funds.

[12]

The bootstrapped standard errors were often error prone during computation in Stata software, especially specifications including variables with some missing observations. As a result, we often reported the results from both type of standard errors.

cise could face a significant limitation due to the potential absence of time variations on the historical and fractionalization variables in a cross-sectional setting. Fortunately, our panel approach allows controlling for their direct impact on immunization by including the country fixed-effects.

Table 7: **Heterogenous effects of Public trust: Decentralization**

	(1) Diff. MCV1	(2) Diff. MCV1	(3) Diff. MCV1	(4) Diff. MCV1
Trust in the president	30.430***	30.430***	20.547*	20.547**
	(7.855)	(6.914)	(11.840)	(7.002)
Trust*Decentralization Index	-37.286	-37.286**	-30.847	-30.847**
	(23.903)	(14.015)	(39.661)	(12.550)
Controls				
Population demographics	Yes	Yes	Yes	Yes
Health financing	Yes	Yes	Yes	Yes
Quality of Governance	Yes	Yes	Yes	Yes
Country Fixed-effects	Yes	Yes	Yes	Yes
Observations	64	64	64	64
N countries	16	16	16	16
T periods	4	4	4	4
Adj. R^2	0.765	0.765	0.810	0.810

The table reports within-country fixed-effects estimates. Standard errors are bootstrapped with 50 replications in column (1) and (3) and cluster robust in (2) and (3). Population demographics controls include changes in total population, population less than 5 years, population less than 15 years, the female population between 15-49 years, population density. Health financing controls include changes in the share of health expenditure out of GDP, domestic general government health expenditure per capita, domestic private health expenditure per capita, external health expenditure per capita, out-of-pocket expenditure per capita. Quality of governance control includes government accountability, political stability, government effectiveness, the rule of law, and regulatory quality. Additional controls include changes in GDP per capita and time distance to the electoral period.

$^{*}p<0.10,^{**}p<0.05,^{***}p<0.01$

Source: World Health Organization (WHO) and Afrobarometer survey

Table 8: **Heteorgenous effects of Public trust: the slave trade and fractionalization**

	(1) Diff. MCV1	(2) Diff. MCV1	(3) Diff. MCV1	(4) Diff. MCV1
Trust in the president	35.995***	43.529***	30.199***	36.990***
	(10.417)	(12.849)	(7.818)	(8.692)
Trust*Log slave exports	-1.206*			
	(0.660)			
Fractionalization				
Trust*Ethnic		-28.739**		
		(12.033)		
Trust*Language			-15.858	
			(10.385)	
Trust*Religion				-20.219**
				(8.770)
Controls				
Population demographics	Yes	Yes	Yes	Yes
Health financing	Yes	Yes	Yes	Yes
Quality of Governance	Yes	Yes	Yes	Yes
Country Fixed-effects	Yes	Yes	Yes	Yes
Observations	64	64	60	64
Adj.R^2	0.741	0.752	0.792	0.753

The table reports within-country fixed-effects estimates. Robust standard errors are reported. Population demographics controls include changes in total population, population less than 5 years, population less than 15 years, the female population between 15-49 years, population density. Health financing controls include changes in the share of health expenditure out of GDP, domestic general government health expenditure per capita, domestic private health expenditure per capita, external health expenditure per capita, out-of-pocket expenditure per capita. Quality of governance control includes government accountability, political stability, government effectiveness, the rule of law, and regulatory quality. Additional controls include changes in GDP per capita and time distance to the electoral period.

$^{*}p<0.10,^{**}p<0.05,^{***}p<0.01$

Source: World Health Organization (WHO) and Afrobarometer survey

7 Discussion

Our results first suggest that public trust in government officials is an essential determinant for uptake and subsequent performance. If we hypothesize a potential causal link from this

robust correlation, a direct policy implication is the need to carefully considering public trust in designing immunization health programs. We find that the effect of institutional trust is identity sensitive and directed towards the specific level of government in charge of the immunization. This result would call for the strategic choice of the public health policy sponsors according to potentially induced public beliefs and attitudes. In particular, the heterogeneous effect of decentralization suggests a closer consideration of the public trust and beliefs citizens hold on public authorities as an additional determinant in the optimal task allocation between the central and local governments. Moreover, early evidence indicates that the prevailing environment is not the sole determinant of the current trust level, but historical factors also influence it. As a consequence, improving trust in the government would not just entail addressing actual government performance but also probably ingrained current beliefs and attitudes likely inherited from the past. Further exploration of this insight, call for more careful consideration of deep-rooted trusting beliefs people hold and local circumstances in which they make child immunization decision. In this perspective, our findings call for questioning the roots and determinants of citizen's trust and their subsequent effect on their behavior towards health interventions.

Although it provides empirical evidence for the correlation between institutional trust and the aggregate level uptake of a health technology involving imperfect information such as vaccines, this study faces serious shortcomings to claim a causal relationship. Country-level institutional trust is endogenous, in particular to health performance, especially in developing countries where primary health care is among the most visible and interactive platform between citizens and government services. Moreover, trust in the state depends on multiple dimensions: individual characteristics capturing early socialization, current governance and institutional quality, current economic and political environment, inherited cultural beliefs, and social norms from earlier generations. Throughout this analysis, we have attempted to provide careful attention to each of these dimensions. Although a country level setting, with aggregated coverages rates, does not allow to carefully model many individuals and local context determinants of vaccination outcomes. Further, it misses a lot of heterogeneities in the individual, household, and local circumstances in which health decisions occur, and the decentralized setting in which health services are provided.

The best configuration was observing the vaccination decisions of those respondents

to the trust survey directly. The second-best could have been to find an instrument for institutional trust, but any potential close candidate for trust in the state, such as protests or media coverage of corruption cases, would probably violate the exclusion restriction. These variables are plausibly, directly and indirectly, influencing immunization coverage rates through ways we are not able to account for and different from our hypothesized public trust channel — the complexity increases in a country level setting and a relatively large sample of 16 countries. An alternative approach would be to move to cross-sectional analysis with potentially more accessible time-invariant candidates, but with aggregated data at the country level, this estimates would face the severe threat of omitted variable bias and this method might likely be inferior to our current approach in the presence of a weak instrument.

Conceptually, our analytical framework could not allow specifying the precise drivers of changes in the within-country trust level. In theory, we claim that they could be originating from different sources, among which persistent rumors in vaccination health intervention, failures or misbehavior in government health intervention, endorsement of conspiracy theories spreading in the grassroots of communities. However, it is crucial to bear in mind that rumors and distrust in government do not always lead to the rejection of government health intervention, hence the distinction between hesitancy and refusal. The boycott is not the rule, but widespread skepticism overall leads to lower uptake (Kaler, 2009).

From the methodological point of view, accurately modeling an aggregate outcome, which is the result of individual decisions, always raises concern as well as finding the right specification. Moreover, despite our time-varying approach, making use of a direct measure of public trust, is a particular and interesting feature of our work, by allowing to control for unobserved and time-invariant country specificities that threaten the identification of the effect of institutional trust, the issue of an unspecified time-variant events correlated with both institutional trust and immunization performance cannot be discarded although we attempt to overcome this problem, by controlling for a rich set of time-varying measures of institutional and governance quality, that are susceptible to capture potential confounding factors. However, such aggregate indicators have shown to be prone to measurement errors and cannot fully capture informal institutional and cultural norms susceptible to influence vaccination outcomes (Algan and Cahuc, 2013). Finally, even when assuming our rich set

of controls address the omitted variable issue, investigating the effect of contemporaneous trust on health outcomes always still raises the serious concern of reverse causality bias. Here also, we performed different exercises that conclusively rule-out this limitation, but we acknowledge that they either rely upon strong statistical identification assumption or secondary evidence which robustness is always subject to discussion.

Finally, one should aim for an analysis of the effect of trust on vaccination at the individual decision-making level. Building on this insightful and informative preliminary evidence—although not inferentially robust—on the complex interplay between trust in the state and the decentralized setting in which health services are provided on the one hand, and the historical and social fragmentation factors on the other hand. This novel approach would further directly account for individual cultural backgrounds and preferences while controlling precisely for heterogeneities in the local circumstances.

8 Conclusion

Mistrust in vaccines is the object of growing global health concern. This paper studies the empirical link between public trust and country-level vaccination rates in sub-Saharan Africa. Our estimates indicate a positive and significant effect of short-term changes in institutional trust on changes in vaccination outcomes. We find that the significant link is specific to trust in the central government authorities. Our interpretation of this result is that our measure of trust in the head of the state captures the behavioral component of institutional trust and is identity salient to the appropriate public authority undertaking the immunization programs. The empirical regularity is robust to accounting for relevant predictors of country-level immunization performance such as individual, population, health financing, institutional quality, and unobserved country specificities.

Further alternative specifications support the idea that we are capturing the short-run update of trusting beliefs towards the state. Moreover, there is no evidence for a general effect of trust in the state on a related health outcome that is child mortality. However, preliminary evidence suggests that the effect of trust in the central state is weakened in a more decentralized governance setting, past exposure to trust eroding historical shocks such as slave trade and in more fractionalized societies. Overall, the paper establishes first that a

part of institutional trust could be quickly revised and might trigger a positive and socially desirable attitude towards the state if leveraged appropriately. This effect is more likely to appear in the provision of imperfect information public service and particular health technologies such as vaccination. First insight, rule in favor of complementarity between institutional and the inherited trust from past generations and shaped by history and cultural norms.

Although informative with providing robust correlations, the study faces potential bias threatening the proper identification of the effect of public trust. Therefore, one should cautiously refrain from claiming any causal relationship despite the attractiveness of our within-country variations approach. Given parents' child vaccination decisions are at the individual and household level, influenced by both their preferences and socio-demographic characteristics, combined with the various economic, social, cultural, institutional, and historical specificities, the question should be analyzed in a more local context.

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Appendix

Preliminary results: individual level analysis and estimation of country level public trust coefficients

The statistical significance of the coefficients associated with country dummies in Table A1 Panel A below shows that citizens from different countries reported a significantly different level of trust in their president relative to those in Senegal across the five survey rounds. The dominance of the negative sign shows that Senegalese citizens frequently reported a higher level of trust than citizens in most other countries. However, one interesting feature emerges from Table A1 Panel A, the variability of the relative level of trust reported by the citizens across different survey rounds. It shows that trust in public institutions or authorities is dynamic and changing from one period to another. An interesting illustration is column 4, corresponding to round 4 of the years 2008 and 2009. In this particular period, Senegalese citizens reported lower trust in their president than nearly any other country: 33% of respondents said they do not trust the President at all, just after the worst score in Zimbabwe where the share of non-trusting reached 37%. This period corresponded to political, social, and economic unrest in the wake of controversial presidential and parliament elections where many political parties boycotted the scrutiny. This trend subsequently changed one survey round later. The following Table A1-Panel B and Table A1-Panel C on public trust in parliament and trust in the local council displays similar qualitative results.

Table A1-Panel A: **OLS ESTiMATES OF COUNTRY FIXED EFFECT ON INDIVIDUAL TRUST IN PRESIDENT**

	(2)		(3)		(4)		(5)	
	Round 2		Round 3		Round 4		Round 5	
senegal	ref.		ref.		ref.		ref.	
botswana	-0.708***	(0.038)	-0.177**	(0.072)	0.944***	(0.050)	0.202***	(0.062)
ghana	-0.269	(0.165)	0.075	(0.150)	0.764***	(0.151)	-0.384***	(0.148)
malawi	-0.698***	(0.078)	-0.129*	(0.077)	0.846***	(0.076)	-0.106	(0.093)
namibia	-0.076	(0.194)	0.049	(0.061)	0.968***	(0.066)	0.270**	(0.105)
nigeria	-1.375***	(0.081)	-1.316***	(0.079)	0.014	(0.087)	-0.902***	(0.082)
south africa	-0.815***	(0.088)	-0.160	(0.109)	-0.072	(0.071)	-0.297***	(0.101)
tanzania	-0.088***	(0.033)	0.416***	(0.041)	1.035***	(0.048)	0.033	(0.062)
uganda	-0.503***	(0.167)	-0.130	(0.147)	0.323***	(0.097)	-0.271***	(0.059)
zambia	-0.586***	(0.045)	-0.707***	(0.091)	0.039	(0.080)	-0.147**	(0.074)
zimbabwe	-0.440***	(0.078)	-0.919***	(0.046)	-0.215***	(0.070)	-0.313***	(0.073)
cabo verde	-1.119***	(0.031)	-0.750***	(0.056)	0.096*	(0.051)	-0.149*	(0.077)
kenya	-0.250**	(0.109)	-0.511***	(0.189)	0.262*	(0.141)	-0.191	(0.142)
lesotho	-0.493***	(0.036)	0.125**	(0.053)	0.219***	(0.047)	-0.215***	(0.049)
mozambique	-0.265***	(0.054)	0.186***	(0.047)	0.975***	(0.085)	0.085	(0.128)
mali	0.006	(0.045)	0.113**	(0.053)	0.373***	(0.053)	-0.797***	(0.071)
Controls	Yes		Yes		Yes		Yes	
N	26065		25870		26879		50940	
adj. R^2	0.222		0.226		0.154		0.136	

Note: The table reports OLS estimates. The unit of observation is an individual. The reported standard errors are adjusted to cluster at the individual ethnicity level. Clustering at the country level gives quasi similar estimates. The individual controls are for age, age squared, a gender and urban dummy variables, three employment fixed-effects, three education fixed-effect and five living conditions fixed-effects. The samples estimated cover all survey rounds for which the respondent answered to the question of how much they trusted their president. The second Round cover the period 2002/2003, the third 2005/2006, the fourth 2008/2009 and the fifth 2011/2013.

$^{*}p<0.10,^{**}p<0.5,^{***}p<0.01$

Source: Data are from the Afrobarometer survey

Table A1-Panel B: **OLS ESTiMATES OF COUNTRY FIXED EFFECT OF INDIVIDUAL TRUST IN PARLIAMENT**

	(1)		(2)		(3)		(4)	
	Round2		Round3		Round4		Round5	
senegal	ref.		ref.		ref.		ref.	
botswana	−0.551***	(0.039)	0.087	(0.064)	0.812***	(0.057)	0.106	(0.067)
cabo verde	−0.706***	(0.035)	−0.294***	(0.064)	0.369***	(0.072)	−0.027	(0.076)
ghana	−0.309***	(0.091)	0.209***	(0.058)	0.665***	(0.081)	−0.263***	(0.083)
kenya	−0.258***	(0.042)	−0.474***	(0.085)	0.399***	(0.067)	−0.116	(0.088)
lesotho	−0.372***	(0.036)	−0.022	(0.055)	0.470***	(0.056)	0.120*	(0.061)
malawi	−0.578***	(0.051)	−0.145	(0.095)	0.372***	(0.068)	0.237***	(0.071)
mozambique	−0.110*	(0.056)	0.447***	(0.072)	1.106***	(0.096)	0.249**	(0.110)
mali	0.148***	(0.053)	0.236***	(0.054)	0.552***	(0.044)	−0.429***	(0.081)
namibia	−0.409***	(0.087)	0.084	(0.058)	0.836***	(0.072)	0.257***	(0.077)
nigeria	−1.200***	(0.079)	−1.048***	(0.081)	−0.049	(0.090)	−0.762***	(0.074)
south africa	−0.621***	(0.097)	−0.100	(0.080)	0.355***	(0.064)	−0.086	(0.087)
tanzania	0.013	(0.034)	0.619***	(0.047)	1.040***	(0.061)	0.382***	(0.074)
uganda	−0.346***	(0.049)	0.111**	(0.051)	0.435***	(0.100)	0.198**	(0.084)
zambia	−0.477***	(0.047)	−0.327***	(0.074)	0.392***	(0.058)	−0.122	(0.089)
zimbabwe	−0.344***	(0.061)	−0.491***	(0.046)	0.531***	(0.053)	−0.104*	(0.059)
Controls	Yes		Yes		Yes		Yes	
N	25418		24876		26367		50223	
Adj. R^2	0.176		0.186		0.100		0.144	

Note: The table reports OLS estimates. The respondents answered literally to the question "How much do you trust each of the following, or haven't you heard enough about them to say: Parliament ?" The unit of observation is an individual. The answer takes four possible values of 0, 1, 2, or 3 : 0 corresponds to the response "not at all"; 1 to "just a little"; 2 "to somewhat"; and 3 to the response "a lot". The reported standard errors are adjusted to cluster at the individual ethnicity level. Clustering at the country level gives quasi similar estimates. The individual controls are for age, age squared, a gender and urban dummy variables, three employment fixed-effects, three education fixed-effect and five living conditions fixed-effects. The samples estimated cover four survey rounds.The second Round covers the period 2002/2003, the third 2005/2006, the fourth 2008/2009 and the fifth 2011/2013.

standard errors are in parenthesis

p<0.10,p<0.05,***p<0.01*

Source: Afrobarometer survey

Table A1-Panel C: **OLS ESTiMATES OF COUNTRY FIXED EFFECT OF INDIVIDUAL TRUST IN LOCAL COUNCIL**

	(1)		(2)		(3)		(4)	
	Round2		Round3		Round4		Round5	
senegal	ref.		ref.		ref.		ref.	
botswana	−0.737***	(0.024)	0.048	(0.095)	0.413***	(0.037)	0.108**	(0.042)
cabo verde	−0.887***	(0.018)	−0.356***	(0.107)	0.112*	(0.066)	−0.009	(0.046)
ghana	−0.595***	(0.055)	−0.159	(0.102)	0.266***	(0.047)	−0.323***	(0.070)
kenya	−0.671***	(0.038)	−0.603***	(0.100)	−0.063	(0.040)	−0.357***	(0.067)
lesotho	−0.448***	(0.024)	−0.089	(0.109)	0.127***	(0.041)	−0.066	(0.044)
malawi	−0.817***	(0.066)	−0.093	(0.105)	0.402***	(0.103)	0.730***	(0.174)
mozambique	−0.519***	(0.085)	0.345***	(0.128)	0.815***	(0.077)	0.189**	(0.091)
mali	−0.226***	(0.040)	0.203**	(0.093)	0.339***	(0.030)	−0.129***	(0.048)
namibia	−0.682***	(0.069)	−0.209**	(0.106)	0.378***	(0.055)	−0.065**	(0.031)
nigeria	−1.183***	(0.101)	−1.008***	(0.117)	−0.309***	(0.084)	−0.690***	(0.055)
south africa	−0.961***	(0.058)	−0.505***	(0.107)	0.080	(0.051)	−0.261***	(0.058)
tanzania	−0.263***	(0.020)	0.350***	(0.107)	0.619***	(0.045)	0.153***	(0.046)
uganda	−0.008	(0.031)	0.248**	(0.096)	0.270***	(0.088)	0.106**	(0.046)
zambia	−1.109***	(0.031)	−0.564***	(0.106)	−0.051	(0.062)	−0.348***	(0.045)
zimbabwe	−0.481***	(0.026)	−0.628***	(0.092)	0.220***	(0.046)	−0.175***	(0.037)
Controls	Yes		Yes		Yes		Yes	
N	24210		24959		26484		47759	
adj. R^2	0.204		0.183		0.098		0.136	

Note: The table reports OLS estimates. The respondents answered literally to the question "How much do you trust each of the following, or haven't you heard enough about them to say: Local council?" The unit of observation is an individual. The answer takes four possible values of 0, 1, 2, or 3 : 0 corresponds to the response "not at all"; 1 to "just a little"; 2 "to somewhat"; and 3 to the response "a lot". The reported standard errors are adjusted to cluster at the individual ethnicity level. Clustering at the country level gives quasi similar estimates. The individual controls are for age, age squared, a gender and urban dummy variables, three employment fixed-effects, three education fixed-effect and five living conditions fixed-effects. The samples estimated cover four survey rounds. The second Round covers the 2002/2003, the third 2005/2006, the fourth 2008/2009 and the fifth 2011/2013.

standard errors are in parenthesis $^{*}p<0.10,^{**}p<0.5,^{***}p<0.01$

Source: Afrobarometer survey

The effect of some individual characteristics on the level of trust in the president is reported in Table A2. A brief overview shows that trust increases with age and gender. More interestingly, more educated respondents reported a lower level of public trust in the president in contrast to most findings in developed countries. Similarly, citizens in urban areas report relatively less trust in the head of state. These findings are interestingly consistent with emerging literature in political sciences distinguishing between established and developing democracies (Godefroidt et al., 2016). A possible explanation to the negative effect of education, they claim, might be that in modern democracies policy performance is decisive in government assessment since strong institutions already exist, while in emerging ones, concern on design and fairness (ethnic bias for instance), lack of transparency and social concerns matters as much as actual government performance. Although uncovering individual determinants of trust in government is out of the scope of this work, this re-

sult is interesting for our particular vaccination outcome variable. It suggests that trust in government is not merely capturing a divide between educated versus non-educated, rural versus urban, and lack of knowledge of patients. A recent study of attitudes towards the government and Ebola found that, in contradiction to traditional stereotypes, distrust and non-compliance were not necessarily based on lack of "knowledge" on the virus transmission, symptoms, and treatment (Blair, 2017). Other correlates of trust in government are associated with the perception of better living conditions and to a lesser extent, job market outcomes. These are in line with the findings of other high-income countries that also emphasize the positive effect of the favorable labor market and occupational group (Foster and Frieden, 2017).

