

Beyond Nation Averages How Vaccine Hesitancy and Perceived Barriers Warp the Relationship between Vaccination Coverage and Disease Incidence

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Abstract:

Whereas there is a theoretical negative relationship between vaccination rates and the occurrence of disease, administrative-level data is often unable to represent the distorting impact of local vaccine hesitancy. By a comparative analysis of China, the United States and Nigeria, this paper shows that non-significant findings in national level analysis accurately show the critical nature of perceived barriers (such as the transportation costs, religious resistance) and some cues to action. This leads to the breakdown of the protective effect of high overall vaccination coverage by forming groups of vulnerable people. The conclusion drives home the importance of using finer-grained data to extract the moderating role of vaccine hesitancy and suggests a policy shift toward targeting and interventions at localized levels rather than national overall averages. Consequently, understanding and addressing community-specific attitudes is essential for designing effective immunization programs. Future research should therefore prioritize the collection and analysis of sub-national data to better identify and resolve disparities in vaccine access and acceptance.

Keywords: vaccine hesitancy; perceived barriers; measles.

1. Introduction

Vaccination is one of the most cost-efficient interventions in the public health. The measles vaccine has helped to reduce measles deaths in the world by more than 80 percent since its introduction in the 1960s. However, even with the undeniable clinical efficacy

of vaccines, a statistically significant relationship between vaccination coverage and morbidity does not exist in every country. In other instances, the regression results show that R^2 is small or the bare minimum p-value, which evidently questions the uniformity of theoretical predictions in the classical theory. The statistically non-significant association

at the national level between vaccination coverage and incidence can be easily obscured through vaccination hesitancy and perceived barriers as unveiled in this paper. It describes how local clustering and systemic vulnerability occur by offering a comparative analysis of other countries. The rationale is that national data can be hiding some valuable local risks and that what appears statistically non-significant can be the activity of these disruptive forces in play and not the absence of vaccine efficacy. This understanding would prove critical in recommending the development of specific policies that go beyond raising national averages to sufficiently ensure herd immunity and reduce outbreaks of vulnerable sub-populations. This article supports that, namely a lack of sufficient national-level correlations perceived through the lens of heterogeneity, is what tells something of considerable strength about what social and structural factors may contribute to the uptake of vaccination.

2. Literature Review

2.1 Vaccine Hesitancy and Perceived Barriers

One of the top ten threats to the global population health recognized by the World Health Organization is vaccination reluctance. Not only is it a denial of vaccine effectiveness, but also a social expression of psychological trade-offs and social decisions made by individuals or groups regarding vaccination. This issue provides a fundamental model to examine by just considering the 3C model of MacDonald which consists of confidence, complacency and convenience [1]. The concept of confidence also includes not only the lack of trust in the population concerning the safety of vaccines but also the lack of trust in governments, international organizations, and pharmaceutical companies. In low-incidence settings where individuals underestimate risk of infection, complacency tends to occur. The elements of convenience are strongly associated with such practicalities as condition of transportation, availability of information, and inequality in the distribution of healthcare resources.

A typical example of the measles outbreak of 2019 in the Orthodox Jewish communities in New York, United States is typical area. Part of this group opposed vaccination because of religious culture and community cohesion processes, which resulted in local vaccination rates significantly lower than the national average and eventually caused 649 concentrated cases in a few days [2]. This incident demonstrates the possibility of increasing the risks to public health through vaccine reluctance in densely populated areas and directly clarifies why the US macro-level data indicated that there is no significant correlation between vaccination coverage and incidence.

This is not so with Nigeria. In 2003-2004, millions of

children were without immunization because of boycotting of oral polio vaccine by religious leaders in the Kano State, which remains to date as one of the histories that led to poor acceptance of measles vaccine [3]. At the same time, inconvenience and perceived barriers are also worsened by transportation problems, inadequate vaccine cold chain, and underreporting at the grassroots level. The statistically non-significant regressions findings represent the noise created by this multifaceted socio-institutional setting and show that national averages cannot be used to accurately reflect local risks.

Conversely, the school-entry vaccination checks system and grassroots network of public health services that is long-established in China provides institutionalized cues to action that effectively bypasses convenience barriers and complacency [4]. The outcome is that not only does vaccination coverage remain high in the long-term, but also display little regional dispersion, resulting in a significant negative association between the regression results and classical theory.

