Chapter 1: Background

1.1. Introduction:

Given the fact that most of the characteristics of public good are embedded in public health, barriers to access public health is a rather obscure, but important research issue. Public health is normally publicly funded and hence lack of financial affordability is not expected to be an important barrier. If this spending is excessive or otherwise inappropriate, the consequences for the economy and for health outcomes could be substantial (Musgrove 1996). Among the different public health indicators child immunization is an important one as it has contributed significantly in reducing the child mortality across the world (WHO 2002). However, still a significant share of child mortality is due to the vaccine preventable diseases and it is more so in case of developing countries (UNICEF 2005). Therefore it is important to identify the factors those act as barriers for child immunization, which is fully financed by government funding.

The first chapter of the present dissertation starts with the definition and concept on access. The section on access elaborates the various definition of it, as used in literature. Next is the section on public health, which covers its definition and issue of access in it. Here the dissertation explains the justification of considering child immunization as an important child health indicator. The section also briefly describes the scope of present dissertation in exploring the barriers to access immunization both from demand and as well as from supply side. In addition to that, the section also justifies the necessity of addressing the issue of quality immunization in terms of its timely uptake. Then it highlights the importance of measuring the technical efficiency of the
health sub centers as the most commonly used service delivery point for child Immunization in India. The chapter next sums up the research objectives and the respective methodologies used to address the objectives. This chapter finishes with the chapterization plan.

1.2. How to define Access?

Access is an important concept in health policy and health services research. In spite of access being the most frequently used words in discussions of the health care system, it is not well defined. Above all, access is used synonymously with terms like accessible and available, which themselves are ill-defined.

According to initial research, to have access means that services are available whenever and wherever the patient needs them and that the point of entry to the system is well-defined (Freeborn and Greenlick 1973, Bodenheimer 1970). On the other hand Beck (1973) uses "medical iceberg" notion to conceptualize access. The iceberg itself represents the set of medical needs that might be treated by a physician. The proportion of the iceberg above water represents those needs which actually receive the attention of a physician. The greater the portion of the iceberg above water, the greater the access to care of the group represented by that iceberg. Donabedian (1973) argues that "the proof of access is use of services, not simply the presence of a facility," and that access can, accordingly, be measured by the level of use in relation to need.

Taken into account all these thoughts, Aday and Anderson (1974) conceptualized access as proceeding from health policy objectives through the characteristics of the health care system. It is the link between the population at risk (inputs) and the outcomes or outputs like actual utilization of health care services and consumer satisfaction with
these services. By characteristics of health care delivery system they actually meant the arrangements for potential rendering of care to consumers. The characteristics of the population at risk are grouped in predisposing, enabling and need components, which Anderson and Newman (1973) describe as the individual determinants of utilization.

Latter, Penchansky and Thomas (1981) used the term access as a concept which represents the “degree of fit” between the clients and the system. They viewed access as a general concept which summarizes a set of more specific areas of fit between the patient and the health care system. They specified five of such specific areas or dimensions of access—availability, accessibility, accommodation, affordability and acceptability.

Hence it can be said that there are two main themes regarding the concept of access that appear in the literature. Some researchers tend to equate access with characteristics of the population (family income, insurance coverage, attitudes toward medical care) or of the delivery system (the distribution and organization of manpower and facilities, for example). Others argue that access can best be evaluated through outcome indicators like utilization rate or satisfaction scores. In other words it can be said that to some researchers access is an input either from demand side or supply side (Guagliardo 2004, Rosero-Bixby 2004, Perry and Gesler 2000) or interaction of both demand and supply side factors (Oliver and Mossialos 2005), while to others it is more of an output like utilization of any particular services. However, utilization involves interaction of demand side and supply side considerations mentioned earlier.

As Penchansky and Thomas (1981) suggested, among the five dimensions of access availability is the supply side factor, whereas affordability and acceptability are more like a demand side issue. On the other hand, accessibility and accommodation
depend on the interaction of both the demand and supply sides. This classification in
terms of demand and supply will get clearer in the subsequent sections when I will
describe how these dimensions are defined by Penchansky and Thomas (1981) and also
by other eminent researcher while deciding upon the factors that influence access.