Table A2: **OLS ESTiMATES OF THE DETERMINANTS OF INDIVIDUAL TRUST IN PRESIDENT**

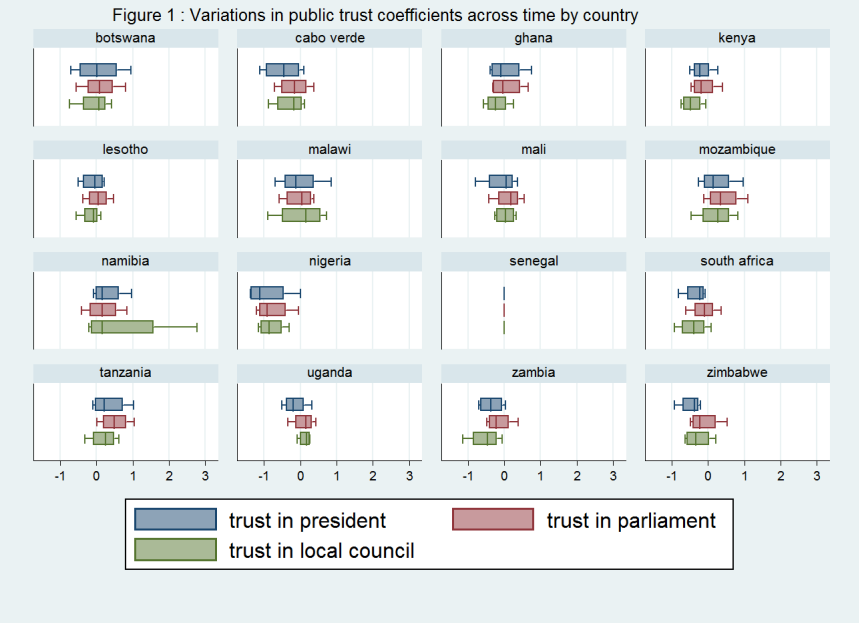
	Round 2	Standard errors
age	0.00877**	(0.00395)
age2	-0.0000695	(0.0000442)
male	0.0346*	(0.0196)
urban	-0.129***	(0.0279)
education : primary	-0.00583	(0.0335)
secondary	-0.180***	(0.0387)
tertiary	-0.268***	(0.0542)
Employment : Job (=No)	-0.0296	(0.0224)
Job (job search)	-0.0114	(0.0337)
Job (part time 1)	-0.0759**	(0.0341)
Job (part time 2)	-0.0135	(0.0272)
Job (full time)	-0.0262	(0.0324)
Living conditions: fairly bad	0.102***	(0.0242)
Living conditions: neither good nor bad	0.182***	(0.0305)
Living conditions: fair good	0.290***	(0.0335)
Living conditions: good	0.435***	(0.0507)
N country	16	
Country Fixed effect	Yes	
N	26065	
Adj. R^2	0.222	

cluster robust standard errors in parenthesis *$p<0.10$,**$p<0.05$,***$p<0.01$

Source: Data are from the Afrobarometer survey

Descriptive statistics: variations in public trust

Figure 1A:



Heterogeneous effect: slave trade and fractionalization

Table A3: **Heteorgenous effects of Public trust: the slave trade and fractionalization**

	(1) Diff. MCV1	(2) Diff. MCV1	(3) Diff. MCV1	(4) Diff. MCV1
Trust in the president	35.995**	43.529	30.199	36.990**
	(17.127)	(29.266)	(20.460)	(16.907)
Trust*Log slave exports	-1.206			
	(1.394)			
Fractionalization				
Trust*Ethnic		-28.739		
		(39.270)		
Trust*Language			-15.858	
			(26.546)	
Trust*Religion				-20.219
				(23.970)
Controls				
Population demographics	Yes	Yes	Yes	Yes
Health financing	Yes	Yes	Yes	Yes
Quality of Governance	Yes	Yes	Yes	Yes
Country Fixed-effects	Yes	Yes	Yes	Yes
Observations	64	64	60	64
Adj.R^2	0.741	0.752	0.792	0.753

The table reports within-country fixed-effects estimates. Standard errors are bootstrapped with 50 replications. Population demographics controls include changes in total population, population less than 5 years, population less than 15 years, the female population between 15-49 years, population density. Health financing controls include changes in the share of health expenditure out of GDP, domestic general government health expenditure per capita, domestic private health expenditure per capita, external health expenditure per capita, out-of-pocket expenditure per capita. Quality of governance control includes government accountability, political stability, government effectiveness, the rule of law, and regulatory quality. Additional controls include changes in GDP per capita and time distance to the electoral period.

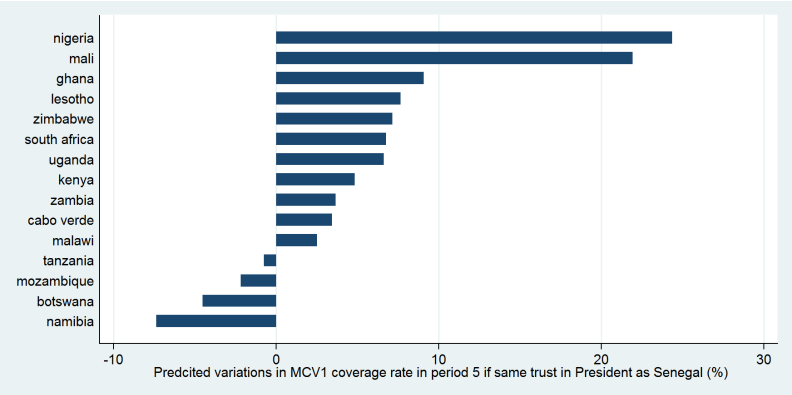
$^{*}p<0.10,^{**}p<0.05,^{***}p<0.01$

Source: World Health Organization (WHO) and Afrobarometer survey

Size of the effect: Counter-factual analysis and size of the effect

To evaluate the magnitude of the effect of public trust found above, we ask the question, what if all the countries in our sample had the same level of public trust than the reference country Senegal? We focus on public Trust in the president for the sake of illustration. Figure 2 below shows the predicted change in the MCV1 coverage rate in period 5 (2011-2013) if citizens in each country had the same level of public trust as Senegal. The graph shows that if Nigerian citizens, the country with the lowest level of public trust in our sample, had the same level of public trust than citizens in Senegal, the country predicted coverage level of MCV1 (first dose of measle vaccine) would have risen by 24%. This figure corresponds to 18 percentage points increase from a current average level of coverage of 79% to 98%. This finding is important because Nigeria is a country where more than 2 million children were not receiving measles vaccines MCV1 in 2007. Measles is an extremely contagious and airborne transmitted disease, and there is currently no specific cure except vaccination. In the period during 2011-2014, an average number of 21,249 cases per year occured in Nigeria. This number is twice more than the total 11,316 deaths due to the Ebola virus in Western Africa. In their study, Hall and Jolley (2011) convincingly show that 1% increases in MCV1 coverage rate are associated with a 2% decrease in disease incidence in the same year and the following year. If we calibrate our findings according to their estimates, the predicted increase of 24% in the MCV1 coverage rate would have led to a 48% drop in measles incidence in the same period and avoided around 10,000 child infections during that period. Although likely an overestimate and not established as causal, the effect would be sizable and significant in public health perceptive. So, it calls for further research on trust and public health in developing countries. Other countries experiencing political crises and social turmoil during the same period, such as Mali, would have also seen significant improvement. In contrast, relatively high performing Southern African countries such as Namibia and Botswana would have seen a decrease in coverage rates.

Figure 2A:


nigeria
mali
ghana
lesotho
zimbabwe
south africa
uganda
kenya
zambia
cabo verde
malawi
tanzania
mozambique
botswana
namibia
-10
0
10
20
30
Predcited variations in MCV1 coverage rate in period 5 if same trust in President as Senegal (%)

The Legacy of the Slave Trade: Towards Identifying the Causal Impact of Mistrust in Medicine on Health Behavior in sub-Saharan Africa

Laure Athias and Moudo Macina

October 27, 2019

Abstract

There is a large body of anecdotal evidence from sub-Saharan Africa of widespread medical distrust leading to health program failures. In this paper, to isolate an exogenous variation in trust in medicine to explain contemporary health behavior in sub-Saharan Africa, we rely on a widespread historical shock: the slave trade. We combine Nunn and Wantchekon (2011)'s historical data on the slave trade by ethnic group with individual-level data, geolocated at the district level, from the Demographic and Health Survey (DHS), during the period 2010-2014. We examine the reduced-form relationship between ancestors' exposure to the slave trade and current vaccination decisions against measles. Exploiting variations both within countries and districts, we find that children from mothers whose ancestors were exposed to the slave trade are less likely to be vaccinated. The size of the effect is more important than the effect of the standard determinants of health demand and preventive behavior, such as education or revenue. Evidence from a variety of identification strategies suggests that the slave trade affects vaccination decisions only through trust in medicine.

Keywords: Trust, Medicine, Slave trade, Health, Culture.

JEL codes: D12, I12, I18, J15, N57, Z13

Contents

1 Introduction

Despite improvements in health technology and access, immunization rates in sub-Saharan Africa remain suboptimal. While we can observe significant differences across countries, none of them reaches the herd immunity level that guarantees the protection of the entire population against the spread of highly infectious diseases such as measles (WHO, 2016). The main explanation given by the extant literature is imperfect information on illness prevention due to both low penetration of public health communication media and low education levels (Dupas, 2011a). More specifically, a series of studies using randomized field experiments confirm that providing information can have substantial impacts on health behavior.[1] They also point out that a discrepancy between actual and optimal behaviors remains even with perfect information, mainly due to the low education levels. In other words, even if the information is easily accessible, it is difficult for individuals to process it, underlying a limited cognitive-ability determinant of health behavior.[2]

However, evidence cries out for the consideration of another potential ground, the lack of trustworthiness of the information provided. In this respect, the Ebola outbreak in West Africa in 2014-2015 is very illustrative. ABC News, on July 28th, 2014, titled: "Doctors battling Ebola are met with fear, mistrust" (Neporent, 2014). The New York Times on March 13, 2015, in turn, titled: "Vaccines face same mistrust that fed Ebola" (Norimitsu and Sheri, 2015), and reports this quote from Dr. Lane, leading the Ebola vaccine trial for the American government research agency in Liberia: "This concept of social mobilization, I had not heard that term before. But I came to realize it is one of the most critical things for success in this country". In its July 2015 report, the World Health Organization mentions the particular case of Mohamed Soumah, 27 years old living in Guinea, the first person to receive the Ebola vaccine: "It wasn't easy. People in the village said that the injection was to kill me. I was afraid. I was the first one to be injected, the very first, here in my village on 23 March 2015" (WHO, July 2015).

Thus, trust comes into play in understanding health behavior. Few emerging papers provide evidence of the importance of trust in medicine to explain health behavior. Significant contributions are from Alsan and Wanamaker (2017) that study the effect of Tuskegee syphilis experiment disclosure in 1972 on black men's contemporaneous demand for health and participation in medical experiments. Martinez-Bravo and Stegmann (2017) study the effect of the disclosure of a more recent CIA fake vaccination campaign in Pakistan. More related to our work is the study by Lowes and Monteiro (2018), who exploit the effect of colonial medical campaigns in central Africa between 1921 and 1956 on today's demand for preventive

[1] For instance, Dupas (2011b), in an experiment in Kenya, finds that adolescent girls are responsive to information provided on the relative risk of contracting HIV by type of partners. An experiment in India conducted by Jalan and Somanathan (2008) shows that informing households that their drinking water is contaminated with fecal bacteria can affect their adoption of purification techniques.

[2] Dupas (2011a), building on Rosenzweig and Schultz (1989), discusses the differential complexity between passive contraceptive methods such as swallowing pills and more active rhythm methods requiring more active computation and cognitive skills.

medicine. They use an innovative and robust approach, these studies exploit isolated and geographically limited shocks, which could not account for the global phenomenon of medical distrust in sub-Saharan Africa that we investigate.

In this paper, to isolate an exogenous variation in trust in medicine, we rely on a more widespread shock in Africa's history, the slave trade that has occurred over five centuries, from 1400 to 1900. We build on previous work by Nunn and Wantchekon (2011) , who empirically establish a causal effect of past exposure to the slave trade and a culture of mistrust, on theoretical insights from Bowles (1998), to argue that the slave trade could have explanatory power in situations distinct from the institutional environments which saw its emergence. Using data from the 2005 Afrobarometer survey, we show that the past exposure of ancestors to the slave trade has an adverse impact on descendants' current trust in health workers, but no significant impact on their perception of other factual health supply dimensions.

We then estimate the reduced-form relationship linking mother's contemporary vaccination decisions to ancestors' exposure to the slave trade and controlling for other relevant determinants of vaccination decision. We use data from the DHS female module, collected in the period 2010-2014. The surveys provide information on mothers and their children (under five years) vaccination status. The survey respondents are geolocalized at the district level, which corresponds to the primary sampling unit: village, city, municipalities. The immunization data are combined with the historical data on the slave trade by ethnic groups from Nunn and Wantchekon (2011). We exploit variations in the exposure to the slave trade within countries. However, as the slave trade heterogeneously affected regions within countries, it could have a lasting effect on the sectoral composition of current employment, or public infrastructure endowments, within countries, and this could affect regional health system performance and institutions, violating the exclusion restriction. Therefore, we introduce essential locality-level variables controlling for the level of economic development, the geography, the existence of natural resources, the disease ecology such as malaria suitability, and recent experience of conflicts in location. Moreover, there may be other omitted historical events or norms determining attitudes towards the state medical interventions, for instance, due to colonial intervention or pre-colonial social norms, that are correlated with the slave trade and subsequent vaccination decision. Again, we introduce important controls at the ethnic group level, such as historical norms of political centralization and succession, and indicators for minority ethnic groups.

Our findings indicate a significant and sizable adverse effect of past exposure to the slave trade on current vaccination decisions. Children of descendants from slave raided-groups are 5 percentage points less likely to be vaccinated against measles than a similar child with a mother from a slave-free ethnic group. The estimates predict a 25% increase in the coverage rate for the group with the lowest immunization achievement in the sample. Moreover, the estimated negative impact of the slave trade is sizable relative to standard determinants of health demand and preventive behavior such as income, mother employment, or access to health facilities. We predict a substantial drop in measles incidence in Northern Nigeria if a

higher trust level prevailed.

We further pursue three strategies to address the concern of whether the exclusion restriction is satisfied. First, we introduce important controls at the ethnic group level capturing social norms relative to contraceptive techniques. Indeed, given that immunization decisions are related to group preferences for the use of preventive techniques and gender norms, we include indicators for ethnic norms of fertility control and norms on girls' sexual behavior.

Second, we exploit variation in slave trade exposure at the ethnic group level within the same neighborhood (primary sampling unit) in the same country. Adopting a within locality estimation strategy is the best way to control for differences in health services performance as well as for any institutional differences between different localities in the same country. However, considering within localities variations implies that the source of identification is the movers in the sample, that is, those who relocate from their ancestors' original ethic homeland and who bring variation in exposure to the slave trade across ethnic groups in their new locations. We argue that the adverse effect of the slave trade is biased downward in case movers are not representative of our overall sample.

Finally, we pursue two falsification tests. If the slave trade affects vaccination decision only through trust in medicine (i.e., if our exclusion restriction is satisfied), then there should be no relationship between the slave trade and health outcomes that are not trust-sensitive. Thus, we examine the reduced-form relationships between the slave trade and the adoption of preventive techniques that acknowledgedly exhibit different levels of uncertainty: the use of malaria insecticide-treated nets (ITNs) on one side, and the consent to an anemia blood test on the other side. As expected, we find no statistically significant relationship between the slave trade and malaria preventives use, but a statistically significant negative relationship between the slave trade and anemia blood test consent.

Having established supporting evidence for our hypothesized trust in medicine channel, we discuss the sources of medical risk in sub- Saharan Africa that might explain why trust is important in health behavior and the adoption of medical technologies. We highlight the importance of imperfect information due to contemporaneous experience of medical misbehavior, such as abusive injections.

This paper contributes to two main streams of research. For the health literature, we shed light on the importance of long-term historical origins to better understand contemporary mistrust in medicine and its consequences in health behavior. We also contribute to this literature by explaining, at least partly, the global phenomenon of medical suspicion that prevails throughout Africa. Our work also complements studies documenting the long-term adverse effect of the slave trade. In particular, the pioneer work by Nunn (2008) and Nunn and Wantchekon (2011), this paper provides evidence of the legacy of the slave trade in situations distinct from the institutional environment in which it initially occurred.