Not only does vaccine hesitancy substantially decrease aggregate vaccination levels, but it is also likely to result in the so-called clustering of susceptible people, which, in turn, increases the susceptibility of localized outbreaks. It has been shown that despite high national coverage of vaccination of 90 per cent and above, local outbreaks can still take place in case sub-national coverage drops below 60 per cent, which has indeed happened during the 2019 US measles outbreak in New York [5,6]. Crisis events can be significant as an indicator of action in promoting vaccination behavior. An example is that New York State rescinded its religious exemption policy after the sudden increase in 2019, and the vaccination rate increased significantly. The system of the school-entry vaccination check is used to establish repetitive institutional cues in China [7]. Conversely, in Nigeria, among others, although they have catch-up campaigns, the impact remains low because of challenges in the systematic removal of the structural social stigmas of the system. Even though many empirical studies have shown a negative relationship between vaccination coverage and the occurrence of the disease, it is important to mention that national-level averages might obscure high-risk scenarios at the local level [7,8]. Especially, when some regions have very low vaccination rates relative to others in social or institutional terms, the statistical insignificance of this problem should rather lead to a further inquiry into the processes at the micro-level and institutional variations [9].

3. Empirical Analysis & Results

3.1 Data and Methodology

The research design is a comparative longitudinal study

and evaluates national-level panel data of China, the United States (US), and Nigeria in 2012-2022. The two variables of interest are the percentage of first-dose measles-containing vaccine (MCV1) coverage (as a proxy of immunization rates) and the rate of annual measles incidence (cases per million population), which is the outcome variable [10]. Sources used to obtain data consisted of the World Health Organization (WHO) Global Health Observatory, the UNICEF State of the Worlds Children reports, and national health statistical year books [11].

The research fitted a fixed-effects panel regression analysis on a country-by-country basis, with the incidence of measles as the dependent variable, and MCV1 coverage as the independent variable. The basic time trends are controlled in the model specification. Nevertheless, the quantitative analysis is explained qualitatively by the socio-institutional circumstances of each case as reported, because the national-level data itself is not sufficient to fully explain the underlying mechanisms. The Figure 1 shows the rates of Nigeria.