1. **Availability:** Penchansky and Thomas (1981) define availability as the
relationship of the quantity and type of existing services (and resources) to the clients' 
needs. They list the adequacy of the supply of physicians, dentists and other providers;
of facilities such as clinics and hospitals; and of specialized programs and services such
as mental health and emergency care under this term. Fein (1972) also defines access in
terms of availability when he argued it in terms of allocation of services by type and
geographic area for a specific clientele. In similar way Donabedian (1973) defines
availability as service producing capacity of the resources. Gugliardo (2004), Perry and
Roser-Bixby (2004) and Gelser (2000) used the word *spatial accessibility* which is again
a matter of location and providers' density. However, simply locating a provider in
community where need exists does not ensure that the client in need will use services.
There are other factors like accommodation, affordability and acceptability that ensure
the usage of services.

2. **Accommodation:** Penchansky and Thomas (1981) defined
accommodation as the relationship between the manner in which the supply resources
are organized to accept clients (including appointment systems, hours of operation,
walk-in facilities, telephone services) and the clients' ability to accommodate to these
factors and the clients' perception of their appropriateness. Combining, availability and
accommodation, Simon et. al (1979) describes an index of accessibility for measuring the timeliness and appropriateness of response to patient's request to enter the system.

3. **Accessibility:** According to Penchansky and Thomas (1981) accessibility is the relationship between the location of supply and the location of clients, taking account of client transportation resources and travel time, distance and cost. This, in turn, is equivalent to geographical accessibility which in Donabedian's (1976) word deals with location of service and its impact on consumer's travel time, distance, cost and effort. In his (Donabedian 1976) opinion geographical accessibility refers to the 'friction of space', which is a function of time and distance that the client must cover to get care. Hence this accessibility is something beyond the mere existence or availability of services or any resources that has been discussed earlier.

4. **Affordability:** The term **affordability** stands for the relationship of prices of services and providers' insurance or deposit requirements to the clients' income, ability to pay, and existing health insurance. Client perception of worth relative to total cost is a concern here, as is clients' knowledge of prices, total cost and possible credit arrangements. Bice et al. (1972) also found affordability as a major influencing factor to increase access. Falkingham (2004) and Jutting (2001) argued availability and spatial accessibility as two important determinants of affordability as individual might not be able to afford to travel long distance to avail a service. In this way, changes in income of those in need may improve affordability and hence increase the demand for the service. Similarly, cost or shadow price of using a service that is not just the price at point of delivery but the additional cost associated with travelling to and from provider, waiting for services and any additional costs associated with the use of services like paying
bribes to someone to get the required services or paying cost for taking along another accompany while travelling a long distance, come under affordability. Moreover, from a supply side angle, Goddar and Smith (2001) include quality and information as important factor deciding the cost of services. In similar line of thought Le Grand (1991) also introduces the concept of shadow price as an affordability element.

But affordability along with service availability and accessibility is not enough to ensure access. For example, Birch and Anderson (2005) note that prevailing rates of public payments for dental care in Canada are often too low to attract many dentist to offer care under these specialization. Where the providers are prevented from making some extra money or charging additional amount, services remain inaccessible despite availability and affordability.

5. Acceptability: The last dimension is acceptability that represents the relationship of clients' attitudes towards personal and practice related characteristics of providers to the actual characteristics of existing providers, as well as to provider's attitudes about personal characteristics of clients (Mechanic 1972, Penchansky and Thomas 1981). In the literature, the term appears to be used most often to refer to specific consumer reaction to such provider attributes as age, sex, ethnicity, type of facility, neighborhood of facility, or religious affiliation of facility or provider. In turn, providers have attitudes about the preferred attributes of clients or their financing mechanisms. Providers either may be unwilling to serve certain types of clients (e.g., welfare patients) or, through accommodation, make themselves more or less available. So it is the beliefs and perceptions that influence the acceptability (McIntyre et al. 2009).
Or it is better to say although these are the different dimensions of access it is the interaction of these dimensions that finally decide access.

Above all there are some issues like information and power relations which are core to each of the access dimensions which facilitate a good fit between the health system and individuals, household and communities (McIntyre et al. 2007).