The outline of the paper is as follows. Section 2 discusses the validity of the slave trade as an instrument for trust in medicine. In Section 3, we turn to the description of the data before

reporting our reduced-form estimates and sensitivity analysis in Section 4. In Section 5, we discuss the sources of medical risk in sub-Saharan Africa. Section 6 concludes.

2 Empirical Strategy

2.1 Conceptual Framework

The key difficulty in estimating a causal effect of trust in medicine is its endogeneity to health system performance. Hence, to identify a causal effect from trust in medicine to health behavior, one has to find some exogenous source of variation in trust in medicine. In addition, as recent Ebola outbreaks have illustrated, medical distrust is widespread in sub-Saharan Africa. As a consequence, one has to find some exogenous source of variation in trust in medicine that could explain the continent-wide medical distrust phenomenon.

We need then a theory of how current trust in medicine is determined in the sub- Saharan context. In their theoretical framework, Bisin and Verdier (2001) suggest that current trust levels are shaped by both the contemporaneous environment and the cultural traditions inherited from earlier generations. A resulting implication is that history determines current cultural traits such as trust in others. In the sub-Saharan context, Nunn and Wantchekon (2011) investigate in a pioneer work the historical origins of current heterogeneities in interpersonal trust across different dimensions and ethnic groups and conclude to a negative causal impact of the slave trade. Ancestors' historical exposure to the slave trade has an adverse effect on their descendants' current trust in relatives, neighbors, co-ethnics, and locally elected people. Building from African historiography, the authors document the pernicious and peculiar institutional characteristics of the slave trade. While early in the slave trade, nearly all slaves were taken in large-scale conflicts or raids, as the trade progressed, individuals began to turn on closer relatives, including neighbors, friends, and even family members that were enrolled through trickery and local kidnappings, to protect themselves (Nunn and Wantchekon, 2011). Building on insights from cultural anthropology, they argue that in such an environment, norms of mistrust towards others were likely more beneficial than norms of trust, and hence would have become more prevalent over time. They also uncover that the most significant impact of the slave trade channels through internal factors to the individual, such as cultural norms and beliefs, rather than external factors such as institutions.

The natural question we face, though, is why we expect that the slave trade affects trust in medicine, in other words, why the resulting culture of mistrust could also affect the medical sector. We know from Bowles (1998), echoing a rich literature in psychology, that preferences learned under one set of circumstances become generalized reasons for behavior (see Ross and Nisbett (1991) for a review). We could then expect that the slave trade had imposed more general patterns of interaction on the people whose ancestors were raided during the slave trade; that it had influenced their process of human development, affecting their personality,

habits, commitments, identities, and values. This, in turn, implies that the slave trade has explanatory power in situations distinct from the institutional environments from which it initially prevailed. Thus, we hypothesize that the slave trade has an impact also on current medical behavior through mistrust in medicine. Importantly, the slave trade occurred over five centuries, from 1400 to 1900, and has exported tens of millions of enslaved Africans. As a consequence, it has the feature of a widespread shock in Africa's history. Hence, we aim to investigate its subsequent impact on trusting behavior in the medical sector.

2.2 Slave Trade and Cultural Mistrust in Medicine

To test this hypothesis, we follow the baseline estimation strategy in Nunn and Wantchekon (2011) to investigate the impact of the slave trade on current trust in medicine. More specifically, we combine their data on slave exports by the ethnic group with individual-level data from the 2005 Afrobarometer survey. The respondents were surveyed about their perception towards health sector and answered the following series of questions about their perception of health workers' trustworthiness: "How many of the following people do you think are involved in corruption, or haven't you heard enough about them to say: Health workers?"[3], as well as to the question: "Have you encountered any problems of lack of attention or respect from staff in your local public clinic or hospital during the past 12 months ?"[4]

We include all the relevant controls following Nunn and Wantchekon (2011)'s baseline estimation. The results are reported in Table 1 below. They show that historical exposure of the ancestors to the slave trade has a negative impact on descendants' trust in the public health workers. In particular, respondents of the round 3 of the Afrobarometer that are descendants from slave-raided ethnic groups are today significantly more likely to perceive health workers as being corrupt and to have encountered problems of lack of attention or respect when they last visited the public health facility.

[3]With effective response going from 0=None, 1=Some of them, 2=Most of them, 3=All of them.
[4]With effective response going from 0=Never, 1=Once or twice, 2=A few times, 3=Often.

Table 1: Effect of the slave trade on trust in health workers

	Trustworthiness	Trustworthiness
	Corrupt health workers	Lack of attention/respect
ln (1 + exports/area)	0.0506**	0.0611**
	(0.0201)	(0.0280)
Individual controls	Yes	Yes
Districts controls	Yes	Yes
Ethnicity-level controls	Yes	Yes
Colonial controls	Yes	Yes
Country FE	Yes	Yes
Adj R-squared	0.057	0.097
N Observations	17829	16701

Note: The table reports OLS estimates. The unit of analysis is the individual respondent in the 3rd round of the Afrobarometer survey. Standard errors are adjusted for two-way clustering at the ethnicity and district levels. The slave export variable ln(1+exports/area) is the natural log of one plus slave exports normalized by land area. The individual controls follow Nunn and Wantchekon (2011) full controls. They include the respondent age, age squared, five living conditions fixed effects, ten education fixed effects, 18 religion fixed effects, 25 occupation fixed effects, and an indicator for whether the respondent lives in an urban location. The district controls include ethnic fractionalization in the district and the share of the district's population that is the same ethnicity as the respondent. Ethnicity-level colonial controls include the prevalence of malaria, a 1400 urbanization indicator variable, eight fixed effects for the sophistication of precolonial settlement, the number of jurisdictional political hierarchies beyond the local community in the precolonial period, an indicator for integration with the colonial rail network, an indicator for contact with pre-colonial European explorers, and the number of missions per square kilometer during colonial rule. Colonial population density is the natural log of an ethnicity's population density during the colonial period.

$^{*}p<0.10, ^{**}p<0.05, ^{***}p<0.01$

Source: Data from Nunn and Wanchekon (2011) and Afrobarometer survey

Although we included a rich set of controls, a potential problem with relying on a simple cross-sectional approach is the presence of confounding factors biasing the estimation of the effect of interest. In particular, slave-raided ethnic groups might be different from ethnic groups that were not affected by the slave trade along dimensions for which we do not control for, such as their trust levels before the slave trade, or historical events or social norms that are correlated with the slave trade and subsequent levels of trust. In order to deal with this statistical nuisance, we use the answers given by the same respondents concerning their perception of other factual health supply.[5]The results are reported in Table 2. We find that there is no significant relationship between the historical experience of the slave trade and the current

[5] The questions are formulated in the following way: "Have you encountered any of these problems with your local public clinic or hospital during the past 12 months?" Then respondents had to answer on different items: Too expensive; Lack of medicines/supplies; Absent doctors; Long waiting time; Dirty facilities, with effective responses:0=Never, 1=Once or twice, 2=A few times, 3=Often.

perception of objective and factual health supply dimensions. This result suggests that the estimated negative effect of the slave trade on the current negative beliefs about health workers is not biased by differences in the perception of quality of the health supply, cost-effectiveness, or service reliability.

Table 2: Effect of the slave trade on the perception of the general health system supply and quality

	Health supplies	Health supplies	Quality of service	Quality of service	Quality of service
	Costs	Medicine supplies	Absence of doctors	Waiting-time	Dirty clinic
ln (1 + exports/area)	0.0262	-0.0142	0.0201	-0.0101	0.0307
	(0.0336)	(0.0273)	(0.0231)	(0.0261)	(0.0267)
Individual controls	Yes	Yes	Yes	Yes	Yes
Districts controls	Yes	Yes	Yes	Yes	Yes
Ethnicity-level controls	Yes	Yes	Yes	Yes	Yes
Colonial controls	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Adj R-squared	0.199	0.172	0.121	0.111	0.082
N Observations	16823	16706	16497	16713	16476

Note: The table reports OLS estimates. The unit of analysis is the individual respondent in the 3rd round of the Afrobarometer survey. Standard errors are adjusted for two-way clustering at the ethnicity and district levels. The slave export variable ln(1+exports/area) is the natural log of one plus slave exports normalized by land area. The individual controls follow Nunn and Wantchekon (2011) full controls. They include the respondent age, age squared, five living conditions fixed effects, ten education fixed effects, 18 religion fixed effects, 25 occupation fixed effects, and an indicator for whether the respondent lives in an urban location. The district controls include ethnic fractionalization in the district and the share of the district's population that is the same ethnicity as the respondent. Ethnicity-level colonial controls include the prevalence of malaria, a 1400 urbanization indicator variable, eight fixed effects for the sophistication of precolonial settlement, the number of jurisdictional political hierarchies beyond the local community in the precolonial period, an indicator for integration with the colonial rail network, an indicator for contact with precolonial European explorers, and the number of missions per square kilometer during colonial rule. Colonial population density is the natural log of an ethnicity's population density during the colonial period.

$^{*}p<0.10, ^{**}p<0.05, ^{***}p<0.01$

Source: Data are from Nunn and Wanchekon (2011) and Afrobarometer survey.

2.3 Identification

The p-value for the instrument is not below 0.0016 (p-value = 0.012), suggesting that the slave trade is a weak instrument. In the presence of weak instruments, we know that hypothesis tests based on IV estimates are not correct. Instead, estimating the reduced form linking current vaccination decisions to the slave trade, including other exogenous regressors, will provide better estimates (see Chernozhukov and Hansen (2008)). Besides, the DHS does not collect any survey measures of trust in medicine, and it is not possible to match the data from the DHS with data on trust in medicine from the Afrobarometer.

For the slave trade to be a valid instrument for trust in medicine, it also needs to be uncorrelated with the error term in the health demand regression. In other words, identification is achieved if the slave trade that has occurred centuries ago does not have a direct effect on current vaccination decision, or any effect running through omitted variables. This restriction could be justified if one adequately controls for contemporaneous health system performance and institutions (the country fixed effects).

Nevertheless, it would be a rather strong assumption. Even though Nunn (2008) highlights the adverse effect of the slave trade on economic development at the country level, the slave trade has differently affected regions within countries, as shown in Figure 1 below. It means that the slave trade could have a lasting effect on the sectoral composition of the current employment or public infrastructure endowments within countries, and this could affect regional

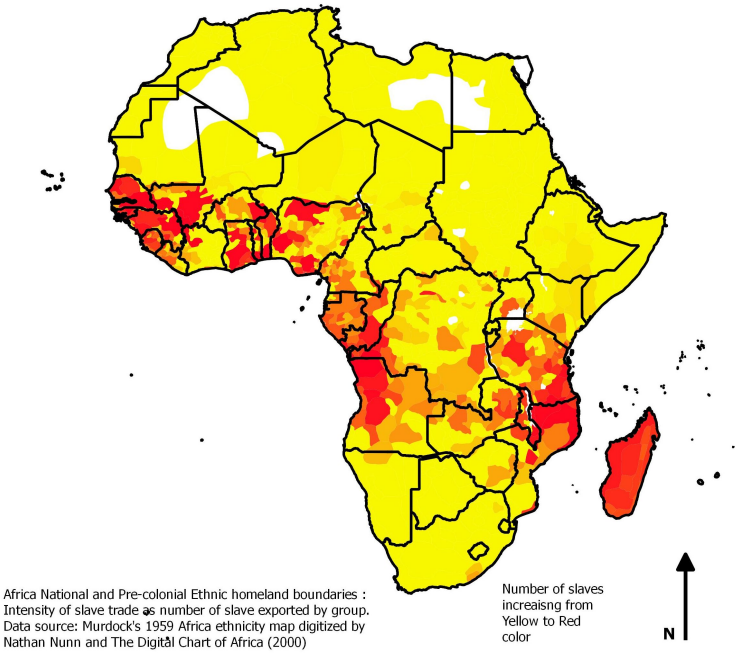
health system performance and institutions, violating the exclusion restriction. Alternatively, there may be unobservable historical events or social norms that are correlated with the slave trade and subsequent vaccination decisions, also violating the exclusion restriction.

In Section 4, we relax this identifying assumption in various ways. First, we include relevant determinants of health access and demand as additional regressors. We include rich set of location controls related to the location economic development (density, luminosity at night, distance to capital city), to geography (elevation, distance to water, distance to the sea), the disease ecology (malaria suitability, agricultural suitability), the existence of natural resources (diamond mines, petroleum plants), to recent experience of conflicts . At the ethnic group level, we include controls related to pre-colonial and colonial characteristics associated with the ethnic group past political institutions such as degree of centralization and norms of political succession, indicators for the split group during the colonial period, and current minority status.

Second, we exploit variation in slave trade exposure between groups within localities. This implies that the source of identification is the movers in the sample (i.e., those who relocate from their ancestors' original ethnic homeland), who bring variation in the exposure to the slave trade across ethnic groups within localities. While we can expect that movers may not be representative of the population, we argue that if our estimates are biased, they are biased downward. Since movers are mostly from slave-raided groups (71% of our sample), and they probably relocate in search of better employment opportunities or better economic outcomes in general, they are more likely to move to slave-free locations associated with higher economic development. The estimated effect of the slave trade on vaccination decisions is robust to these alternative strategies.

Third, we perform falsification tests. If the slave trade affects vaccination decision only through trust in medicine (i.e., if our exclusion restriction is satisfied), then there should be no relationship between the slave trade and health outcomes that are not trust-sensitive. Thus, we examine the reduced-form relationships between the slave trade and health outcomes that arguably exhibit different degrees of uncertainty and trust sensitivity. We test the effect of the slave trade on the use of malaria insecticide-treated nets and the acceptance to up-take a free anemia blood test.

Figure 1: Map of Africa ethnic homelands with the intensity of the slave trade



3 Data sources and Description

3.1 Historical data

The historical data on slave exports by ethnic groups comes from Nunn (2008). The author combined data from various historical records that report the ethnic identities of slaves exported from Africa with data on the number of slaves shipped from each African port or region during the transatlantic and the Indian Ocean slave trades. The primary data sources for slaves exports are from the Transatlantic Slave Trade Database constructed by Eltis et al. (2010) and from Austen (1979) Austen (1979, 1988, 1992) for the Indian Ocean trades. Using available information on the ethnicities of the slaves, Nunn (2008) could match a total of 80,656 slaves to 229 identified ethnic groups for the trans-Atlantic slave trade and more than 21,048 slaves to 80 distinct ethnic groups for the Indian Ocean slave trade. In a final step, Nunn and Wantchekon (2011) match their identified historic ethnic identity records to more recent ethnic identity reported by respondents of the Afrobarometer surveys and based on historical classification constructed and mapped by Murdock (1959).

We follow the same procedure for the ethnic designation reported by the respondents in the DHS survey that we match when necessary to Murdock (1959) classification, allowing a simple merge to Nunn and Wantchekon (2011) ethnic groups slave exporting data. The matching goes from relatively simple correspondence (e.g., in the case of Uganda, BaGanda or BaSoga ethnic group from DHS corresponds to GANDA and SOGA in the Murdock classification) to slightly less straightforward correspondence (e.g., in the case of Senegal, where Pulaar ethnic group in the DHS is related to FUTATORO in Murdock ancient classification). In our study, we end

up with a final sample of 98 ethnic groups, with 68 (69%) groups recorded as exporting slaves and 30 as slave-free from Nunn (2008) data. Each ethnic group represents a minimal share of 5% of its country population.

3.2 Modern Data

We combine the historical data on slave exports by ethnic groups with DHS data from the most recent compatible surveys (collected between 2010 and 2014, except for Central Africa, Niger and Ethiopia collected respectively in 1994, 1998 and 2003), and in particular the female modules questionnaires containing information on the immunization status of their children born in the last 5 years. We restrict our interest to countries where geolocalized survey data exist and where the respondent's ethnic group identity is reported. The baseline sample in our study consists of 157,405 children born to 107,771 adult mothers from 98 ethnic groups with a minimal size of 5% of each country population, covering 18 sub-Saharan African countries.

We focus on a particular infectious and vaccine-preventable disease that is measles, which remains one the world-leading cause of children under-five mortality and morbidity, particularly in developing countries which concentrate more than 95% of the deaths due to measles worldwide. In 2015, there were 134,200 measles deaths globally, according to the WHO estimates, which amounted to about 367 deaths every day or 15 deaths every hour (WHO, 2018). Even when it does not lead to death, child infections might result in lifelong disability such as blindness, deathless, or severe respiratory infections, undermining the child's future education and economic prospect. Moreover, by focusing on a traditionally one-shot vaccine, we avoid the complexity and sequentiality involved in other vaccines requiring multiple shots and hence, more active computation, memory, and reasoning (Dupas, 2011 and Cummings, 2014).

Despite the vaccine safety and effectiveness and free provision by public health facilities, measles were the lowest-performing vaccine in terms of coverage rate across sub-Saharan Africa in 2016, with an average country coverage of 75% in 2016. A brief narrative description illustrates the ethnic group variations in immunization rates that we will further investigate in the empirical section of this study. In Burkina Faso and Uganda, for instance, there are variations in coverage rate between ethnic groups according to the intensity of historical slave-raiding status. In Burkina Faso, groups like Senufo scores 70% in measles coverage comparative to 60% for Fulani or 64% for related Gourmatche. In Uganda, the difference increases to 14 points between the slave-raided Baganda and the slave-free Ngakarama.

The DHS provides a rich set of questions we build upon to control for the child-specific characteristics that might influence mother's vaccination decisions, such as the gender, the birth-order, the birth interval with the previous child, and an indicator for whether the child was delivered at home or within a health facility.

We also have information about mother education, employment status, religion, age, and her age at first childbirth to capture for early pregnancy. We also add a variable capturing the

subjective assessment of access to health facility using the mother answer to the question of whether distance to the health facility was a problem or not. Mother's fertility preferences have been shown to affect the investment in child health and protection. Thus, we include the mother's total children. Importantly, we also include the mother's subjective report of the ideal number of children. Births reported by women as unwanted are a good proxy for her adoption of contraceptives and hence, her preferences regarding the use of preventive health techniques in general. By controlling for these reported preferences, we expect to take into account the mothers' specific characteristics different from their trust levels, associated with general attitude and risk preference for adopting preventive health behavior and technology. We also take into account the household's socio-demographic characteristics, capturing intra-household resources allocation and bargaining dimensions. In particular, we control for father employment status, the gender of the head of the household, the household wealth index, and assets ownership. Table A.1 in the Appendix summarizes descriptive statistics on covariates across groups.