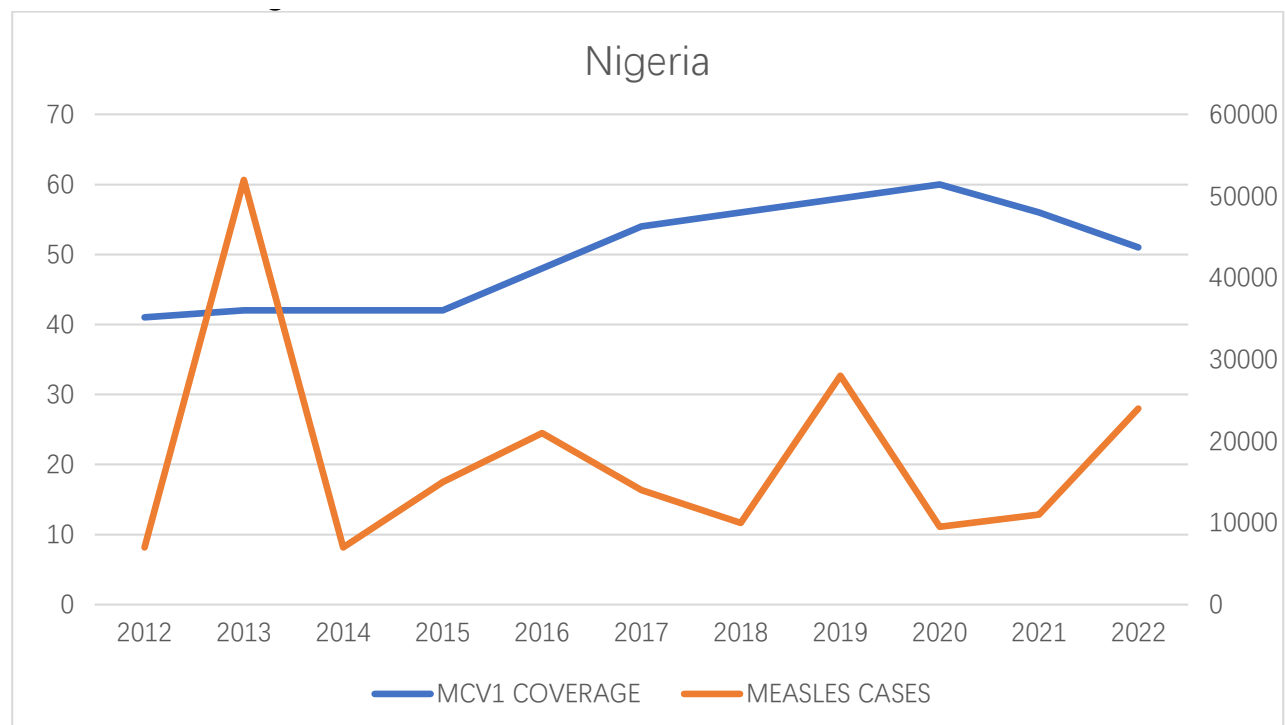


Fig. 1 The Comparison of MCV1 Coverage and Measles Cases of Nigeria
Picture credit: Original

3.2 Descriptive Overview and Country Contexts

It is a preliminary descriptive analysis that shows sharp contrasts. China was very stable during the decade. There was never a drop in MCV1 coverage, which remained between 91% and 99 percent, far exceeding the herd immunity threshold of about 95 percent against measles. Therefore, the incidence of measles was maintained at a low level (most annual rates were lower than 10 cases per million people). The visual representation of this pattern represents the traditional ideal of high coverage low incidence of public health.

High national MCV1 coverage was also observed in the United States, with an average of between 91-94 over most years. But below this average national figure was a great deal of sub-national heterogeneity. Mandatory school immunization laws broadly resulted in high com-

pliance, although non-medical exemption policies in some states created opportunities of under-vaccination. The best-known example is the Orthodox Jewish community in New York, which had an estimated coverage of less than 60 percent in some neighborhoods before the outbreak of the 2019 epidemic. The main feature that cannot be captured using national aggregates is this domestic imbalance.

Things were very different in Nigeria. Coverage of MCV1 was more unstable with the baseline rate (approximately 54 percent in 2012) steadily rising to about 71 percent with a wide margin from the mark of a healthy herd immunity. Crucial to this persistent low coverage were vast regional imbalances between the northern and the southern states. The reported sporadic rates were thus in several orders of magnitude higher than those of China or the US, in some instances over 100 cases per million population,

and very high levels during major epidemics.

3.3 Regression Results and Non-Significance Interpretation

Chinese model yields a significant result ($p < 0.01$) and a large correlation 0.782. The MCV1 coverage coefficient is negative, and the coefficient value is highly precise (small standard error). This is a strong validation of the classical epidemiological theory on the national level. It suggests that in a universal and homogenous environment with universal coverage and reduced systemic barriers through institutional arrangements, national average is an entirely valid and effective predictor of the risk at the population level. The difference in incidence can be attributed mostly to the difference in coverage.

The US results are distressingly non-significant, in classical statistical terms. The p-value (0.111) is larger than the usual threshold of 0.05, the R^2 is very low at 0.257. This would imply that variation in national coverage can explain only approximately 25.7% of the change in national measles incidence. The coefficient is negative and is very imprecise (158.70 standard error). That is no reason that the vaccine does not work. It is, rather, direct statistical evidence of the clustering effect of the community. The national average coverage (e.g. 94% in 2019) hides the fact that there are high-risk clusters (e.g. parts of New York at <60%). These clusters give rise to outbreaks which generate a disproportionate number of cases (649 in NY, 2019), which are then added to the national incidence rate. This overstates the national incidence of the same year and thwarts the optimal negative association with the national coverage rate. This “noise” - the random influence of local outbreaks caused by heterogeneity rather than a lack of vaccine effect - is reflected by how large the

standard error is.

