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A new approach to assess the performance of the Brazilian National Immunization Program (NIP)

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ABSTRACT

The present study develops an alternative measure of efficiency to assess the Brazilian National Immunization Program (NIP) using Data Envelopment Analysis (DEA), an output-oriented variable returns to scale (VRS) model, to combine different homogeneity indicators within a unique composite index and evaluate the socio-demographic differences among states. The new DEA index allows homogeneity indicators to be measured for various vaccines in the same model, which enables the development of a composite index for "the first year of life" immunization cycle. In Brazil 2010, the mean efficiency score for the 26 states was 0.89 (0.14 SD). Eleven states were considered efficient, and eight of them were located in regions with a high Human Development Index (HDI) and small rural population, which reinforces the concept that regional and socioeconomic differences must be considered during immunization planning. To reach the frontier of best practice, each state should have an individual and attainable goal for vaccine homogeneity.

1. Introduction

Immunization is the process whereby a person is made immune or resistant to an infectious disease, typically by the administration of a vaccine. Vaccines stimulate the body's own immune system to protect itself against subsequent infection or disease. Immunization is a proven tool for controlling and eliminating life-threatening infectious diseases, and it is estimated that immunization prevents between 2 and 3 million deaths each year. Immunization is one of the most cost-effective health investments, with proven strategies that make it accessible to even the most hard-to-reach and vulnerable populations [1].

In 2000, all of the 193 United Nations Member States accepted eight Millennium Development Goals (MDGs). One of these goals was to reduce child mortality by two-thirds compared to 1990. The United Nations General Assembly Special Session (UNGASS) included goals to eradicate poliomyelitis, reduce measles mortality, and eliminate maternal and neonatal tetanus by 2005. Comparatively, the UNGASS goals to achieve by 2010 were to ensure full immunization of children under one year of age with 90% national coverage and at least 80% coverage in every district or equivalent administrative unit. To achieve these objectives, core activities have been developed to assess and monitor the immunization policies in each country and evaluate the coverage, quality and safety of current immunization systems [2].

The first vaccination campaign in Brazil dates from 1904. A century ago, mankind was beginning to understand the mechanisms of infectious disease transmission. Consequently, apprehensive individuals rebelled against vaccination worldwide because vaccines were a new medical discovery at that time. Since then there have been many Brazilian campaigns with inspiring results, such as the eradication of urban yellow fever in 1942, smallpox in 1973 and poliomyelitis in 1989. Additionally, severe cases of tuberculosis, neonatal and accidental tetanus, diphtheria and whooping cough have been controlled [3].

The present Brazilian National Immunization Program (NIP), which functions as a health policy and establishes vaccination

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schedules, dates from 1973. The NIP is public, universal (all Brazilian citizens have the right to be vaccinated for free), managed by state or regional health authorities and organized by life cycle stages. Brazil is a country of continental dimensions that requires qualified human and material resources throughout, therefore logistics are a major challenge for this program. Brazil currently has 190,732,694 inhabitants distributed among five regions – North (8.3%), Northeast (27.8%), Southeast (42.1%), South (14.4%) and Center-West (7.4%) – and 26 states that cover an area of 8,514,876 km^2. Nonetheless, the NIP has been considered a benchmark by many health organizations because it provides good coverage even in places of difficult access [4].

According to the World Health Organization (WHO), the usual assessment of immunization coverage is based on three main indicators [5]:

- Coverage is calculated by the actual number of applications divided by the expected number of applications according to the demographic structure of the state or region. As the expected number is used to estimate the number of necessary doses, this indicator is the most reliable and easiest to obtain;
- Homogeneity is the proportion of cities in the state with greater than 95% coverage. The importance of this indicator relies on the capacity for herd or community immunity, which occurs when the vaccination of a significant portion of a population provides protection for individuals who have not yet developed immunity;
- The abandonment rate for multiple dose vaccines is determined by calculating the difference between the number of initial and the number of final doses administered and dividing by the number of initial doses. This measure is a proxy for the number of people with access to the complete dosage that guarantees full coverage and protection.

Additionally, these indicators can be analyzed according to different levels of aggregation (cities, states or regions, macroregions, and countries) and diverse population groups (children, pregnant women, elderly people, or other vulnerable groups).