4 Estimating the Effect of Trust in Medicine on Vaccination Decision

4.1 Reduced-form Estimates

As already highlighted in Section 2.3, our goal is to estimate the reduced form linking contemporary vaccination decisions to ancestors' exposure to the slave trade, including relevant controls. If the slave trade is correlated with trust in medicine, which in turn influences vaccination decisions, we expect to find a significant effect of the slave trade on vaccination decision, after controlling for the other determinants of vaccination decisions. Thus, we estimate the following equation:

$$Vaccin_{i,m,e,l,c} = \alpha_c + \beta\ Slave_e + \mathbf{X'_{i,m,e,l,c}}\ \gamma + \mathbf{X'_{m,e,l,c}}\ \omega + \mathbf{X'_{l,c}}\ \phi + \mathbf{X'_{e}}\ \theta + \epsilon_{i,m,e,l,c}$$

where $Vaccin_{i,m,e,l,c}$ is a binary indicator variable equal to one if child i born to mother m from ethnic group e in locality l and country c is vaccinated against measles, and zero otherwise. α_c denotes country fixed effects, which are included to capture country-specific factors, such as health institutions and health system performance, that may affect vaccination decision. $Slave_e$ is a binary indicator variable equal to one if child's mother ethnic group e has been slave-raided, zero otherwise.[6]

$\mathbf{X'}_{i,m,e,l,c}$is a set of child individual controls (gender, birth order, birth interval with previous child, homedelivery), while $\mathbf{X'}_{m,e,l,c}$ is a set of mother/households controls (mother: age,

[6]We also estimated the equation with survey-year fixed effects. The results were quantitatively similar.

education, literacy status, job, 5 religion fixed effects, total number of children, ideal number of children, age at first birth, access to health facility; household controls: gender of household head, father job, wealth index, assets ownership).

The vector $\mathbf{X'}_{l,c}$ consists of controls for the location economic development (density, luminosity at night), the geography (elevation, distance to water, distance to the sea, distance to capital city), the existence of natural resources (diamond mines, petroleum plants), we also include controls for the recent experience of conflicts,violence and riots from ACLED. We account for the possibility that slave-raided regions were more prone to infections and diseases, and the possible influence on current attitudes towards medicine and include controls for the locality disease environment using the malaria stability index constructed by Kiszewski et al. (2004). This rich set of controls are retrieved from Michalopoulos and Papaioannou (2013, 2014, 2016) and are spatially matched to our DHS sample localities.

$\mathbf{X'}_e$ includes ethnic group level controls, including controls for pre-colonial institutions, and cultural attitudes towards the state through norms of centralization/decentralization, indicators for pre-colonial norms of political succession. We also include dummies for colonial intervention characteristics resulting in groups split across country borders and current minority or majority status of the ethnic group in contemporaneous national borders (Gennaioli and Rainer, 2007; Michalopoulos and Papaioannou, 2016).

Many explanatory variables in equation (1) do not vary across individuals but at the ethnic group or the locality level, potentially leading to within-group correlation of the residuals. We then adjust all standard errors for clustering within ethnic groups or two-way clustering within ethnic groups and districts.We estimate a linear probability model for ease of interpretation of the results.[7]

The estimates in Column (1) of Table 3 only reflect within-country variations and are adjusted for individual, mother, locality, and ethnicity-level main characteristics, with standard errors clustered both at the ethnic group level, and at the ethnic group and district levels. More specifically, a child born from a mother belonging to a slave raided ethnic group is 5 percentage points less likely to be vaccinated against measles than a child whose mother is from a slave-free ethnic group. To assess the magnitude of the slave export coefficient, we compare its explanatory power against other variables in the regression. We find that the adverse effect of the slave trade offsets the positive effect of belonging to the highest quintile of the income distribution, offsets the positive effect of employed mothers, and dominates the negative effect of perceived distance to health facilities. The estimates a 25% increase (from 20 to 25%) in coverage rate for Hausa in Northern Nigeria — the ethnic group with the lowest immunization rates in our sample — had they been a slave-free, leading to 50% drop in measles incidence rate according to some calibrations and 10, 625 cases of infections avoided each two years between 2011 and 2014.[8]

[7]The results using a probit model were qualitatively similar.

[8]Hall and Jolley (2011) predict that a 1% increase in the MCV1 coverage rate is associated with a 2% decrease

Table 3: Exposure to the slave trade and measles vaccination decision

	(1) Measles	(2) Measles	(3) Measles
Group exports slaves (=1)	-0.0573**	-0.0907***	-0.0586***
	(0.0233)	(0.0248)	(0.0217)
	[0.0232]	[0.0247]	
Child controls	Yes	Yes	Yes
Mother controls	Yes	Yes	Yes
Location controls	Yes	Yes	No
Ethnic controls	Yes	Yes	Yes
Ethnic controls preventive	No	Yes	Yes
Country FE	Yes	Yes	No
Location FE	No	No	Yes
Adj. R-squared	0.154	0.156	0.213
N Observations	80088	80088	82467
N country	18	18	18

Note: The table reports LPM estimates. Below each coefficient, two standard errors are reported. The first, reported in parentheses, are standard errors adjusted for clustering within ethnic groups. The second, reported in square brackets, is standard errors adjusted for two-way clustering within ethnic groups and localities (district-city-village). The locality controls include level of economic development captured by population density, night luminosity, geographic controls for malaria suitability, agricultural suitability, distance to water, number of diamond mines, petroleum plants, distance to capital city, the sea, and border, elevation, dummy for coastal location and for recent conflicts (violence, riots). Ethnic controls include ethnic group past centralization, norms for political succession, split group during the colonial period, minority status. Ethnic group preventive controls include norms of post-partum sex taboo and rigidity of norms related to sexual behavior for girls.

$^{*}p<0.10,^{**}p<0.05,^{***}p<0.01$

4.2 Controlling for Ethnicity-level Preferences for Prevention

Identification fails if the instrument has a direct effect on vaccination decisions through other omitted variables. In particular, there may be omitted historical events or social norms that are correlated with selection into the slave trade and with subsequent vaccination decisions. For example, the possibility that ethnic groups overall more inclined to take risks were more likely to be involved in the trade, and these groups were inherently less in favor of protective measures in general and in health in particular, and that these groups continue to be less in favor of preventive medicine today. Although hypothetic and unlikely, to rule out this possibility, we further include ethnic group cultural and institutional precolonial norms related to preventive behavior, such as the use of contraceptive techniques and societal rigidity towards the sexual behavior of young girls. Including these controls is relevant per see, even in the

in the disease incidence in the same year and the following year.

absence of selection concern. We postulate that these norms capture both the cultural heritage in adopting health preventive techniques in general and the flexibility towards modern and unconstrained preventive techniques related to reproductive contraception or vaccination. We use data on pre-colonial ethnic group norms, from Murdock's 1967 Ethnographic Atlas database. We have indicators on the existence and duration of post-partum sex taboos, capturing the duration before resuming sexual activity after childbirth. We also have an indicator of the norms of premarital sexual behavior of girls capturing the prevalence of early female marriage, insistence on virginity, promiscuous, or freely permitted sexual behavior. These variables might also account for risk attitudes towards sexually transmitted infections. The results are displayed in column (2) of Table 3. The estimates suggest that our findings are robust to allowing for ethnic group differences in preventives preferences. The effect of the slave trade on vaccination decisions increases sensibly and becomes significant at 1%.

4.3 Accounting for Local Differences

To assess the robustness of our estimates, we also exploit variations in the exposure to the slave trade at the ethnic group level within localities. Table 4 below presents basic descriptive statistics of measles immunization outcomes at the locality level. The sample of interest includes 9726 clusters (primary localities) from the 18 sub-Saharan countries. There is an average of 1.70 ethnic groups by locality with a standard deviation of 0.87. At least more than 25% of clusters have more than two ethnic groups, reaching a maximum of 7 different ethnic groups in some clusters. There is an average of nearly 22 infants under age five and of more than four adult respondents mothers by locality. The average measles vaccination rate at the locality level is 66% with sizable variations and a standard deviation of 21 percentage points.

However, this within locality estimation strategy implies that the source of identification are the movers in the sample (i.e. those living in a location different from their ancestors), who bring variation in exposure to the slave trade across ethnic groups within localities. While we can expect that movers may not be representative of the population, we argue that if our estimates are biased, they are downward biased since movers, mostly slave-raided ones (71% of our sample), in search of better employment opportunities or better outcomes in general, would rather move to slave-free locations associated with higher economic development.. The results are reported in Column 3 in Table 3, including location fixed effects. We find that the effect of the slave trade variable on vaccination decision drops to its initial level around 6 percentage points and remains significant at a 1% level.

Table 4: **Basic descriptive statistics of our baseline DHS sample at the locality level**

	count	mean	sd	min	max
N ethnic grp. location	9726	1.70	0.87	1	7
Cluster size	9726	21.75	11.57	1	91
N mother cluster	9726	4.14	2.33	1	25
Measles	9726	0.66	0.21	0	1

Data are from Nunn and Wanchekon (2011) and DHS.

4.4 Falsification Tests

Despite our attempts to control for both observable and unobservable factors at the locality level, and for observable factors at the ethnic group level, there may still be unobservable factors at the ethnic group level that might account for the estimated effect of trust in medicine on vaccination decision. To address the concern of whether the exclusion restriction is satisfied, we perform the following falsification test that examines the reduced-form relationships between the slave trade and health outcomes that arguably involve a various degree of trust sensitivity. We investigate the use of a highly effective malaria prevention technique that are insecticide-treated bed nets (ITNs), and the consent to up-take a free anemia blood test. The expectation that malaria preventives use is not trust-sensitive is in line with Dupas (2009)' results. Using experimental variation in prices interacted with experimental variation in framing and targeting strategies in Western Kenya, she finds that liquidity constraint is the only barrier to the resort to ITNs. As for the blood test consent, Lowes and Montero (2018) use it as a proxy for trust in medicine. More precisely, they consider consent to a free blood test to be a revealed preference measure of trust. Thus, we use the DHS female modules surveys that also provide information on mothers' consent to a blood test, and on their use of insecticide-treated nets (ITNs).

If the slave trade affects health behavior only through trust in medicine, then there should be no relationship between the slave trade and the use of malaria insecticide-treated nets, where there is no trust involved. By contrast, given our estimates for the impact of the slave trade on vaccination decisions, we expect a robust negative relationship between the slave trade and blood test consent. The findings are in line with our predictions, as reported in Table 5 below. We estimate a statistically insignificant relationship between the slave trade and the use of malaria preventive ITN, but a statistically significant relationship between the slave trade and blood test consent, with an estimate close to the one obtained for vaccination decision.

Table 5: Slave trade exposure and use of malaria preventive techniques and acceptance of anemia hemoglobin test

	Use Malaria ITN Net	Accept Anemia Test
Group exports slaves (=1)	0.0217	-0.0483**
	(0.0182)	(0.0200)
Child controls	Yes	Yes
Mother controls	Yes	Yes
Location controls	No	No
Ethnic controls	Yes	Yes
Ethnic controls preventive	Yes	Yes
Country FE	No	No
Location FE	Yes	Yes
Adj. R-squared	0.339	0.204
N Observations	83276	32025

The table reports LPM estimates. Robust standard errors are clustered at the ethnic group level. The specification reported corresponds to the specification of Column (3) in Table 3.

$^{*}p<0.10, ^{**}p<0.05, ^{***}p<0.01$

5 Sources of Medical Risk in sub-Saharan Africa

Trust in medicine might affect health behavior because different trust levels may entail different propensities to take risks or overcome uncertainty. Thus, when there is no risk involved, the effect of trust in medicine vanishes, which could explain why we find no significant effect of the slave trade on the use of ITNs. However, if vaccines are inherently risky, given the injection of activated or unactivated pathogenic agents in the organism, understanding the source of risk associated with a blood test appears less obvious.

One possible explanation is that the risk comes from the health technology used. Some health technologies, such as the use of needles, might hurt or even endanger the patient when they are inadequately performed. Experience of intra-muscular injections by untrained medical staff, leading to physical disabilities, might justify the fear of injections. In this case, considering the alternative mode of administration, such as oral administration of vaccines, might trigger uptake.

Another possibility for the origin of medical risk lies in the uncertainty surrounding the effectiveness of the health technology considered. As stressed by White (1997), the uncertainty associated with needles and injections does not come from the fact that they are new and foreign technologies in 21st-century Africa. Instead, there is a large body of anecdotal evidence from Africa of contemporaneous abusive injections that might explain the uncertainty associated with this health technology. Washington (2007b) provides telling examples of medical misbehavior in different countries and contexts: infamous Dr. Bason involved in the murder by poisoning, of hundreds of blacks in South Africa and Namibia, under apartheid,

from 1979 to 1987; patients murder by lethal medical injections in Zimbabwe during 1980s and 1990s; unethical medical research in breast cancer treatment on South African black patients in 2000, among others instances. Overall, these well-publicized mistreatments could have spread uncertainty surrounding the use of needles throughout Africa, even in countries not directly affected. As a consequence, people believe that vaccines might be contaminated with HIV or sterilization agents in disguise.[9]

Importantly, the diversity of the contemporaneous history of abusive clinical trials in sub-Saharan Africa could imply that imperfect information for Africans is not limited to needle or injection technology (see Washington (2007) for review, and Meier (2003) for the AZT treatments testing in Africa in the 1990s). Trust in medicine might then explain health behavior in much broader situations. In the context of growing medical experiments in the continent, and their relevance for alleviating the disease burden, reducing the sources of medical uncertainty and misbehavior is critical for public health policy.

6 Conclusion

Trust in medicine appears to be an important determinant of current health behavior in sub-Saharan Africa. One contribution of this paper is to show that the slave trade emerges as an important determinant of trust in medicine. We have then pointed out that it is a valid instrument for trust in medicine in the reduced-form relationship between ancestors' exposure to the slave trade and current measles vaccination decision, including a rich set of relevant controls across several dimensions. Leading to the second and main contribution of this study: The component of trust in medicine explained by the slave trade is an important determinant of vaccination decision. The next natural step is a deeper understanding of the origins of medical risks in sub-Saharan Africa in order to reduce its impact on health decisions. This paper advances two complementary explanations. Nevertheless, they emphasize different agendas for future research.

Given that different levels of trust and propensity to adopt health technologies exist between communities, health intervention design could be improved by leveraging cooperations from early adopters. Such strategy triggers the early benefits of externalities and spatial spillovers in preventive health and the potential positive benefit of social learning between groups through feedbacks on the effectiveness of technologies. In the context of vaccine trials in the wake of epidemics, such an approach might be beneficial to overcome initial suspicion and resistance. However, a practical implementation should carefully consider the issue of discrimination and limitations in case of emergency.

[9]Feldman-Savelsberg et al. (2000) report how in 1990 a rumor in Cameroon that public health workers were administering a vaccine to sterilize girls and women, led Cameroonian schoolgirls to "squeeze through doorways and leap from windows to flee the vaccination teams that were visiting their schools as part of a campaign to decrease neonatal tetanus".

The legacy of the slave trades might be much more important than what we expected. This paper provides evidence of the legacy of the slave trade in situations distinct from the institutional environment, which accounts for its original adverse effects. This paper offers a potential avenue for the explanation of the resurgence of epidemics (as in the particular case of measles) in developed countries as well (see Athias and Arnoult (2019) for an investigation of the impact of cultural differences on vaccination decisions within Switzerland). The question of the historical origins of cultural norms differences of medical behavior in developed countries is also an interesting future path of research.

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A Appendix

Table A.1.: **Aggregate ethnic level variations in mother and child outcomes**

	count	mean	sd	p50	min	max
Ethnic size	98	1696	1512	1255	155	10014
Ethnic pop. share	98	0.15	0.10	0.11	0.05	0.60
Father employed	98	0.99	0.01	1.00	0.90	1.00
Mother employed	98	0.68	0.19	0.73	0.11	0.95
Sexe of child5	98	0.49	0.02	0.50	0.45	0.55
Polygynous	98	0.25	0.13	0.24	0.01	0.63
Has Health card	98	0.79	0.18	0.86	0.19	0.98
Measles	98	0.62	0.14	0.64	0.16	0.82
Vaccine ever	98	0.81	0.16	0.87	0.23	0.99
Home delivery	98	0.41	0.22	0.41	0.03	0.98
Husb. educ. yrs	98	5.02	2.87	5.11	0.35	10.79
Mother educ. yrs	98	3.77	0.69	3.70	2.50	5.69
N child living	98	3.53	0.37	3.50	2.03	4.68
Total child	98	4.07	0.46	4.07	2.24	5.14
Birth last 5 yrs	98	1.75	0.14	1.74	1.37	2.18
First sex age	98	16.22	0.80	16.03	14.75	18.57
Ideal N child	98	5.73	1.35	5.53	3.14	10.41
Husb. want more child	98	0.46	0.16	0.45	0.16	0.87
Not wanted last child	98	0.29	0.15	0.28	0.03	0.58
N Ethnic size	98	324	280	240	53	1662
Ethnic child mort. rate	98	0.07	0.02	0.07	0.03	0.13
Urban	98	0.31	0.16	0.28	0.01	0.85

Source: Data are from DHS country level survey data.

Ethnic Distance and Ebola Virus Disease Spread in Sierra Leone: A Spatial and Dynamic Analysis

Moudo Macina and Laure Athias

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Abstract

In this paper, we test whether the spatial propagation of Ebola Virus Disease (EVD) follows the pattern of social interactions. Using weekly data on the differential incidence of Ebola across Sierra Leone chiefdoms from May 2014 to September 2015, we estimate a spatial and dynamic epidemic model and investigate the effect of ethnic distance on the spatial propagation of the disease. Our findings suggest that the social network based on chiefdoms' ethnic linkages accounts more for the spatial spread of the EVD epidemic in Sierra Leone than the traditional geographic distance or contiguity-based networks. The model predictions are robust and in line with specific features of Ebola transmission channels. Investigating the relative explanatory power of alternative networks, we find that our social ethnic distance matrix is one of the main determinants of EVD spread.By contrast, traditional vectors of extensive epidemic spread across communities, such as roads and markets, did not play a significant role. The results have several potential theoretical and practical implications for future epidemiology modeling, strategic epidemic control, and public health intervention planning.

Keywords: Ethnic distance, Ebola, Epidemics, Spatial and dynamic model, Sierra Leone

Contents

1 Introduction

The Ebola Virus Disease (hereafter referred to as EVD) epidemic in West Africa has been the deadliest outbreak of the disease and the one with the broadest geographic propagation. Three countries have carried the essential burden of the death toll: Guinea, which experienced the first infectious cases in December 2013 (Pigot et al. 2014, Bausch and Schwarz, 2014), which then spread to Sierra Leone, and Liberia[1]. The particularity of the West African Ebola epidemic is that human-to-human transmission was exclusively the single influential channel documented in contrast to zoonosis–transmission from animals to humans (Richards et al., 2015). The main routes of human transmission of the EVD are either through direct contact with symptomatic patient's bodily fluids and secretions, such as blood, sweat, vomit, or through indirect contact with surfaces and materials contaminated with these fluids (WHO, 2018). Thus, in addition to the traditional nosocomial infections in health facilities, physical contact in social interactions was an essential channel for contagion. The latter involved close contacts in households and family interactions, and during social events (marriages, funerals), and potentially more casual contact in market exchange or public transport[2].