A quotation from Donabedian (1973) aptly summarizes many of the concerns expressed here with respect to the conceptualization and measurement of access:

"The proof of access is use of service, not simply the presence of a facility. Access can, accordingly, be measured by the level of use in relation to need. One should recognize, however, that clients and professionals evaluate need differently. Further, one must distinguish two components in use of service: initiation and continuation. This is because different factors influence each, though any one factor may influence both. It is hardly necessary to emphasize that barriers to access are not only financial but also psychological, informational, social, organizational, spatial, temporal, and so on".

The most common definition of health care access that has earned the unanimous agreement among the researchers describes it as the timely use of services as per the need (Schneider & Symons 1971, Aday and Andersen 1974, Campbell et al. 2000, Peters et al. 2008). There are multiple factors that influence such ‘timely use’. In other words, it acts as hindrance and interface with people’s access to healthcare (Goddard & Smith 2001, Waters 2000, Percy-Smith 1996, Olson and Rodgers 1991, Mooney 1987, Penchansky and Williams 1981, Aday and Andersen 1974, Donabedian 1973, Bradshaw
Many of these factors are actually imbedded into the definition or dimension of access those have been discussed so far.

Considering the definitions and the barriers to access, the term ‘access’ is commonly used in two ways (Gulliford et al. 2002):

• **Having access** denotes the theoretical potential to utilize a service if required. To have access to a service means that the service required exists, is available, and that there are systems in place that would allow service utilization.

• **Gaining access** alludes to the actual procedure of admission into the processes of utilizing the service. Here, if access has been gained it means that the service has been utilized.

Given the definition of access and the barriers to access, it is imperative to say that while the supply side factors are important to *have* access, demand side factors are crucial to *gain* access, given the person has access.

### 1.3. What is Public Health?

According to C.E. A. Winslow (1920) public health can be defined as the science and the art of preventing disease, prolonging life, and promoting physical and mental health and efficiency through organized community efforts for the sanitation of the environment, the control of community infections, and education of the individual in principles of personal hygiene, the organization of medical and nursing service for the early diagnosis and preventive treatment of disease, and the development of the social machinery which will ensure to every individual in the community a standard of living adequate for the maintenance of health.
Hence Public health services are conceptually distinct from medical services. They have a key goal of reducing a population’s exposure to disease — for example through assuring food safety and other health regulations; vector control; monitoring waste disposal and water systems; and health education to improve personal health behaviors and build citizen demand for better public health outcomes. Public health services produce public goods which is non excludable and is with huge social benefit. Poor public health conditions directly result in repeated episodes of illness and hence a continuous spending on it. They also reduce labor productivity that discourages investments and hence hampers the economic growth and poverty reduction. It has been well proved that prevention is better than cure and it is also cost effective. Hence given the equity and externality issue associated with public health, it is often argued that it should be provided by public sector. For example due to high externality attached with the vector borne disease control if its provisioning is left with the private sector one may end up with a very high inequitable pro rich service delivery. A study suggests that in the US, the life expectancy at birth increased from 45 years to 75 years in one hundred years starting from 1890. However, only 5 out of these 30 incremental years in life expectancy came from medical care, while the rest came from improvement in nutritional content, housing conditions, sanitation and occupational safety, most of which come under the aegis of public health (Bunker et al., 1994).

Given these facts, public health services are needed to be publicly funded. Today, most governments recognize the importance of public health programs in reducing the incidence of disease, disability, and the effects of aging. However, there is fundamental difference in the concept of public health in between developing countries and the
developed world. While in the developed world public health became a basic standard of life, in the former group its importance is yet to be realized wholeheartedly and there is still a live debate on the boundaries and modalities of public health programs (Das Gupta, 2005). In both these groups, however, it is accepted that the preventive health care should mainly be provided under the aegis of the government, rather than leaving it to the market.

However, considering the investment and importance given to public health is far smaller than that to medical care. In 1992, while the average cost of medical care for an American citizen was $3007, that of the public health was only $34! (US Public Health Service 1994).

Almost all countries, except a few like Cuba, has been retelling the same story times and again. The primary reason for this general neglect of the public health facilities are:

- Most of these services are invisible to the public and their need is recognised only when the system fails.