The results of Nigeria are also insignificant ($p=0.599$) and the R^2 is extremely low (0.0319). The standard error is enormous (626.03), which means that the data is extremely volatile. In this case, the absence of a definite correlation is the result of systemic vulnerability and noise of data. The associations between coverage and incidence are dominated by confounding: religious opposition causes refusal regardless of the availability of vaccines; transport barriers and cold chain issues cause lack of access, so reported coverage is not equal to effective immunity; and underreporting of cases is common, hence the actual incidence is not known, and the reported statistics is not reliable. The model does not fail due to local clusters in high coverage environments, but due to the system-wide presence of barriers that decouple the measured coverage and the actual immune status of the population as well as decouple the reported incidence and actual disease burden.

The low R^2 and high p-value of the regression in the US and in Nigeria are an unexpected result of the classical theory of simple expectations. The important finding is this deviation. It shows that: A major outcome (China) confirms the theory in the best conditions of perfect and fair coverage. A non-significant finding is open to two different interpretations.

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Figure 2 shows that regression results in Nigeria.

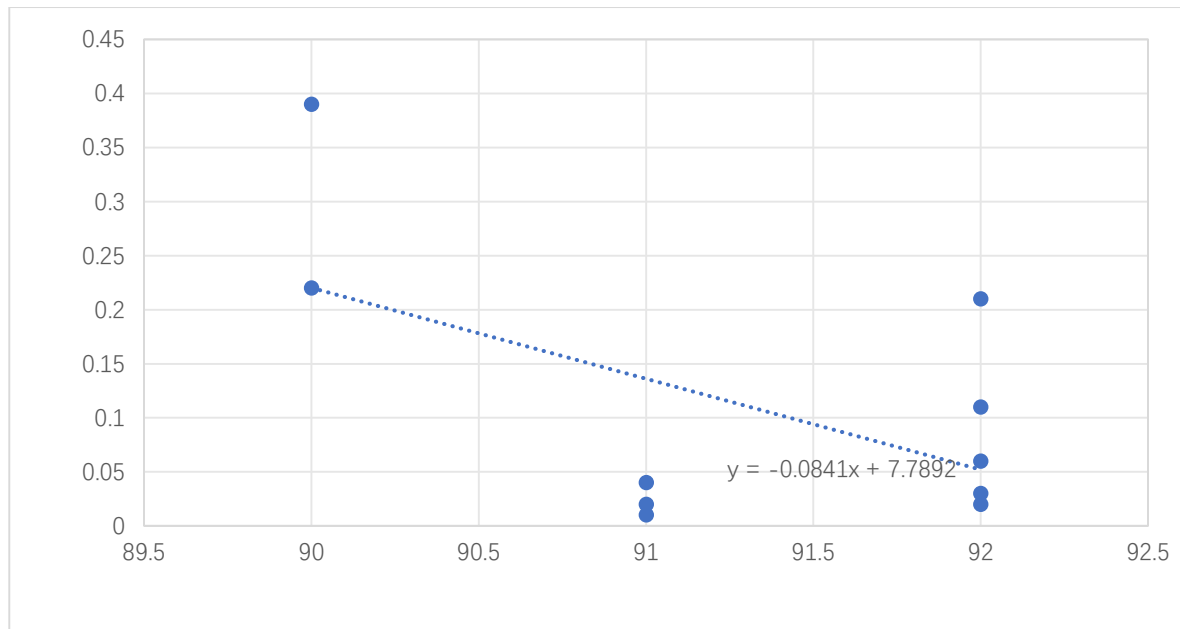


Fig. 2 The regression of Nigeria
Picture credit: Original

Consequently, such non-ideal model outcomes are not failures; they are strong indicators that vaccine hesitancy and perceived barriers are strong moderating variables. They demonstrate that it is necessary but not sufficient

to pursue high national average coverage target unless localized hesitancy or systemic impediments are also addressed. Table 1 shows the main results below.