Although the West African EVD displayed a large scale outbreak, the epidemic presented two unique and remarkable features. First, there was important heterogeneity in the spatial distribution of cases across the different administrative units within the same country (district, chiefdoms, and villages). For instance, in Sierra Leone, the EVD affected 114 chiefdoms out of 153, leaving more than 25% of chiefdoms Ebola-free, and a sensible heterogeneity in cumulative incidence rates even between neighboring chiefdoms (Fang et al., 2017). Second, its growth dynamics were much slower than the alarming scenario initially predicted by early epidemic forecast[3]. Indeed, one severe and early forecast from the United States Center for Disease Control (CDC) researchers was predicting more than 1.4 million cases

[1]The Ebola virus disease caused more than 28,602 official cases and led to the death of at least 11,301 confirmed cases (WHO, 2016). Sierra Leone, has officially registered 8,704 confirmed infections and 3,589 confirmed deaths (WHO, 2015), corresponding to a fatality rate of 41%.

[2]For the 1976 Zaire episode of the epidemic, the probability of transmission was 27,3% among close family contacts (spouses, parents, children) and 8% for other relatives (Kiskowski, 2014).

[3]Some studies uncovered polynomial dynamics at the subnational level which is significantly slower and different from the exponential and soaring patterns that most traditional epidemic growth model display (Chowell et al., 2015; Kiskowski and Chowell, 2016).

for the West African EVD outbreak in absence of intense and adequate response (Meltzer et al., 2014, Funk et al., 2018). However, this alarming scenario never occurred.

Even when taking into account the effectiveness of epidemic control and medical interventions, the discrepancy between the expectations and the observed pattern of disease propagation remains puzzling. There is one study by Fang et al. (2016) that focuses on the EVD transmissibility spatial pattern. They document heterogeneity of spatial spread across chiefdoms in Sierra-Leone, without exploring the reasons for this heterogeneity. Therefore, the underlining motivation of this paper is to improve on our understanding of EVD spatial propagation by acknowledging that the spread of epidemics could be determined by social interactions. In other words, how a country's social network structure based on ethnic linkages and interactions could favor or hamper the spread of infectious diseases such as Ebola.

In the African context, community interactions at the society level are widely determined by co-ethnicity. Therefore, ethnic distance, that is, the identification in different ethnic groups (Gomez, 2017), potentially plays a significant role in the spread of communicable disease epidemics. We further extend the concept of ethnic distance to consider how different the languages between two distinct ethnic groups are. Thus, in this paper, we test whether the pattern of EVD epidemic propagation observed across Sierra Leone chiefdoms is determined by their ethnic distance.

Theoretically, we build upon a new insight from social contact networks theory of reduced disease transmission in spatially constrained contact structures as developed for Ebola transmission by Kiskowski and Chowell (2016). We argue that ethnic distance as defined above might be the best candidate to capture constrained social interactions between Chiefdoms in Sierra Leone. The hypothesized mechanism is that ethnic distance generates a spatially constrained social network of chiefdoms within the country that shapes the spatial diffusion of communicable diseases across them. As a consequence, the ethnic distance might beneficially hamper disease progression between populations living in different and highly ethnically homogeneous Sierra Leone chiefdoms.

There are several potential competing networks for explaining the spatial pattern of the EVD epidemic propagation across Sierra Leonean chiefdoms in addition to the traditional geographic distance. In sub-Saharan Africa, more intense relationships occur within

the traditional personal networks based on kinship, as captured by the network of formal and informal alliances. The mobility of individuals within this network–in attending social events such as marriages, funerals, or seeking care nearby traditional healers–could potentially account for the pathways of infectious disease transmission (Richards et al., 2014). Moreover, co-ethnicity equally shapes the intensity of economic interactions through market linkages and trade in Africa by reducing transaction costs (Fafchamps, 2001). In a more recent contribution, Aker et al. (2014) find that common ethnicity favors intra-ethnic exchanges between markets within and across national borders. The resulting structure of market linkages form networks of communities and interactions that can also explain the underlining propagation of communicable diseases. For instance, in studying HIV infections in sub-Saharan Africa, Oster (2007) finds a positive relationship between trade exports and HIV infection spatial propagation. The author uncovers trucking and export-transit as the primary mechanism underlining the relationship. They also find that the intensity of the effect is higher in areas close to transportation roads and large cities. In light of their findings, roads and market exchanges are potential candidates for explaining the spatial propagation of epidemics. Another competing explanation is that epidemics spread via the network of modern health facilities through which people seek medical treatment during a health crisis. Thus, we also perform an exercise of comparison of the relative importance of potentially different sources of spatial variations between our ethnic distance network matrix and these alternative traditional physical distance and socio-economic networks.

Our research design is based on a quantitative approach to provide empirical foundations on the pathways of ethnic distance and Ebola spatial and dynamic spread in Sierra Leone. We build upon rich data collected on the incidence of Ebola, which is measured by new laboratory-confirmed cases every week at the chiefdom level from May 2014 to September 2015. The data were shared by Fang et al. (2015) from the original records of the World Health Organization (WHO) and the National Ministry of Health of Sierra Leone. In order to determine ethnic group composition at the chiefdom level, we use Sierra Leone 2004 population and housing census data to identify the dominant ethnic group in each chiefdom. Two chiefdoms are defined as ethnically distant if two different groups dominate them. In Sierra Leone, chiefdoms are quite homogeneous, with most chiefdoms primarily dominated by a single group. For instance, Glennerster et al. (2003) document a strong preference for

ethnic sorting in Sierra Leone and show that there is a significant willingness to live in areas traditionally dominated by one's ethnic group. We focus on Sierra Leone, for which we have data at the most refined and historically meaningful spatial unit of analysis corresponding to the chiefdoms.

We estimate a spatial panel dynamic epidemic model at the chiefdom level. We estimate both a locality and time fixed-effects variants of our spatial and dynamic model to account for unobserved heterogeneity. We introduce spatially lagged dependent variables and thus constrain the direction of any causal relationship and rule out simultaneity bias. Doing this, we investigate the relative size of the direct and indirect spatial effect from own and neighboring chiefdoms in the propagation of the epidemic, leading to the critical epidemic infection transmission dynamic parameter captured by the reproductive rate, i.e., the average number of secondary cases per infectious case. We also explicitly address the identification issues related to the spatial autoregressive term and the spatial autocorrelation of errors following Yu and al. (2008).

Our main results show that the social network weighting matrix based on our ethnic distance measures is an important determinant of the spatial propagation of the EVD. More specifically, its explanatory power is more important than the network formed by the contiguity of neighboring chiefdoms or than the geographic distance-based networks. The size of the positive and statistically significant spatial spillover effect is even larger with a more refined definition of our ethnic distance network matrix, taking into account the language distance between Sierra Leone's major ethnic groups (Gomes, 2017), and is robust to a more restrictive definition of ethnic dominance. We also find that the estimated direct effect from cases emerging from one's chiefdom is 4 times higher than the spatial effect from neighboring chiefdoms. This finding is in line with the EVD transmission rates higher within chiefdoms through close contacts, and confirms previous studies comparing transmission rates across space and emphasizing the role of close contacts (Merler et al., 2015). The estimated total direct and indirect effect from previous cases of EVD on current infections is lower than 1. This result indicates an average reproductive rate of the epidemic lower than 1, implying that each infected patient on average infects less than one individual. Our spatial model prediction, as a consequence, is in line with the overall sub-exponential growth rates of Ebola transmission cases observed and documented in the case of Sierra Leone (Chowell

et al., 2015)[4]. Our results are qualitatively robust to alternative modeling of spatial error dependence, and the use of longer spatial time lags for the disease propagation. We also simultaneously investigate the relative importance of different sources of spatial dependence relative to our ethnic distance network matrix. In addition to contiguity and geographic networks, we define socioeconomic networks based on the country's network of health facilities, transportation, roads, periodic markets, and economic distance. We find that our ethnic distance network accounts for more spatial spillover than any physical distance or socioeconomic network, except for the country network of health facilities. We interpret this finding as potentially capturing the pattern of mobility and contagion from infected patients seeking care and the higher rate of contamination within health facilities. However, the effect is not robust to fully accounting for the spatial dependence of contiguous neighbors. Finally, we examine the relevance of our spatial propagation model for public health interventions, such as quarantine.

Our work complements the epidemiology literature by proposing a potential new avenue for modeling communicable disease spread in sub-Saharan Africa by explicitly considering ethnic inter-linkages and their implications in the pattern of social interactions. Ethnic distance might practically reduce the rate of community-mixing even within communities, independently of population size, which makes traditional predictors such as population density of limited explanatory for the observed heterogeneities in the epidemic spatial spread or disease incidence. Our work also complements the health related literature documenting the benefit of closer social ties between individuals and communities since social proximity favors positive health outcomes by facilitating disease and community control, social learning, and health knowledge diffusion through facilitated communication (Dupas, 2011; Zelner et al., 2012; Gomez, 2017). We conversely mitigate the potential public health benefit by showing that close ethnic links could also favor the propagation of infectious diseases between communities. Our results are line with early findings that more segregated partner choice through assortative mating explain higher rates of sexually transmitted diseases within African American communities relative to other groups (Laumann et al., 1998). We also contribute to the emerging literature in economics that uncovers the potential "dark side" of social capital (see for instance Shanker et al. (2017) on the importance of social cap-

[4]In Figure 1 in the Appendix, we provide a graphical illustration of the sub-exponential growth patterns within districts (Source: Chowell et al., 2015).

ital to explain the historical downfall of the German democracy that led to the rise to power of the Nazi party).

Finally, our work has practical implications by shedding light on the potential for improvement of strategic epidemic control interventions through better predictions of the pattern of infections and population movement and more effective and less costly mobility restrictions strategies such as widespread quarantines. The findings might equally advance the strategic implementation of ring vaccination for susceptible infectious areas.

The remainder of this paper is organized as follows. Section 2 discusses the background on the Ebola epidemic in Sierra Leone chiefdoms, and the related literature is presented in Section 3. In Section 4, we turn to the description of the data, before presenting our empirical strategy in Section 5. Section 6 reports the main results and robustness checks, discusses the effectiveness of policy intervention. Section 7 presents evidence on the competing networks of spatial dependence. Section 8 concludes and discusses policy implications.

2 Background on the EVD epidemic in Sierra Leone Chiefdoms

The Ebola Virus Disease is a severe and fatal infection first identified in Central Africa in 1976. Since then, more than 25 outbreaks have successively occurred mostly in central Africa and around the tropical forest in countries such as Gabon, Uganda, and Congo (DRC). These outbreaks were characterized by a high fatality rate but remained very localized and did not reach national scale or export significant cases across borders. The most deadly of these successive outbreak episodes registered 425 incidence cases and a fatality rate of 53%, according to the WHO[5]. However, the West African epidemic which started in December 2013 from an infectious case in Meliandou, a remote village in the forest district of Gueckedou in Guinea, further expanded and crossed the shared borders with Sierra-Leone and Liberia to become the first outbreak that the WHO will declare a public health emer-

[5] The average case fatality rate across epidemics is 50% and has varied from 25% to 90% across the history of different disease outbreaks (WHO, 2018).

gency of international concern on 9 August 2014, 8 months later after the epidemic onset. By the end of the epidemic, Sierra Leone registered more than 14,124 cases, and the virus propagated to more than two-thirds of its chiefdoms.

Sierra Leone chiefdoms are historical and stable local administrative units officially prevailing in the country since 1896, that is, after the British colonial power created the Sierra-Leone protectorate (Acemoglu et al., 2013). Initially, the colony of Sierra Leone, created in 1788, was established to host former slaves from American colonies and was delineated around Freetown. Areas in the hinterland benefited from political autonomy, and traditional chiefs were only linked to British power by treaties designed to protect trade routes (Reed and Robinson, 2013). Under the British indirect rule, paramount chiefs were the sole recognized local government authorities and were chosen among a group of local notables families and elected for life by a Tribal Council. They enjoyed significant political, judicial, and economic power through their ability to raise taxes, allocate land tenure, and arrange settlement of legal disputes in addition to the fundamental responsibility of the well-being of people under their authority. Even in the post-colonial area, paramount chiefs remained the only local government institution until the World Bank sponsored a system of an elected local council in 2004, in the wake of the end of a decade of civil war between 1991 and 2002. Glennerster et al. (2010) document that since independence, chiefdom boundaries have remained relatively stable, and constitute the geographic unit by which most Sierra Leonean self identify. More importantly for our work, they document that when they relocate, people are more likely to choose chiefdoms where their ethnic group is dominant. They also show that a highly homogeneous population settles most of the rural communities corresponding to villages or a collection of villages in terms of ethnic identity and that many people still widely value living in areas that were historically occupied by co-ethnic ancestors.

Richards et al. (2015) document some narratives of the social pathways of EVD in Sierra Leone during the Ebola epidemic. The authors describe a case of EVD transmission originating from the Daru area in the Mende dominated chiefdom of Jawie, in Kailahun district, in Eastern Sierra Leone where the outbreak started. The epidemic reached Daru through the wife of the paramount chief of Jawie, returning from a visit of her sick sister, who was also the wife of the paramount chief in the neighboring chiefdom of Kissi-Teng. After returning home from her trip, the chief's wife fell sick and seeded the epidemic in Daru. Later, a con-

taminated boy from Daru went to visit his father in the neighboring Kenema district, was taken to hospital, tested positive to Ebola and died. The boy's father became infected but decided not to attend the hospital. Instead, he traveled to his home town in Fogbo, located further from Kenema, in the Mende dominated Kori chiefdom of Moyamba district, in central Sierra Leone. Once at home, the father was taken care by his sister, a Sowei, who was a traditional healer and an elder of the women's secret society reputed for her medical knowledge. A few days later, the Sowei became sick and died. The fellow women decided to give a proper burial to the respected Sowei, in the absence of the safe burial teams, and override their instructions not to wash the body. Given the importance of traditional burial, they did wash the corpse and performed local rituals for the late Sowei. After that, the chiefdom registered more than 16 women deaths. From then, the epidemics escalated in the area and spread to neighboring villages where people came to attend the Sowei's funeral.

From the above narrative, Richards et al. (2015) illustrate how EVD spreads across chiefdoms according to the interplay between the network of family and ethnic groups alliances, taking the form of a family visit of sick relatives, or traditional health-seeking, or traditional funerals. In particular, the story points out how the funeral of a chief's wife in ethnic dominated Kissi chiefdom saw the attendance of a wife of a neighboring Mende dominated chiefdom due to family alliances. In addition, the sick father decided to seek care in his home chiefdom, which is also ethnically similar to his location of residence. These patterns of behavior, when generalized, might result in the observation that chiefdoms are more likely to be infected by ethnically close chiefdoms. The author also documents the general reliance on close and long-distance family ties for health assistance in case of a disease. Interestingly, they also highlight that marriage and funerals are essential, not only as social obligations but as an essential determinant of land rights and inheritance rights. Access to land rights and inheritance might be compromised without appropriate traditional burial of the deceased, although forbidden by health authorities. Moreover, when marriages are considered as incomplete according to the traditional bride rules, it is not rare that the right to bury the body of the deceased wife is denied to the husband that must, as a consequence, transport the body, often through long-distance, to her relatives. These situations are more likely to arrive when the wife is a stranger and contracted in inter-ethnic alliances. When the EVD caused a death, the funeral requirements became a high-risk factor of infection

and epidemic spread. Other important related social factors, particularly for long-distance spread, are potentially associated with migration and trading patterns from markets centers. New EVD cases that occur in localities where markets are situated could potentially trigger long-distance spread of the epidemic, following trade routes.

3 Related literature

This paper is related to a rich body of research in epidemiology that studies and models the propagation of epidemics. Within this epidemiology literature, we find tyo types of modeling for propagation. One type of modeling assumes random-mixing in social interactions, meaning that each individual has a small and equal chance of coming into contact with any other individual in the population. This implies homogenous spread across chiefdoms and leads to overestimate the rate of epidemic spread (Bian, 2013; Do and Lee, 2015; Merler et al., 2015; Tiffany et al., 2017; Xia et al., 2015). The second type of modeling is the so-called network-based epidemiological models. These models capture the permanence characterizing many social network relationships at the individual level, but also at the geographic level between villages, or chiefdoms in our Sierra Leonean context. An influential study is the one by Kiskowski and Chowell (2016), which proposes the new framework of "reduced disease transmission in spatially constrained contact structures." The critical insight relates to the concepts of community-mixing rates and local saturation rates of infections, which refer to the intuition that in small communities, infected patients are more likely to enter into contact with already infected individuals, which limits the potential for new infections and further propagation of the epidemic. However, this modeling is unable to explain the differential epidemic propagation between communities with a similar population size. Hence our framework brings to this modeling a new spatial constraint in contact structures related to the ethnic distance between chiefdoms.

We also contribute to the related health literature that studies the contribution of social factors relative to geography and ecological factors on the spatial propagation of infectious diseases such as cholera or malaria. Giebultowicz et al. (2010, 2011) find that the spatial spread of cholera is primarily related to the spatial dimension and seldom to social networks. They argue that cholera is transmitted mostly through the local environmental

factors rather than through person-to-person contact. Our results complement their findings by investigating a human-to-human transmitted communicable disease inversely. We show that a different pattern for spatial spread and correlation of EVD emerges where the ethnic social network is more important than the geographical dimension.

Second, the paper relates to early literature studying the patterns of social networks between different ethnic groups and their impact on their differential rates of infectious disease transmission. Laumann et al. (1999) argue that the different sexual behavior between African Americans and other ethnic groups, in particular the fact that they adopt more segregated partner choice and assortative mating, explains their higher rate of infections and transmission. On the same topic, Oster (2005) suggests that the high HIV transmission rates in Africa relative to African American are explained by higher infections from other untreated sexually transmitted diseases.

A third related strand of literature deals with the effect of co-ethnicity and the existence of a negative ethnic border effect to trade (Aker, 2014). In our setting, we pursue the same logic and posit that the "ethnic borders" in Sierra Leone might fortunately prevent the propagation of communicable diseases between distinct ethnic groups during health crises. In this sense, we complement previous work studying the link between trade and HIV propagation in Africa. Oster (2017) shows that truckers, through their export-transit mechanism, are an essential channel for HIV propagation across African borders. The author uncovers the potential intensification effect of roads and the economic development of agglomerations on the risk of infection propagation. We contribute to this literature by highlighting the effect of ethnic distance acting as a social network border – beyond a trade border – to disease propagation across Sierra Leone chiefdoms, as our results suggest the dominance of the ethnic distance network for Ebola propagation in comparison to physical distance, trade routes, or markets.