- It is easier to calculate the immediate cost of organising the public health system, but it is extremely difficult to measure the benefits accruing from it in the long run. Thus people and the state are often unwilling to pay short term costs in order to obtain a benefit in long term.

- Public health offers a pure public good, creating lots of externality benefits to the society as a whole. Controversy arises because those who pay for public health are not those who benefit from it primarily. The existence of a sharp difference
between private benefits and social benefits in these services creates economic barriers to have private investment here and almost unequivocally it is supposed to be a responsibility of the government. However, within the government as well, we find a gross neglect of public health because often those who need the services most do not share their voice in public policies. Therefore, the willingness to pay for public health by the elite politicians, bureaucrats and donors has been minimum.

Given this scenario, it becomes extremely important for a developing country like India to focus on its public health programmes, given the dominance of the communicable and controllable diseases by vaccine in her epidemiological status till date. India has already identified some of these issues and a number of programmes are targeted for this purpose, though the funds allocated are really small compared to other medical care services.

The present dissertation would like to take off from this background only.

In recent past, public health programs like vaccinations have contributed significantly in promoting health, including the eradication of deadly disease like smallpox, drastically reduced cases of Polio, Malaria and Leprosy. Successive governments in India have come up with many schemes for the provision of safe water, sanitation, nutrition, vaccination coverage, education and employment. With its focus on health promotion and disease prevention, public health provides a foundation for our health care system that ultimately means lower health care costs.
However, in spite of its contribution in disease prevention public health has been called the "invisible profession" (Sagar 2006). It has been increasingly concerned with targeted prevention programs aimed at specific problems that disproportionately affect minority and economically disadvantaged groups and are epidemiologically less important. An examination of morbidity and mortality from communicable diseases reveals that the budgetary allocation is not following any epidemiological logic (Sagar 2006). It also appears that, except from certain specific diseases, the success of overall public health programme is yet to come. The diminishing return needs to be compensated by substantial big push in public health initiatives for which understanding and addressing the barriers to access the public health services is important. The barriers both from demand and supply side – need to be identified and extent of inequality needs to be analyzed to assess the impact of the barriers in an inequitable scenario.

1.4. Immunization Programme and Barriers to Access Immunization

Mother and child health is the most focused public health area where progress is significant. Especially in immunization, clear leaps of advancement have been observed, where over the last two rounds (2002-04 and 2007-08) of District Level Household Survey (DLHS) the proportion of children fully immunized increased from 45.8 percent to 53.5 percent. On the other hand, there is not much progress in institutional birth delivery (as per the latest DLHS data less than 50 percent of the births in India take place in health facilities). Even in child immunization significant disparity remains across states or regions, gender, and socio-economic status.

The disparity manifests in retarded progress of public health outcomes in the backward states and among disadvantaged section of the population with a probable
consequence of stagnant or diminishing return to the overall public health initiatives. Hence, for a nation which largely depends on reactive measure to control diseases, promoting awareness of prevention and hence public health is an important component of health sector reform.

The introduction of childhood vaccination in the history of the public health brought sea changes through the pathway of unprecedented lower prevalence of vaccine preventable diseases in childhood and resultant child survival, particularly since 1970s (WHO, 2007). Considering its importance, Government of India (GOI) also adopted the Expanded Programme on Immunization (EPI) in 1978, with the objective of providing free vaccination services to all children in a phased manner, throughout their infancy and also during childhood. Later on EPI was reframed as the Universal Immunization Programme (UIP), to reduce mortality and morbidity from six vaccine preventable diseases namely, Tuberculosis, Diphtheria, Pertussis, childhood Tetanus, Poliomyelitis, and Measles.

However, in spite of such proven success, childhood immunization programme is yet to achieve its full potential. World Health Organization (WHO) estimates that every year nearly two million children die from vaccine preventable diseases (WHO, 2002). Along the expected lines, the burden of vaccine preventable child deaths is disproportionately higher for the developing countries. UNICEF (2005) reports that the highest absolute numbers of un-immunized children are found in seven countries, namely, India, Nigeria, China, Pakistan, Ethiopia, Indonesia and Democratic Republic of Congo, with each possesses more than a million un-immunized children. Such large
number of unimmunized children worldwide indeed poses a barrier for making the earth as the “safe haven” (Yezbeck, 2009).