In Brazil, children under one year of age must receive vaccines for the prevention of the following diseases: severe tuberculosis (BCG), poliomyelitis (polio vaccine), diphteria, tetanus, whooping cough and *haemophilus influenzae* B (also known as tetravalent vaccine), hepatitis B (HpB), measles, mumps and rubeola (also known as trivalent MMR), rotaviruses, *pneumococcus*, meningoencephalitis and yellow fever (the latter is administered in endemic states).

To measure the coverage performance of the NIP during the first year of life exclusively, it is assumed that there are fourteen diseases to prevent, which are aggregated in nine different vaccines. Not all of these vaccines are administered in the same month after birth; some of the vaccines are repeated in the following months to achieve full coverage. Consequently, children are required to go to the vaccination unit at least eight times in their first year of life.

The goals set for each coverage indicator are usually arbitrary and close to an ideal theoretical situation (90% percent coverage and 80% homogeneity according to MDGs and less than 5% abandonment rate), although the actual regional values may vary because of socioeconomic discrepancies, access, organizational issues, urbanization and infrastructure. For example, 80% coverage would be satisfactory for a distant location in the Brazilian Amazon rainforest (where mobile teams are required), however it would be considered unacceptable for a metropolitan area in the Southeast.

The present study aims to develop an alternative measure of efficiency to assess the Brazilian Immunization Program in 2010 by using Data Envelopment Analysis (DEA) to combine multiple indicators into a single index and evaluate the available resources in Brazilian states.

2. Methodology

Many performance and benchmark reviews approach the issue of health care assessment from an efficiency perspective. Chillingerian and Sherman [6], Hollingsworth [7] and O'Neill et al. [8] conducted health care efficiency studies that collectively provided a comprehensive overview of the theme by identifying the general advantages, concerns and limitations of applying these methods in multi-product organizations and complex public policies, such as entire healthcare systems [9] and vaccination programs [10,11].

The most frequently used technique, Data Envelopment Analysis (DEA) determines which health units are efficient, provides the magnitude of inefficiency and indicates ways to improve efficiency by setting targets for each of the inputs and/or outputs individually [12]. The measure of productivity and efficiency of DEA is generated by linear programming (LP), which compares similar units, or Decision Making Units (DMUs), using multiple inputs to generate several outputs that only differ in terms of the amount consumed and produced. A DMU is considered to be efficient if it shows a higher production for fixed amounts of resources (output-oriented) and/or if it uses fewer resources to generate a fixed amount of products (input-oriented) compared to other DMUs. By defining the DMUs with the best practices, DEA creates a frontier of empirical production (the border of estimated production possibility set); the level of efficiency varies between 0.00 and 1.00 depending on the distance between the unit and the frontier (envelope model; Appendix A). This measure of efficiency is known as technical efficiency, and the spatial projection of inefficient units in the frontier is delimited by a reference group of efficient units that are next to the projection (hence the term benchmark). By definition, according to the dual theory, efficient units produce the best weighted sum of outputs given a weighted sum of inputs consumed without the influence of a decision maker (multiplier model).

Given a set of input vectors that produce a set of output vectors, the frontier production function defines an optimum relationship for producing the maximum amount of weighted outputs from the given inputs [13]. This frontier is required to satisfy Pareto-Koopmans conditions; however, in real world problems, non-Pareto-efficient portions of the frontier can be achieved through radial projections. In this case, the dual multipliers assume undesirable weights equal to zero.

The production function of this study assumes that coverage in the first year of life – not only individually but also geographically comprehensive – is a performance marker of a good immunization schedule that reduces preventable diseases and lowers child mortality. Because it is futile to set goals of less than 100% coverage, less than 95% non-abandonment rate or to trade off these measures with other assessment indicators, the vaccination homogeneity indicator of coverage was selected to be included in the model.

This model considers variable returns to scale (VRS) and is oriented towards increasing the outputs for the frontier projection (maximization) or obtaining the maximum success (immunization coverage) given a fixed amount of resources (children and cities to be covered). The formula of the VRS model allows an inefficient unit to be exclusively compared with other efficient units that are either of a similar size or are operating on a similar scale. Therefore, it is the appropriate model to manage the diversity of state sizes and social scenarios.

The DMUs of the present study are the immunization offices of each Brazilian state that are responsible for the organization and logistics of the NIP. The inputs (x) are the number of births in 2009 (expected number of applications) and the number of cities in each