Other directly related literature on the same topic explores the political economy dimension of epidemic propagation. Wilkinson and Fairhead (2017) investigate the role of state legitimacy and compliance with Ebola epidemic control measures. Soumahoro (2017) emphasizes the role of ethnic politics in public health intervention to control the EVD epidemic. More recent and forthcoming research in the same context investigates the link between EVD epidemics and the emergence of conflicts (Gonzalez-Torres and Esposito, 2018).

Here instead we focus on within-chiefdom variation in Sierra Leone.

4 Data

4.1 Data sources

We build upon rich data on the incidence of Ebola measured by new confirmed cases occurring every week at the chiefdom level from May 2014 to September 2015. The data was shared by Li-Qung Fang et al. (2015) and collected from the World Health Organization and the National Ebola Response Center (NERC) in Sierra Leone. We focus on Sierra Leone, for which we have data at the most refined and meaningful administrative level. Moreover, it has recorded the highest number of confirmed Ebola cases. Our sample forms a panel of 153 spatial units observed over 69 weeks. We use Sierra Leone 2004 population and housing census data to identify the composition and the dominant ethnic groups in each chiefdom.

Sierra Leone is among the world's most diverse countries. By exploiting the 2004 population and housing census data (also used in studies such as Gleenerster et al., 2010), we identify major ethnic groups. The country is dominated by Mende and Temne ethnic groups representing around 31.9% and 31.4% of the population. They are followed by Limba, Kono, Koranko, Fullah, and Susu, which constitute the next largest groups, at 8.4%, 5.1%, 4.4%, 3.8%, and 2.9% respectively. Other ethnic groups represent a substantially smaller share, such as Kissi, Loko, Mandigo Sherbro, Yalunka, Krim, Vai, or the Krio, including the country's descendants of freed slaves and foreigners. By comparing with data from the 1963 Census, Gleenerster et al. (2010) demonstrate the stability of national, ethnic composition over time.

In addition, people from different groups often speak different languages. Following recent works by Demset et al. (2016) and Gomes (2017), we also use data on Languages of Sierra Leone from Ethnologue to build language tree and compute pairwise language distance following (Gomes, 2017) (see Figure 1 below). Apart from English and Krio, which is an English-based Creole belonging to the Indo-European family, the other main African languages are members of the Niger-Congo language family. The Niger-Congo is divided

into two main and distinct branches between the Mande languages – including Mende, Kono, Kuranko, Susu, Loko, Mandingo, Yalunka, and Vai – and the Atlantic-Congo languages, including Temne, Limba, Sherbro, Fullah, Kissi, and Krim. One important feature is that the two distinct groups are mutually unintelligible to each other and much further apart linguistically in comparison to English and German, for instance, given the number of branches separating them (Gleenerster et al., 2010). This redefinition allows accounting for the networks of ethnic alliances through marriages and social exchange, such as those described above in the background on EVD spatial spread in Sierra Leone chiefdoms. Groups belonging to the same language family might have more intense interactions and exchanges facilitated by more fluid communication. They might as well share similar cultural features smoothening social interactions and strengthening cross-group social ties.

Figure 1: Sierra Leone Language tree

4.2 Descriptive statistics on the spatial spread of EVD in Sierra Leone Chiefdoms

Table 1 below summarizes basic statistics on Ebola incidence at the chiefdom level in Sierra Leone and their nearest adjacent neighbors. The figures show that, on average, chiefdoms are dominated by an ethnic group representing 81% of the population, confirming the homogeneity of the ethnic distribution at the chiefdom level. Each chiefdom is on average surrounded by five neighbors, among which 70% of neighbors are ethnically similar to them and 30% dominated by other ethnic groups.

Chiefdoms have, on average, officially recorded around 55 Ebola cases with significant heterogeneity between them as captured by a high standard deviation of nearly 214 cases. Temne dominated chiefdoms have recorded a higher number of cases with an average of 171 cases with an important variation (the standard deviation is 410), whereas Mende Chiefdoms recorded an average of 22 cases. Similarly, Kono dominated chiefdoms recorded 21 cases, Koranko dominated chiefdoms recorded 17 cases, Kissi dominated chiefdoms 15 cases. Limba , and Loko dominated chiefdoms record an average of 8 cases (figures are rounded to the lower nearest integer in column (2)).

Some particular features of the statistics in Table 1 are interesting for our work. For instance, chiefdoms dominated by relatively minority groups recorded a limited number of cases (a mean of 8 for Loko and 15 from their similar neighbors), even when surrounded by neighbors with high incidence rates reaching more than 322 cases. Limba dominated chiefdoms are located in the Northern part of the country and surrounded by the administrative district of Bombali and Port-Loko . Port-Loko registered the highest Ebola incidence rate during the Sierra-Leone outbreak, with Temne dominated chiefdoms such as Buya Romende and Kaffu Bullom having recorded more than 30 new cases per week at the pick of their local outbreak. Another typical illustration is given by the chiefdom of Magbemba Gowahun, dominated by the Loko and surrounded by two Temne chiefdoms, Sanda Loko and Gbanti Kamaranka, the chiefdom of Biriwa belonging to the Limba and Gbendembu to the same group, the Loko (Figure 2, below). Magbemba remained Ebola-free officially, whereas its four neighbors recorded an average of 23 cases. Among them, three were ethnically distant. In the surrounding Bombali district, Temne neighbors of Loko dominated Magbemba, such as the chiefdom of Makari Gbanti recorded more than 262 cases. Within the Port

Loko district, Temne chiefdoms often recorded a high number of cases, whereas minority Tambakha-Susu, Magbemba-Loko, and Libeisaygahun-Loko reported relatively few cases (see the map in Figure 2 and Figure 3 below for illustration).

Table 1: **Some first evidence on the mean incidence cases at the chiefdom level, its neighbors, and neighbors from the same ethnic group. Mean are taken by ethnic group**

	Major ethnic share	Total Cases	Mean Cases All Neighbors	Mean Cases Same Neighbors	N Neighbors	N same Neighbors
Mende	0.87	22.39	26.42	26.67	5.65	4.80
	(0.14)	(54.89)	(29.85)	(42.05)	(1.60)	(1.42)
Temne	0.79	171.51	107.95	132.36	5.46	3.68
	(0.20)	(410.43)	(144.29)	(192.30)	(2.13)	(1.81)
Loko	0.66	8.00	322.48	15.25	5.00	1.00
	(0.21)	(14.70)	(545.58)	(17.04)	(1.41)	(0.82)
Sherbro	0.64	0.25	5.48	0.25	3.75	0.75
	(0.13)	(0.50)	(8.62)	(0.50)	(2.99)	(0.50)
Limba	0.70	12.00	30.49	10.12	6.33	2.67
	(0.20)	(12.56)	(42.08)	(6.75)	(1.32)	(1.22)
Kissi	0.89	15.40	25.57	23.30	2.40	0.80
	(0.07)	(21.47)	(24.72)	(26.69)	(0.55)	(0.84)
Kono	0.72	21.73	23.13	23.73	5.91	4.18
	(0.19)	(29.76)	(15.65)	(15.07)	(2.12)	(1.54)
Susu	0.86	5.00	27.72	5.00	4.50	1.00
	(0.05	(1.41	(21.96	(1.41	(0.71	(0.00
Fullah	0.55	0.00	0.40	0.00	4.00	1.00
	(0.12)	(0.00)	(0.57)	(0.00)	(1.41)	(0.00)
Krim	0.58	0.00	0.20	0.00	5.00	0.00
	.	.	.	.	.	.
Yalunka	0.80	0.00	0.00	0.00	4.00	0.00
	.	.	.	.	.	.
Koranko	0.87	17.67	23.75	41.22	5.50	2.67
	(0.08)	(43.27)	(8.24)	(21.40)	(1.76)	(1.21)
Total	0.81	55.61	52.53	49.54	5.43	3.78
	(0.17)	(213.95)	(120.91)	(109.06)	(1.87)	(1.94)

Standard deviations are in parenthesis.

Source: WHO and Ministry of Health official Data

Figure 2: Spatial distribution of Ebola cases across chiefdoms in Sierra Leone

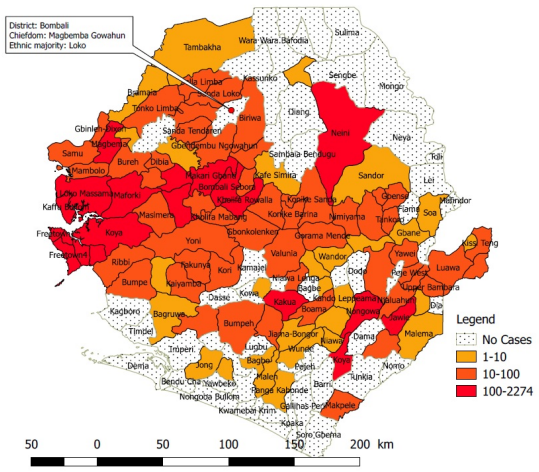
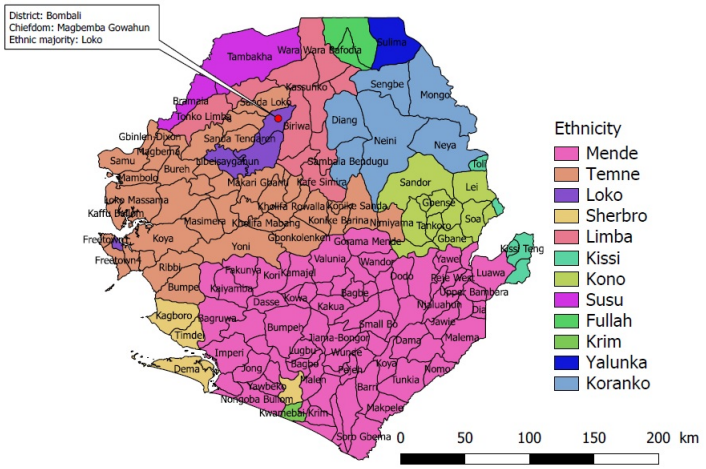


Figure 3: Sierra Leone Ethnic groups



5 Empirical Strategy

5.1 Baseline estimation

We estimate the following spatial and dynamic regression model:

$$\log(y_{i,t}) = \beta \log(y_{i,t-1}) + \rho W_1 \log(y_{j,t-1}) + \mu_i + \epsilon_{i,t} \quad (1)$$

where $y_{i,t}$: is the number of new cases per 1000 hbts, corresponding to incidence rate (IR) at the chiefdom i at week t (we estimate the logarithm of $y_{i,t}$); $y_{i,t-1}$: is the time lagged dependent variable of the incidence rate (IR) at the chiefdom i at week $t-1$; $y_{j,t-1}$: is the space and time lagged IR in other chiefdoms different from i, where the included neighboring chiefdoms depend on the structure of the weighting matrix W. The weighting matrix W_1: is a (NxN=153x153) spatial social network weighting matrix defining neighborhood relationships between chiefdoms. μ_i is a chiefdom i fixed-effect parameter absorbing both observable and unobservable time-invariant characteristics of i influencing the dependent variable; it can also include a time fixed-effect. $\epsilon_{i,t}$ is time autoregressive and spatially dependent error term. Thus, the parameter β captures direct effect, within chiefdom, of time-lagged dependent variable while ρ captures indirect marginal effect of spatially lagged

dependent variables from neighbors, and is our parameter of interest.

On the spatial weighting matrix:

- W_1 is a (NxN=153x153) spatial social network weighting matrix defining neighborhood relationships between chiefdoms:
  - the weight $w_{i,j}$ is the element of the ith row and the jth column and measures the importance of $y_{j,t-1}$ on $y_{i,t}$; they are exogenous weights.
  - W is a real non-negative matrix with $w_{i,j} \geqslant 0$ for all i and j.
  - The rows of W sum to one, that is $\Sigma_{j=1}^{N} w_{i,j} = 1$ for all i. W is row-normalized or standardized, which ensures that the spatial parameter in many spatial stochastic processes is comparable between models (Anselin and Bera, 1998).
  - W_1 is time invariant. If $w_{i,j} = 0$ then unit j does not affect unit i. Spatial variables $\Sigma_{j=1}^{N} w_{i,j} y_{j,t-1}$ are weighted average of values taken by neighboring chiefdoms of i (according to the weighting matrix).

5.2 Weighting matrices definitions and construction

- Geographic Contiguity matrix: this matrix is based on a neighborhood contiguity network matrix. A chiefdom is considered as neighboring chiefdom when it belongs to the n-closest nearest neighbors. We take as the baseline the average number of neighbors in our sample, that is, 5, and test the robustness of our results to the consideration of 10 neighbors and the full sample.
- Geographic Distance matrix: this matrix is based on the geographical distance from the centroid of each chiefdom. A chiefdom is considered as neighboring chiefdom if it belongs to the 25km, 50km radius around the centroid of each chiefdom. We also test the full and continuous inverse distance weighting matrix.

- Ethnic Distance Binary matrix: this matrix corresponds to our social network weighting matrix defined according to the major dominant ethnic group in each chiefdom. Ethnic distance equals to 1 if a neighboring chiefdom belongs to a distinct ethnic group, 0 otherwise. We test an alternative definition of dominance by taking into account how dominant is the group by restricting our sample to chiefdoms leading by at least 50% share.

- Language Distance matrix: this matrix refines the definition of ethnic distance by taking into account the language distance between two groups as defined by the number of shared branches between two languages in the Sierra Leone language tree. We use Languages of Sierra Leone (SKU-21-Digest-SL) from Ethnologue to build a language tree and compute pairwise language distance following Gomes (2017). The higher the number of shared branches, the closer are two languages because it intuitively captures more recent divergence between the two languages. In Sierra Leone, African languages from the Niger-Congo family and Indo-European languages such as Krio or English share no branch and are entirely distant. Most distinctions for African languages are made between Atlantic-Congo and Mende language families that share only one branch. The closest languages are, for instance, Sherbro and Kissi language or Kono and Kuranko languages that share six branches (see Figure1).

5.3 Identification issues

Failing to control for spatial error correlation leads to biased results in the estimation of spatial effects parameters. In particular, spatial correlation for the error term implies that we have:

$$\epsilon_{i,t} = \lambda \, W_2 \epsilon_{j,t} + \nu_{i,t} \quad (2)$$

- λ: is a spatial parameter for the disturbance error term; $\nu_{i,t}$: is an independently and identically distributed error term with zero mean and variance σ^2_ν; W_2: is a geographical distance spatial weighting matrix controlling for spatial correlation due to

proximity. Individuals who are socially connected are more likely to live close one to another and be affected by the same unobserved environmental risk factors and exogenous characteristics. It is chosen according to its best fit to account for the spatial autocorrelation effect across different specifications. By introducing (2) in (1) we obtain the following equation:

$$\log(y_{i,t}) = \beta \log(y_{i,t-1}) + \rho W_1 \log(y_{j,t-1}) + \mu_i + \lambda W_2 \epsilon_{j,t} + \nu_{i,t} \quad (3)$$

- Inference: If equation (3) is estimated using typical Least Squares procedures, it would be inefficient and biased due to the autoregressive nature or correlation of the endogenous Wy term and the error term. Furthermore, the standard errors produced would be biased due to correlation over time and spatial correlation. To estimate this spatial autoregressive and spatial error model, Yu et al. (2008) propose an approach based on a Quasi-maximum likelihood method for estimating the effects of interest. Lee et al. (2010a) propose an extension for models with time fixed effect (see Le Gallo et al. 2017 for a survey). Hsiao (2002) previously theoretically concluded that MLE is consistent and asymptotically normally distributed and more efficient than GMM. LeSage and Page (2001) suggest using MLE to take into account spatial dependence and autoregressive error (Elhorst, 2014, for a survey). Belotti et al. (2017b) propose a Stata module for spatial panel data models estimation. We take logarithm, allowing to mitigate heteroscedasticity (Zhu and al, 2018) and leading to interpret the coefficient as the elasticity of new confirmed cases to previous cases from own and neighboring chiefdoms. We compute robust standard errors clustered at the locality level.

- In contrast to the non-spatial model, the marginal effect of change in lagged and endogenous dependent variables from a neighbor might be different from one neighbor to another. In fact, because of spatial interactions, a change in the explanatory variables from a single individual not only has a direct impact on one's outcome (direct effect) but also on other neighboring individuals due to spatial correlation (indirect

effect). So the direct comparison between the coefficient of spatial models to non-spatial models is not relevant since the former captures direct marginal effect only, one needs to compute the average direct effect, the average indirect effects and the total effects (Han et al., 2016). Pace and LeSage (2006) suggest a desirable summary measure of these varying impacts:

- Average Total Impact:
  - summing the total marginal impacts on each observation (Average Total Impact to each Chiefdom) and then taking an average over all chiefdoms.
  - summing over the total marginal impacts from each observation (Average Total Impact from each Chiefdom) and taking an average over all chiefdoms.
- Average Direct Impact: an average of the direct marginal effect from each chiefdom provides a summary measure of the Average Direct Impact.
- Average Indirect Impact is, by definition, the difference between the Average Total Impact and Average Direct Impact.

6 Results

6.1 Baseline Results

In this section, we present the baseline results. We follow the method proposed by Yu et al. (2008) and use the Quasi-maximum likelihood estimation method spatial dynamic models. We first estimate our baseline spatial dynamic model for which the results are reported in Table 2 below. Building a traditional contiguity (Column 1) and geographic distance (Column 2) spatial weighting matrix, we use these as the benchmark for our baseline estimates of the direct and indirect spatial effect of neighboring chiefdoms based on our binary ethnic distance matrix as discussed above (Column 3).

We then test the robustness of our results to the more refined definition of ethnic distance based on the language distance adjusted spatial weighting matrix (Column 4) and a more restrictive definition of a dominant ethnic group (Column 5). For the latter, we focus on groups leading the second larger group by at least 50 percentage points.

We find that the spatial weighting matrix based on our ethnic distance network accounts more for the spatial spread of EVD incidence than the geographic distance or contiguity based matrix. The geographical distance considering 25km spherical regions around the centroid of each chiefdom has no statistical significant spatial effect. Moreover, the network of 5 contiguous nearest neighbors is associated with a spatial indirect effect of 0.12 relative to 0.17 from our ethnic distance network. These findings are in line with our hypotheses that Ebola clusters more on social and ethnic dimensions than geographically, in comparison to other infectious diseases such as cholera (Giebultowicz et al., 2010). The size of the effect of ethnic distance is even more significant (0.26 relative to 0.17) when we refine the concept of ethnic distance by introducing language distance (Column 4). Given that we have two main language branches in Sierra Leone, introducing language distance will increase the likelihood that two chiefdoms dominated by different ethnic groups will be considered as less distant than under binary weighting matrix, which, as expected, increases the likelihood of EVD between these chiefdoms. Our findings are also robust to alternative and more restrictive definitions of ethnic dominance across chiefdoms, increasing the degree of ethnic homogeneity at the chiefdom level (Column 5). Fang et al. (2016) simulate that, on average, 16,83% of infectious cases were imported from neighboring districts, reflecting a high level of mobility. We manage to replicate an estimate of the indirect spatial spillover effect relative to the total effect from past cases ranging between 14% to 26%.