Table 1. Regression results

Nation	R ²	P-Value	Standard Error
Nigeria	0.0319	0.599	626.03

4. Discussion

These different regression results in the three countries eloquently demonstrate the main thesis that national averages are highly deceptive in situations where heterogeneous local conditions exist. The United States is a critically important case study because the statistical result was statistically non-significant. It is mainly due to the strong community clustering effect, in which a highly concentrated population with low vaccination levels serves as a reservoir of the virus. The 2019 measles outbreak in the Orthodox Jewish community of New York is an excellent textbook case of the 3C model in action: a lack of confidence (based on certain religious-cultural attitudes and distrust toward external medical authorities) and complacency (underestimating the personal and community risk of measles because it is rare) combined with a lack of convenience (not only physical access, but also major cultural and institutional barriers that make vaccination a socially costly choice in the community) to reduce local

immunization rates. Because such a vulnerable population is geographically and socially concentrated, a local outbreak will not take long before cases pile. The national statistics then drag these cases to the overall incidence rate, in essence dragging it upwards to rupture the negative, clean relationship between the high national average vaccination rate and the expected relationship. This results in the national mean being a poorer predictor because it flattens hot spots of extreme vulnerability.

By a wide margin, the great negative correlation, to China, supports the other extreme side of the scale. That is explained by huge and very equal distribution of vaccination coverage which is also dictated by powerful institutional processes including the school-entry vaccination check system. A good measure of population-level immunity is therefore the national average. The antagonists of convenience and complacency are overcome systematically through a device of the means of health directed by the state, in such a way that the biological power of the vaccine can be conceptualized directly in the epidemiological

evidence, without involving in the definition too substantial social intruding factors.

Another form of data obscurity can be seen in the Nigeria case. Here, the statistically significant difference is not brought about in a significant part due to localized clustering in the face of a general high coverage sabotage (as in U. S.), but due, rather, to systemic weakness which cuts across the health system. Problems that have underlain vaccination activities such as deep-rooted religious seeming in certain areas, massive transportation challenges that exclude a great number of individuals and underreporting of data are sorely missing, presenting a critical level of background noise. This racket and noise conceal the background message of the effectiveness of the vaccine. The regression model does not find an apparent relationship not because it does not necessarily exist, but because the data is not consistent, and therefore is disjointed and reflects a health infrastructure that is unable to offer services and measure outcomes in a uniform and consistent way. By doing so, non-significance, here, would be a pure manifestation of the weakness of the system and the insufficiency of data, rather than of the local reluctance.

All combined, these cross-national cases contribute to the realization that vaccine hesitancy and perceived barriers are not only personal psychological issues but are an inseparable part of a socio-cultural and institution specific environment. Therefore, the absence of a high correlation on national-level average measures does not normally mean that vaccines are not effective but may instead accumulate and become compromised locally or saturate the system. The masking phenomenon is particularly acute in the US and Nigeria, however, owing to two individual factors, although in China, this is sufficiently offset by active institutional buffering mechanisms.

5. Conclusion

This cross-national case study of the US, China, and Nigeria shows an average negative correlation between measuring vaccination coverage and the incidence of measles, although the results lack statistical clarity varying per country. The non-significant finding in the US does not imply the ineffectiveness of vaccinations, but it is due to a strong grouping effect by lower vaccination rates in sub-national areas than in the entire country, which is also strongly influenced by several socio-cultural differences. This very high material score of China shows that given high, stable and equitably distributed coverage, enforced by well-established institutions, national averages are not losing their explanatory power. The difference between Nigeria as significant and not is mostly due to the presence of religious opposition, transportation problems, and data integrity problems, which caused excessive noise and demonstrated the vulnerability of health systems.

These inconsistencies explain why the principal significance of the given work does not lie in rediscovering that vaccines are efficient but in solving the puzzle that the statistical indicators at the national scale do not necessarily indicate the positive flow. It notes vaccine hesitancy and perceived barriers to be the most significant moderating items defining the prevalence of this gap. In other words, statistical non-significance is not reason to reject vaccines, it is a diagnostic indicator, a red flag that indicates one of the two wrongful options discussed above of localized clustering of susceptible or localized operational defeat.

These findings demonstrate that the following phase of research and social policy in the immunization area must now cease to be confined within the framework of raising the single measure of national average rates of coverage with vaccines. The government must also formulate and presuppose more judgmental analytical and governance frameworks urgently. This would require the development of so-called vaccine hesitancy indexes and so-called perceived barrier indexes in order to select the at-risk communities in a structured manner and devise fine-grained risk maps that facilitate the distribution of resources and the development of culturally competent interventions tailored to specific population groups. Only in this way is it possible to construct a long-term herd insurance, and then to be able to underwrite the most endangered units of the population by the unfeudalized volume of disease burden to which they are liable.

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