The straightforward answer to the question that why so many children are still out of the safety net of childhood immunization service, is likely to be embedded in some perceived or actual barriers to access such service. To identify those barriers is the primal task of this dissertation. In this dissertation access is defined as timely use of services according to the need (Peters et al. 2008) and barrier to access is “anything that restrains or obstructs progress, access, etc” (Kanjilal et al. 2008). Hence understanding and addressing these barriers are essential steps to achieve the goal of universal immunization in the countries that fall short. Following Peters et al. (2008) four dimensions of access has been considered covering both demand and supply element -geographical accessibility, availability, affordability and acceptability.

Fortunately a number of researches have attempted to locate the barriers to access childhood immunization in India and in other developing countries. The crucial barriers that have emerged from such researches could be broadly grouped into two categories; supply side barriers to have access and demand side barriers to gain access.

Demand side barriers to access immunization services are related to the issue of acceptability and affordability which in turn talks about consumers’ willingness and capability. Acceptability of childhood immunization has been seen to have its roots in the individual characteristics attached to the norms or culture, caste, religion, exposure to education and socio-economic status (Perry et al. 2007, Patra 2006, Bawah et al 2006, Enson and Cooper 2004, Koenig et al. 2001, Steele et al. 1996, Tangerose et al 1984, Wan and Gary 1978). Studies have identified an important role of gender disparity
particularly in South Asian countries to pose barriers against immunization uptake of
female children (Gwatkin and Deveshwar-Bhal, 2001).

A strong demand side predictor that facilitates uptake of childhood immunization
services has been mother's exposure to education (Bawah et al. 2006, Koeing et al. 2001,
Srivastava and Saksena 1988). Studies have shown that acceptability of vaccination
increases with proper exposure to community education and also gets influenced by the
synergy between various public health services (Kravdal 2004). For example, a study on
childhood mortality and health in India has showed that apart from maternal factors like
her age, parity and birth intervals, medical attendance at birth affect the child mortality
(Sharma 2007). Srivastava and Saksena (1988) in their study in rural Uttar Pradesh found
that provisioning of health care advice to mothers during her ANC (anti-natal care)
accelerate the immunization uptake. They find that while the impact of father education is
visible only at higher level of his education, for mother just being literate has a greater
impact on child immunization uptake. Similar findings regarding prenatal care and
immunization uptake has been shared by Choi et al. (2006) on India. According to them
once the mother had participated in prenatal health care programme, she develops a
familiarity with the health care system. Thus child's full immunization becomes more
likely event when the mother receives the prenatal care with mother's education in the
control variables. They (Choi et al. 2006) also highlighted that how the sex composition
and birth order of the siblings influence the immunization uptake.

Apart from parents' background characteristics, there are other cultural factors
that hinder the immunization uptake. A study in slums area of Dhaka Bangladesh (Perry
et al. 2007) has shown that traditional belief about the origins of vaccine preventable
diseases and faiths on traditional healers for curing the same restrict them from vaccinating the child. The study also showed how perceived barriers act as hindrance. For example, the parents believed that the young children are too 'delicate' to give an injection. Lack of previous experience with the immunization site and lack of trust and confidence on technical quality of the vaccinator also act as barrier.

Supply side barriers relate to a very significant aspect involving service availability. Such barriers in the delivery system encompass a large number of aspects linked to equipments, human resources and their management. Improper vaccine storage practice, poor cold chain management, inadequate/non-availability of refrigerating facility given interrupted power supply, irregular functioning of immunization center are few to name. Along with it, non-availability or absenteeism of efficient health workers, their incomplete knowledge about vaccination is also important constraint in efficient service delivery (Perry et al. 2007, Nyarko et al. 2001, Gupta 1993).

Barriers to access immunization service not only pose difficulties for rural part of India, growing evidence suggests similar situation in urban India too. For example, a study in Mumbai, one of the leading metropolises in India, has pointed out inconvenient location and timing as the two main reasons for not availing the urban public health services, which is identical with the problem that is faced in rural areas (Dilip and Duggal, 2004). However, problems in rural India have many other dimensions. Such encompasses the distance to the health facilities from the villages, poor road connectivity with seasonal deterioration, infrequent household visits by the health workers and lack of proper outreach campaigns (Srivastava and Saksena 1988, Nair et al. 2004, Choi 2006), Purohit and Siddiqui (1994) also stated that it is the distance to the health facility that acts
as a barrier to access health care. Acharya and Cleland (2000) added that when the health centers are regularly supervised by higher authority that makes the outreach activities more vibrant.