The direct effect of past EVD cases from one's chiefdoms is 4 times higher than the spatial effect from neighboring same chiefdoms as captured by the baseline ethnic distance spatial weights matrix. These results are in line with higher transmission rates of Ebola through close contacts within chiefdoms. In comparison with previous findings in the literature, Merler and al. (2015) estimated that the rate of infections was 3 to 5 times higher in households than in funerals, emphasizing the role of close contact. The average total effect (elasticity) we find is lower than one, which is in line with a sub-exponential growth rate of Ebola transmission cases observed in the case of Sierra Leone (Chowell et al. 2015).

Table 2: **Baseline Estimation Results of the Spatial and Dynamic Panel Model**

Determinants	(1)	(2)	(3)	(4)	(5)
	Geo: Contiguity	Geo: Distance	SocioNet: Ethnic Distance	SocioNet: Ethnic Distance	Ethnic Distance
	5 Nearest Neighbors	25km radius	Binary	Language Dist. Adjusted)	Diff. Share 1st-2nd sup 50pc
Direct Effect: Log (IR t-1)	.7306045	.7424411	.7236509	.7262284	.7284708
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Indirect Direct Effect:W*Log (IR t-1)	.1259023	.0038806	.1802742	.2660449	.1570782
	(0.002)	(0.721)	(0.000)	(0.000)	(0.000)
Total Effect	.8565068	.7463217	.9039251	.9922733	.885549
	(0.000)	(0.000)	(0.000)	(0.0200)	(0.000)
Spatial coefs:					
Spatial rho	.1538531	.0017456	.206061	.2717828	.182944
	(0.002)	(0.689)	(0.000)	(0.000)	(0.000)
Error lambda	.0348311	.2057558	.1350252	.1600562	.1529869
	(0.513)	(0.000)	(0.000)	(0.000)	(0.000)

Robust standard errors are clustered at the chiefdom level
Note: Numbers in parentheses are p-values

6.2 Sensitivity Analysis

We perform different a sensitivity analysis with alternative modeling and specification of the geographic distance and contiguity matrices. The results are shown in Table 3 below. We find that closer spatial regions within 10 km radius from the chiefdom centroid or further to 50 km radius, do not capture any spatial dependence of cases around the chiefdom, where sizable spatial dependence is captured by the spatial error coefficients (Column 2 and 3). This pattern is persistent when widening neighborhood definition to 10 nearest neighbors or potentially all chiefdoms, which does not account for more spatial correlation of the Ebola cases (Column 4 and 5). We also test the robustness of our results to the alternative modeling of the spatial error autocorrelation, in Table 4 below. We find the same qualitative results. The ethnic distance network accounts for a sizable share of the spatial spillovers from neighboring chiefdoms on new cases from the centroid chiefdom. Moreover, considering more extensive geographic areas do not account for local spatial spillovers of error disturbance. This finding justifies the choice of the 5 contiguous nearest neighbor matrix as our baseline specification to model spatial autocorrelation of errors.

Similarly, we allow for the introduction of time fixed-effects (weeks) and also perform some falsification exercise against randomly drawn spatial weights (see Appendix A). Our results are qualitatively similar, although the short period fixed effect leads to a relative decrease in the size of the coefficients estimates but keeps the ranking across alternative weighting matrices, as shown in Table A.1. In the following Table A.2, we perform a "falsification" exercice with randomly generated spatial binary and continuous weighting matrix

and full inverse distance matrix assuming all chiefdoms are neighbors. The random binary and continuous weighting matrices capture global negative spatial correlation, a result that we interpret as a piece of potential evidence that the positive spatial spillovers our theory-driven spatial matrices capture, reflects the actual chiefdom spatial dependences that the random links generated are not able to account (Column 5 and 6).

We also perform robustness analysis to the alternative specification of the spatial lags of the dependent variable by taking alternative lag structure (we allow for the further incubation period of 2 weeks and 3 weeks) to investigate the role of delay between infection, symptoms onset and infectiousness (see Table A.3). The alternative spatial lags show that the relative persistence of the direct and indirect spatial spillovers is heterogeneous in time. The further spatial lags from within chiefdom have relatively less effect on one's chiefdom new cases than the indirect spatial effect from neighboring chiefdoms, which seems constant over time.

Table 3: **Robustness to alternative geographic contiguity and distance matrix of spatial correlation realative to baseline ethnic distance weighting matrix**

Determinants	(1)	(2)	(3)	(4)	(5)
	SocioNet: Ethnic Distance	Geo: Distance	Geo: Distance	Geo: Contiguity	Geo: Contiguity
	Baseline	10km radius	50km radius	10 Nearest Neighbors	All Neighbors
Direct Effect: Log (IR t-1)	.7236509	.7355173	.4965433	.7405875	.7416324
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Indirect Direct Effect: W*Log (IR t-1)	.1802742	.0161107	-1.390743	.0628599	.0260552
	(0.000)	(0.016)	(0.004)	(0.000)	(0.000)
Total Effect	.9039251	.751628	-.8941993	.8034474	.7676877
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Spatial coefs:					
Spatial rho	.206061	.0743427	.1001789	.0797013	.0354124
	(0.000)	(0.016)	(0.000)	(0.000)	(0.004)
Error lambda	.1350252	.177804	.4848609	.185289	.2034189
	(0.000)	(0.012)	(0.000)	(0.000)	(0.006)

Robust standard errors are clustered at the chiefdom level.

Note: Numbers in parentheses are p-values

Table 4: **Robustness to alternative modeling of spatial error correlation of the baseline specification results of the Spatial and Dynamic Panel Model**

Determinants	(1)	(2)	(3)	(4)
	Geo: Contiguity	Geo: Contiguity	Geo: No-Cutoff	Geo: No-Cutoff
	10 Nearest Neighbors	10 Nearest Neighbors	All Neighbors	All Neighbors
Direct Effect: Log (IR t-1)	.7232768	.7238862	.723208	.724089
	(0.000)	(0.000)	(0.000)	(0.000)
Indirect Direct Effect: W*Log (IR t-1)	.2081156	.1704402	.2093296	.1676407
	(0.014)	(0.316)	(0.000)	(0.008)
Total Effect	.9313923	.8943264	.9325376	.8917297
	(0.000)	(0.000)	(0.000)	(0.0200)
Spatial coefS:				
Spatial rho	.2315408	.1968649	.2326151	.182199
	(0.013)	(0.292)	(0.000)	(0.310)
Error lambda	.0209172	-.0632452	.0126931	-.0125384
	(0.396)	(0.032)	(0.327)	(0.310)
Location Fixed-Effect	Yes	Yes	Yes	Yes
Week Fixed-Effect	No	Yes	No	Yes

Robust standard errors are clustered at the chiefdom level.

Note: Numbers in parentheses are p-values

6.3 Epidemic Phase and Intervention Dynamics

Quarantines are one of the most common public health interventions to control epidemic since the Middle Ages. Their objective is to identify and isolate cases, monitor contacts, and break chains of transmission (Gleason et al., 2017). Despite their benefit in stabilizing epidemic propagation, there is still a debate on their effectiveness due to the high social and economic costs they might impose on the population through movement restrictions. In Sierra Leone, the public health intervention for epidemic control occurred across different phases.

From May 2014 to September 2015, Sierra Leone was facing the Ebola epidemic. Furthermore, the country experienced localized intervention such as the building of the Ebola treatment center and diagnostic laboratories in the eastern Kenema District during June and July. The epidemic was initially relatively under control, with the reported weekly average number of new cases lower than expected. However, the Sierra Leonean government initially underrated the amplitude of the epidemic but finally declared the national state of emergency on the 6th of August 2014. In September 2014, the country experienced a soaring number of cases, reaching an unprecedented peak around 60 confirmed infections per week. The epidemic propagation was out of control in the capital city, Freetown, and the neighboring district of Port-Loko. The substantive nationwide intervention started in the wake of the first emergency session of the United Nations Security Council that qualified the epidemic as a threat to world peace and security on the 18th of September. This convention was immediately followed by 3-day nationwide quarantine decided by the national government and its international partners. During this campaign, more than 28,500 trained volunteers and community workers performed door-to-door information and education about Ebola, hygienic kit distribution such as soap, and search for suspected infected patients to be isolated and taken to ETC and corpses to be safely buried. In October 2014, Sierra-Leone experienced the launch of the Strategic Plan of UN Mission for Emergency Ebola Response consisting of a Nationwide Campaign of case isolation and safe burials (SDBs). The goal was to gradually achieve 70% of cases isolation and safe burial after two months and 100% after three months. The end of September and beginning of October thus marked the first widely country intervention against the epidemic (Fang et al., 2016). It is only by December 2014 that the full scale of the country intervention program reached 100% case isolation and safe burials. After December 2014, the epidemic started its progressive and sustained decline corresponding to its final phase leading the country to be officially declared free of Ebola in November 2015 by the WHO. We define, following Fang et al. (2016), as Phase 0 the period before October 2014, where there was no large scale intervention. Phase 1, the period between October 2014 and December 2014, where the interventions were gradually scaling to reach 100% cases isolation and safe burial, and the Phase 2 corresponds to the period post-December 2014, after complete implementation and coverage social distancing measures.

We assess the potential interaction between ethnic distance and epidemic intervention effectiveness. We find that before and after the October intervention, the transmissibility at the chiefdom level decreases. The elasticity of the number of new infectious cases caused by previously infected patients in the same chiefdom decreases from an average of 0.66 (benchmark) to 0.46 (-30%) as shown in Table 5 below (Column 1 and 2). In their study, Tiffany and al. (2017) predicted an upper bound decrease in secondary cases of 36,5% due to Red Cross's safe and dignified burial programs at the district level. The average indirect spatial effect decreases from 0.17 to 0.13 in the same period (-23%). The intervention appears to have a higher effect in limiting direct transmission within chiefdoms than limiting spatial spread.

Across more detailed sequential intervention phases (case isolation, household quarantine, safe burial), we find that the average direct effect from within chiefdoms had decreased from 0.66 to 0.34 between Phase 0 and Phase 1 (before and after intervention started) and remained stable for Phase 2, after full completion of the intervention (-50% reduction). The average indirect spatial effect from ethnically close neighboring chiefdoms decreases progressively 0.17, 0.12 to 0.0 after 100% case isolation, and safe burial implementation (Column 3, 4, and 5 below). We interpret this result as illustrating that case isolation and safe burials might be rapidly effective initially at the local level (reducing close contact with infectious patients or corpses), and only progressively later in controlling spatial spread between chiefdoms for which limiting population movement is relevant. Full implementation of isolation measures is necessary to derive benefits from restricted population movement. Ferguson et al. (2006) found in studying influenza that domestic travel and border restriction are ineffective to delay spatial spread unless 99% is effective.

However, one should keep in mind that many interventions and actors implemented overlapping actions that all simultaneously contributed to epidemic control in different locations, such as increasing resources in health care facilities, building new or increasing the number of beds capacity in ETCs. Besides, community and social mobilization campaigns also fostered behavior changes leading the epidemic to decline. We solely rely on major internationally coordinated intervention phases to study the effectiveness of quarantine, and on national isolation measures, due to data limitations on the actions and timing of their implementation at the local level. As a consequence, one should be cautious and remain

aware that such an approach might arguably suffer from confounding factors and severe limitations.

Table 5: **Intervention Effects: Estimation Results of the Spatial and Dynamic Panel Model**

Intervention	(1)	(2)	(3)	(4)	(5)
	Ethnic Distance: Binary	Ethnic Distance: Binary	Ethnic Distance: Binary	Ethnic Distance: Binary	Ethnic Distance: Binary
	Before October	After October	Phase 0	Phase 1	Phase 2
Direct Effect: Log (IR t-1)	.6658689	.4691152	.6656352	.3475902	.3439069
	(0.000)	(0.000)	(0.000)	(0.003)	(0.000)
Indirect Direct Effect: W*Log (IR t-1)	.1797891	.1329492	.1786158	.1203475	.0033678
	(0.00)	(0.000)	(0.000)	(0.005)	(0.659)
Total Effect	.845658	.6020643	.844251	.4679377	.3472747
	(0.000)	(0.000)	(0.003)	(0.003)	(0.000)
Spatial coefs:					
Spatial rho	.2188887	.2270917	.2177781	.2677399	.0128979
	(0.000)	(0.000)	(0.000)	(0.000)	(0.577)
Error lambda (W: 5 Nearest Neighbors)	.1442451	.0243823	.1454472	.0075058	0450979
	(0.000)	(0.542)	(0.000)	(0.880)	(0.174)

Robust standard errors are clustered at the chiefdom level.

Note: Numbers in parentheses are p-values

7 Evidence on other networks of spatial dependence

After having established a significant and sizable spatial spillover effect of our ethnic distance matrix on Ebola spread between chiefdoms, we attempt to establish its relative importance in explaining the observed spatial correlation relative to other competing network candidates associated with traditional contiguity and physical distance.

We use data on indicators of the presence of health utilities, roads, and the aggregate economic status in each Sierra Leone chiefdom, as shared by Gleenerster et al. (2013). From the National Public Services Survey Secondary Community Questionnaire in 2008, we code new variables on the presence of periodic or permanent market at the chiefdom level. The survey questionnaires were shared by Casey (2015).

We build a network matrix based on the network of public health utilities across Sierra Leone chiefdoms. We assume that epidemic propagation is likely to follow the network of health services because of population movement in seeking health treatment during epi-

demics. If infected patients in remote rural areas travel for medical care in major cities, where the medical hospitals and Ebola treatment units are located, it is plausible that spatial infection propagation depicts the pattern of modern medicine seeking behavior, as the mechanism described for traditional healing earlier. Several contaminations occurred through transportations of patients by relatives, and also within health districts through nosocomial infections as the death of people from the medical staff in the early onset of the epidemic illustrates. Merler et al. (2015) estimate that 38.3% of infections were acquired in hospitals.

We also build a network matrix based on the presence of paved roads within the chiefdom (only 50% of Sierra Leone Chiefdom had a paved road passing through them in 2008). Roads are a potentially significant determinant of spatial propagation of human-to-human infections through mobility of persons and goods, as illustrated in the case of HIV infections in sub-Saharan Africa (Oster, 2007).

Moreover, we additionally introduce a more direct and specific network matrix to capture the influence of markets and trade routes. An attractive and specific pattern of trade in Africa is the presence of many periodic markets, rather than permanent markets. These mobile markets are held usually weekly and see the meeting of traders and buyers from different areas (50% of Sierra Leone chiefdoms reported the presence of periodic markets). More interestingly, for our analysis, traders and truckers follow these trading routes and travel all around the country and even across national borders. We thus investigate the potential explanatory power of the network of the periodic market to account for the spatial spread of Ebola.

Finally, we introduce a matrix capturing the economic distance between chiefdoms, which account for the various size of influence between chiefdoms according to their economic power. We conjecture that chiefdoms with higher economic status are more likely to interact with chiefdoms with low economic status. Notably, for the case of epidemics, this matrix could depict population movement to seek traditional care from urban locations to their chiefdom of origin, or inversely those moving from their rural chiefdom to urban centers to seek modern medical care.

We follow contributions by Atella et al. (2014) and Bruni and Mammi (2017) proposing an empirical approach to estimate a spatial autoregressive model simultaneously introduc-

ing our baseline ethnic distance social network matrix and alternative competing channels to explain the spatial propagation of Ebola across Sierra Leone chiefdoms.[6]

Table 6 below presents a summary of the results. The spatial spillover effects from the ethnicity network are stable across candidates and statistically significant at 1%. We show the size of the spatial effects in each simultaneous estimation of the spatial autoregressive model of Ebola propagation using two spatial weights matrices. We find that once we account for our baseline ethnic distance social network spatial spillovers, traditional contiguity or geographic distance spatial weight do not account for a sizable effect of the spatial dependence in the data. As for the socioeconomic networks, we find that the network of modern health utilities has a significant and sizable effect that even dominates the effect of the ethnic distance matrix. This result is interesting and might be interpreted as illustrating the role of private mobility of sick or symptomatic patients and their relatives, seeking treatment in health-care facilities. It could equally reflect the mixing between infected and non-infected patients within hospitals. When focusing on roads and periodic market networks, we do not find any sizable effect on the spatial spillovers relative to the ethnic distance matrix, and the transportation network effect is even negative. These results might not be surprising given the distinctive features of the Ebola virus transmission channels. Since the virus is primarily transmitted through close contact, market interactions might not be promiscuous enough to induce transmission. Moreover, patients with advanced Ebola symptoms and particularly infectious see rapidly their physical autonomy declined by the illness. In this respect, the EVD infection pattern differs drastically from HIV, which features much more extended incubation periods between infection and disabling symptoms. The information asymmetry on illness status is also higher for HIV since Ebola is relatively symptomatic, and casual contacts adapt their behavior accordingly. Our results are thus different from previous findings on the exports-transit mechanism uncovered for HIV infection spread in Africa (Oster, 2007). As for our economic distance matrix, it captures positive spatial spillovers of the Ebola transmission, but which remains more than two times lower than our ethnic distance matrix. The conjectured economic urban versus rural economic mobility channel does not seem to account for a relatively sizable effect once we control for the ethnic distance network.

[6]The model is estimated in Stata using the user-written command spm.

In sum, our results suggest that the physical distance and the traditional contiguity network are not a good predictor of the spatial pattern of the Ebola spread. The social distance network, as captured by the ethnic distance between Sierra Leone chiefdoms, has a higher explanatory power for the spatial spread of Ebola in Sierra Leone, alongside the network of health utilities. However, the effect of the health network is not robust to accounting for the spatial dependence of neighboring chiefdoms in our baseline model. Networks considering the effect of roads, markets, and chiefdom economic opportunities are of relatively limited or non-significant effects. Although our results are illustrative of the relative importance of different transmission channels, one should remain cautious given that they rest on the assumption of exogeneity of socioeconomic network weighing matrices, which is questionable in the presence of adaptation during a health crisis. For instance, during epidemics, the periodic market might be canceled or prohibited. Also, people might refrain from attending them, which could drive the insignificant spatial effect. Although nationally official quarantine and movement restrictions were implemented only three days during the epidemic, local initiatives and disease mitigation strategies could have enforced similar measures.

Table 6: **Relative importance of different sources of spatial dependence: Simultaneously using Double Spatial Weights Matrix**

		Ethnic distance network
Competing Network	Spatial effects: Rho2	Spatial effects: Rho1
Classical Networks		
5 Nearest Neighbors	-.030*	.168***
10 Nearest Neighbors	-.030*	.168***
25 Km around centroid	-0.822*	.163***
50 Km around centroid	-.032	.173***
Socioeconomic Networks		
Health Utilities	.163***	.12***
Roads Network	-.088**	.176***
Periodic Market Network	.010*	.152***
Economic Distance	.084***	.185**

This table summarizes the spatial spillover effect estimates of the spatial and dynamic model with a double spatial weights matrix. All estimations include chiefdom and time fixed-effects. Robust standard errors are computed.

p<0.10,p<0.05,***p<0.01*

Source:

8 Conclusion

Social interactions matter for human-to-human transmission of communicable diseases. In sub-Saharan Africa, ethnicity plays a significant role in the intensity of social interactions. As a consequence, ethnic distance very likely determines the pattern of social interactions across communities. From this premise, we postulate that individuals are more likely to be contaminated by someone who is ethnically close to them, so that, having a distant neighbor could shelter from disease contagion. This paper investigates whether this proposition, intuitive at the individual level, holds between chiefdoms in Sierra Leone, where the Ebola epidemics displayed significant heterogeneity of cases incidence across neighboring chiefdoms. Our findings point to higher rates of transmission between neighboring chiefdoms that are ethnically more similar, both in terms of co-ethnicity or language proximity. Our findings suggest, to explain the observed Ebola spatial spread in Sierra Leone across chiefdoms, our ethnic distance network has a higher explanatory power than the standard geographic or socioeconomic networks.

From a theoretical point of view, we propose a new avenue for modeling communicable disease spatial spread and interpreting key epidemic parameters in the sub-Saharan African context. We propose a new methodology for capturing ethnic groups' social interactions through spatial and dynamic panel models and social distance weighting matrix. Conceptually, our work brings new evidence for the recently emphasized potential benefit of further investigating the contextual and differential intensity of interactions between ethnic groups rather than static and symmetric measures of ethnic diversity or polarization. Diversity does not necessarily lead to distance, conditional on culture, language, or trust. Overall, this study presents a more nuanced picture of co-ethnicity and the positive benefit of social capital.

For strategic policy intervention, our study has potential implications for the improvement of three primary interventions to control epidemic spread: quarantine, contact tracing, and vaccination. First, our results suggest that understanding the pattern of social network mobility and future potential spatial propagation could avoid costly and generalized quarantines that fuel suspicion, distrust, and social protest resulting in the rejection of health interventions and effort to stop contagion. If necessary, quarantines could be more localized

according to the risk of propagation. Fundamental knowledge of social network linkages could improve a strategic limitation of quarantine areas. Second, effective containment of epidemics is inherent to successful contact tracing of the transmission chains (identification of initial index case, further contacts, contacts of contacts). However, previous studies have highlighted the difficulty in identifying the complete transmission chain and in implementing reliable contact tracing processes, particularly at the onset of epidemics. In case of failures, massive outbreaks could occur as simulated by Kucharski et al. (2016). Our study, by highlighted the potential effect of ethnic ties on the probability and intensity of interactions during epidemics, suggests in practice complementaries to transmission chain identification through contact tracing and reporting. Notably, in the context of a new or unknown epidemic, and a cultural context of mistrust, it is likely that cooperation on which the effectiveness of contact tracing relies is uncertain. Taking into account social context and ethnic connections between locations might be relevant for pro-active intervention, by anticipating the most likely epidemic paths and individual contacts and potentially imply less dependence on the accuracy of contact tracing. Third, epidemic containment also usually calls for medical intervention such as vaccination. In the context of limited resources and vaccines, Ebola containment uses ring vaccination. Ring vaccination strategies do not rely on geographic contiguity such as mass vaccination would do, but build upon the ability to identify the social network of the infected patient, the contacts of this confirmed case and the contact of the contacts (including in general,family members, friends, potential contact at specific locations, such as workplaces, hospitals or during burials). Our study contributes by improving the accuracy of modeling the relevant social network. For Ebola, when faced with arbitrage, our study suggests, for instance, that vaccinating the traditional family healer or religious leader, even physically distant, could be superior to a co-worker or a fellow traveler.

Although we attempted to build a rigorous study design to uncover the role of ethnic distance and social network on the spread of Ebola in Sierra Leone, our study faces some limitations that first are related to the available data collected during the epidemic crisis. Individuals' cases were not recorded with ethnic identity and transparent transmission chain from contact to infection. As a result, we rely on a second-best solution, using demographic data to infer the potential ethnic identity of recorded cases. However, this approach is rel-

atively common in the literature. In addition, collecting information on patient's ethnic identity during an epidemic crisis might be problematic since the simple fact of referring to ethnicity might be a source of mistrust and tensions according to the local context. From a methodological point of view, one would imagine a time-varying spatial weighting matrix, changing according to the specific epidemic phases and interventions implemented at the local level, which will determine potential case import from neighboring chiefdoms or not. However, such type of design might become quickly untractable, and their findings difficult to interpret in a spatial setting. Nevertheless, the relatively short period of the epidemic mitigates the issue of changing social network, which is a more long term process.

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A Appendix

Figure 1A: The cumulative number of EVD cases on a semi-logarithmic plot by district and in all of Sierra Leone. (Source: Chowell et al., 2015)

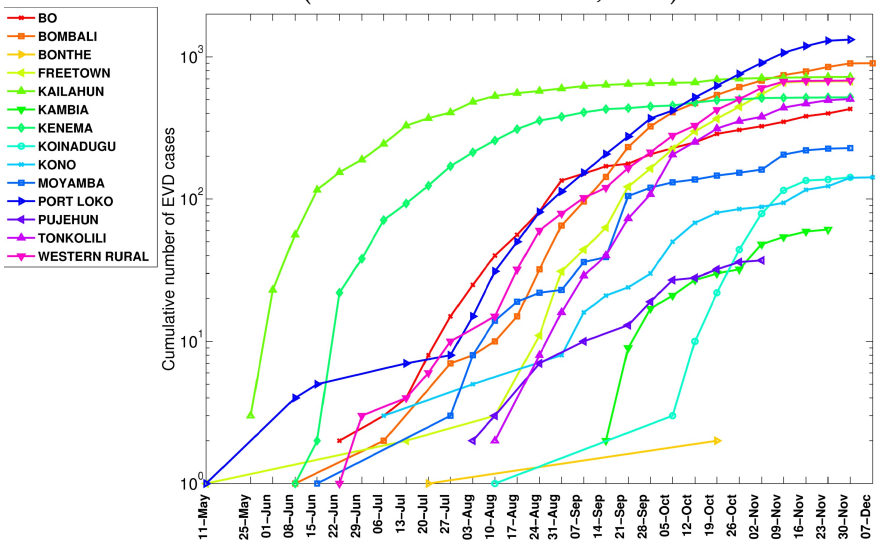

Table A.1: **Robustness of baseline estimation results of the Spatial and Dynamic Panel Model to inclusion of time (week) fixed-effect**

Determinants	(1)	(2)	(3)	(4)	(5)
	Geo: Contiguity	Geo: Distance	SocioNet: Ethnic Distance	SocioNet: Ethnic Distance	Ethnic Distance
	5 Nearest Neighbors	25km radius	Binary	Language Dist. Adjusted)	Diff. Share 1st-2nd sup 50pc
Direct Effect:Log (IR t-1)	.7262659	.7316122	.7233843	.7295921	.7270041
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Indirect Direct Effect: W*Log (IR t-1)	.0957373	.0304549	.1395456	.162668	.1052598
	(0.014)	(0.316)	(0.000)	(0.008)	(0.008)
Total Effect	.8220032	.7620671	.8629298	.8922601	.8322638
	(0.000)	(0.000)	(0.000)	(0.0200)	(0.000)
Spatial coefS:					
Spatial rho	.1221127	.0121846	.1663926	.182199	.1311426
	(0.013)	(0.292)	(0.000)	(0.001)	(0.007)
Error lambda	.0313201	.1116633	.120023	.1478743	.1370369
	(0.548)	(0.037)	(0.000)	(0.000)	(0.000)
Location Fixed-Effect	Yes	Yes	Yes	Yes	Yes
Week Fixed-Effect	Yes	Yes	Yes	Yes	Yes

Robust standard errors are clustered at the chiefdom level.

Note: Numbers in parentheses are p-values

Table A.2: **Falsification: Robustness to global distance weighting matrix and random weighting matrix specifications relative to baseline ethnic distance weighting matrix**

Determinants	(1)	(2)	(3)	(4)	(5)	(6)
	Ethnic Distance	Ethnic Distance	Geo: Distance	Geo: Distance	Geo: Contiguity	Geo: Contiguity
	Baseline	Baseline	Full Inverse Distance	Full Inverse Distance	Full Random Binary	Full Random Continuous
Direct Effect: Log (IR)	.7236509	.7233843	.7277286	.7315744	.7290353	.7292254
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Indirect Direct Effect: W*Log (IR t-1)	.1802742	.1395456	.2667306	.1556693	-.2214992	-.3234273
	(0.000)	(0.000)	(0.000)	(0.364)	(0.000)	(0.000)
Total Effect	.9039251	.8629298	.9944592	.8872437	.5075362	.4057981
	(0.000)	(0.000)	(0.000)	(0.020)	(0.000)	(0.000)
Spatial coefS:						
Spatial rho	.206061	.1663926	.1673727	.1002235	-.4298266	-.7884427
	(0.000)	(0.000)	(0.000)	(0.212)	(0.000)	(0.000)
Error lambda	.1350252	.120023	.1398395	.1376993	.1618793	.1612815
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Location and Week Fixed-Effect	Yes/No	Yes	Yes/No	Yes	Yes	Yes

Robust standard errors are clustered at the chiefdom level.

Note: Numbers in parentheses are p-values

Table A.3: **Robustness to alternative time (week) spatial lags using baseline ethnic distance weighting matrix**

Determinants	(1)	(2)	(3)	(4)	(5)	(6)
	Ethnic Distance	Ethnic Distance	Ethnic Distance	Ethnic Distance	Ethnic Distance	Ethnic Distance
	Baseline(t-1)	Baseline(t-1)	Week(t-2)	Week(t-3)	Week(t-4)	Week(t-5)
Direct Effect: Log (IR)	.7236509	.7233843	.6462795	.5652895	.5095707	.426261
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Indirect Direct Effect: W*Log (IR)	.1802742	.1395456	.1450373	.1487939	.1464542	.1348534
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Total Effect	.9039251	.8629298	.7913168	.7140834	.6560249	.5611144
	(0.000)	(0.000)	(0.000)	(0.0200)	(0.000)	(0.000)
Spatial coefS:						
Spatial rho	.206061	.1663926	.1886573	.2137364	.2280156	.2447772
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Error lambda	.1350252	.120023	.1120866	.1514545	1725772	.1960336
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Location and Week Fixed-Effect	Yes/No	Yes	Yes	Yes	Yes	Yes

Robust standard errors are clustered at the chiefdom level.

Note: Numbers in parentheses are p-values

General Conclusion

This dissertation emerges from established evidence on the field of suboptimal demand of highly effective preventive health techniques in developing countries, despite their remarkable success to alleviate the infectious disease burden over the last decades. This situation results in the persistent prevalence of highly infectious diseases, often leading to deadly epidemic outbreaks, which undermine long-term effort to improve public health. The related rich literature has highlighted standard economic supply and demand constraints to effective prevention of infections and epidemic resurgence, with enlightening evidence on the underlining mechanisms: low competence and misbehavior from health providers, or limited public health information and low education levels, but also financial constraint and behavioral bias from the demand side. Although increasingly recognized as an essential determinant in health demand decision, the role of trust and its potential explanatory power relative to traditional determinants have not been further investigated.

In order to fill this research gap, this dissertation builds on the particular observation of the persistent history of resistance to medical health interventions in sub-Saharan Africa, and the recent experience of pervasive mistrust and resistance to vaccines and the noncompliance with government social-distancing mechanisms during the last Ebola outbreaks. The goal of this thesis was to achieve three main objectives. First, to investigate the empirical relationship between institutional trust and uptake of standard preventive health techniques that are vaccines in sub-Saharan Africa. Second, to uncover the causal effect of cultural mistrust in medicine and on the demand behavior in the up-take and adoption of preventive health techniques in sub-Saharan Africa. Third, to investigate the role of social interactions through ethnic distance on the spatial and dynamics spread of the last Ebola epidemic in Sierra Leone. In the following paragraphs, we present a summary of the thesis main findings and then highlight their implications, and finally present thesis recommendations and discussion for future work.

In this thesis, we have first shown that an increase in country-level public trust in the government is positively and significantly correlated with an increase in national level immunization performance across sub-Saharan African countries. We have also found that the positive relationship of trust only holds for the government authority in charge of immunization policy, particularly the central government. Investigating the potential role of shared mandates, we find that the positive effect of public trust in the central government is lowered in more administratively decentralized countries. Similarly, fractionalization and past exposure

to adverse negative shocks on trusting norms, also lower the positive effect of institutional trust.

We conclude from these findings that trust in authorities in charge of preventive health intervention has a significant impact on the level of adoption and subsequent policy performance. Moreover, the beliefs and perceptions people hold on their public authorities are subject to high variations in short periods, and these fluctuations influence the aggregate health performance. The results suggest that there is potential scope for improving the success of health interventions such as immunization through strategically choosing the health policy sponsor according to attitudes and beliefs the public holds on the authority in charge. The design and content of health policies are relevant, but health intervention is not identity-neutral. Our findings might also suggest including public trust as an additional relevant dimension to be considered in the optimal allocation of mandates between the different levels of government in the provision of health services.

Second, we use a robust empirical approach to establish the causal effect of mistrust in medicine on demand for health in sub-Saharan Africa. We first establish that historical negative shock on interpersonal trust during the slave trade has translated into current negative perception of the trustworthiness of medical health workers. Moreover, the first evidence leads to ruling out a negative effect through differential access to better health infrastructure or supplies. We also find that the slave trade, through its impact on trust in medicine, has a significant and negative impact on the individual vaccination decision, after taking into account an unusually rich set of standard determinants of health access and demand, but also less standard controls for individual and group preferences for fertility and preventive norms. In particular, the predictive power of mistrust is sizable and highly economically significant relative to the standard determinants of health outcomes in developing countries such as income, education, employment, and access to health infrastructure. We also find that the effect of the slave trade varies according to the level of uncertainty associated with the preventive health techniques, with no significant effect in less imperfectly informed decisions such as sleeping under a bed net compared to a blood test.

This study sheds new light on the potentially long-term persistent historical origins of mistrust in medicine in sub-Saharan Africa. Trust potentially plays a significant dimension in health decisions in the presence of uncertainty, even taking into account traditional determinants. Given the evidence of historical persistence, merely providing information or increasing education might not be sufficient to trigger the desired health behavior. Understanding the cultural background and norms from which individuals undertake their health decisions is critical to increasing the social desirability of health interventions or technology. Moreover, our results suggest that some communities, through their historical background or collective norms, might be more inclined to the adoption of new health technologies. This insight suggests a strategic choice of early adopters of preventive health techniques to leverage the positive spillover effect and social learning through the feed-back mechanism could

help achieve a higher level of health techniques adoption. Finally, this paper highlights the potential for reducing the sources of medical risk and the detrimental effect of disclosure of medical misbehavior in sub-Saharan Africa, given these might undermine long-lasting effort to improve attitudes towards effective health techniques.

Third, we studied the role of social interactions through ethnic distance on the spatial and dynamic spread of the Ebola epidemic across Sierra Leone chiefdoms during the West African Ebola outbreak. We find a robust and significant spatial dependence of Ebola incidence between neighboring chiefdoms from similar ethnic groups leading us to conclude that neighboring chiefdoms are more likely to import cases from neighbors from a similar group. We find that the social network based on chiefdoms ethnic linkages account for a higher share of the spatial spread of Ebola cases in Sierra Leone than the traditional geographic distance and contiguity-based network. The results are robust to many alternative specifications, and our model has a high predictive power of specific features of Ebola transmission in Sierra Leone. We also find that the social network based on the ethnic distance between chiefdoms accounts more for the spatial spread of Ebola spread than traditional markets or trade routes networks. In this paper, we empirically establish the role of social interactions in the spread of Ebola in Sierra Leone. The study stresses the theoretical potential of introducing social interactions and ethnic distance in future modeling of infectious disease propagation in sub-Saharan Africa. The results underline the potential of understanding the pattern of community social interactions to strategically design social-distancing measures during epidemics such as quarantines and avoid their high economic and social costs when generalized. We also suggest potential contributions for improving contact tracing of infection transmission chain during epidemics without entirely relying on uncertain cooperative behavior in a distrusting environment. We also derive the practical implications for the optimal design of ring vaccination, primarily social network-based.

Overall, this research could be of valuable contribution in the context of the ongoing Ebola outbreak in Congo (RDC) and Uganda, where new experimental vaccine trials are launched. Our findings would suggest less government-sponsored interventions, or at least presented as such, in areas previously prone to high conflicts and negative perception towards the central government, since these will probably face a considerable level of distrust as some evidence suggest. Introducing more trusted actors in the process should be valuable, such as long-time established NGO's. Moreover, understanding the pattern of inter-ethnic exchanges and border mobility between the two countries could potentially help predict epidemic propagation and implementation of ring vaccination in the field.

Another set of practical recommendations are related to the ongoing introduction of human papillomavirus vaccines against cervical cancer for young girls in Africa. Our findings indicate that, in a context of current or past widespread rumors associated with sterilization and vaccine rejection, the policymakers should carefully understand the specific context of intervention and accordingly design public health communication in order to avoid suspi-

cion and distrust. Our results also suggest that miscommunication from the international and national health authorities amalgamating vaccination and fertility control could induce a considerable adverse effect on short-term fluctuating public trust and undermine the uptake of the vaccine. Besides, understanding local cultural norms on young girl's fertility and sexual behavior should allow predicting cultural barriers to uptake.

This dissertation presents several limitations. On the data side first, we call for an urgent need to improve demographic health surveys with rich modules on trust in health. In this research, we often relied upon indirect measures of trust due to data limitations on comprehensive, more detailed, and nationally representative measures of trust in the health sector. Similarly, individual-level data on the ethnicity of patients during a health crisis or daily health visits could beneficially improve national databases for epidemic analysis, and hence our understanding of the pattern of health behavior across groups, and national health intervention planning. These could also potentially be extended to other relevant socio-demographic indicators.

Another significant issue is related to the practical implementation of some policy recommendations, which rely upon a frank assessment and consideration of the issue of ethnic identity, the related behavior, and patterns of social interactions. Given the sensitivity of the issue in the field, the policy implications should be rigorously and carefully thought, designed, and inclusively implemented to permit their social desirability.

This dissertation, in its core results, indeed, speak for co-design and co-creation between different stakeholders in public health interventions, seriously accounting for the local cultural experience and interpretation of disease and illnesses. Those collaborations with transparency might be cornerstones on the pathways for building trust and compliance with public health interventions. This essential question should be further investigated, similarly, for the relevant dimension of different types of trust and their effect on health behavior. Indeed, the institutional trust might be more relevant for overall health interventions implemented at the state level, while more ingrained interpersonal trust is relevant in personal interactions with health workers. Also, the inter-group trust might be more relevant in shaping disease propagation across groups and their ability to implement disease mitigation strategies collectively. These interesting questions should be addressed in future research.