Apart from the above mentioned factors, the role of the health workers in influencing vaccine coverage in developing countries has been investigated by Anand and Bamighansen (2007). They found significant impact of health workers density on vaccine coverage. Though health worker needs to spend little time for vaccinating a child, health workers are needed to be available over time and place because one needs subsequent visits to the health workers for complete immunization. Most importantly what they found is the interrelation between health workers availability and mother’s education. According to their study, though one time visit to provider for vaccination could be motivated, subsequent visit at predetermined time and place need advanced planning for which female education might be helpful. Dutta et al. (2013) showed that health workers pay regular visits and better quality of services to the relatively more educated and economically better-off mothers as the latter themselves are more aware of their rights. Another study (Chakraborty et al. 2003) in rural Bangladesh has shown that mother’s education has significant impact on maternal health care. In another paper Gupta (1993) added that inadequate transport facilities also restrict the mobility of the health worker. His paper also added the problem of inadequate knowledge among the health worker about the process of vaccine storage. He also added that once the beneficiaries are illiterate it is difficult to make them understand the importance of immunization. Along with that lack of proper training of the field health worker, their low motivation and poor co-ordination between the top level planners and implementers
are some of the other supply side issues that affect the immunization coverage. However, another study on health infrastructure and immunization coverage has shown that presences of community health workers are not associated with increase immunization coverage (Datar et al. 2007).

The importance of outreach campaigns both in terms of increased coverage and effective following up to reduce drop out cases has been documented in case of Kenya (Yazbeck, 2009). The paper also concluded that such campaigning not only improved the vaccine coverage but also do the same among the poorest quintile. Additionally, studies have shown that access to public health services can be facilitated by making innovations in delivery of services (Rahman 2008). Howard and Roy (2004) stated that though the Indians have shown a greater willingness to pay out of pocket for private care, for preventive health services public sector remains their primary choice.

In spite of such a wide range of literatures on demand and supply side barriers to access childhood vaccination, there are not many studies focusing on both these aspects in India and also in other developing countries. However, it is essential to get an overview of the bottlenecks in both the aspects, since the relation between demand and supply can be perceived to be considerably strong to influence the outcome.

Against this backdrop this dissertation attempts to explore the role of various demand side and supply side factor those act as a barrier to immunization coverage. In the present dissertation the immunization coverage has been used as a proxy of access to the service, which is an ex-post access as it represents the actual utilization instead of ex-ante access. This idea was first endorsed by the WHO member states in 2005, where universal coverage was defined as access for all to appropriate promotive, preventive,
curative and rehabilitative services at an affordable cost (Carrin et al. 2008). In fact the single most crucial indicator of the success of immunization programme in any economy is the overall coverage of all essential vaccines and/or individual vaccines separately among the general population. While innumerable studies attempted to evaluate performance of immunization programme in developing countries by its full coverage (BCG, three doses of Polio, three doses of DPT and Measles) or their drop outs (Gage et al. 1997, Nyarko et al. 2001, Steele et al. 1996, Sharma 2007, Kumar and Mohanty 2009), there is a growing awareness about the limitations of evaluating the immunization performance solely by its coverage irrespective of the overall quality of that performance (Datar et al. 2007). The maintenance of time schedule has been considered as crucial proxy indicator of quality of coverage of immunization (Akmatov et al. 2012, Datar et. al 2007, Luman et al. 2005). Therefore, in addition to overall coverage of vaccination (which is termed as non-month-specific henceforth), the coverage of immunization given at right time (which is termed as month-specific henceforth) is to be considered with utmost importance.

However, till date there is hardly any literature that estimates month-specific coverage in developing countries. Only few studies are available for some developed countries. Additionally, there is few studies identifying socioeconomic barriers behind receiving timely immunization doses; the available ones are, however, on settings of developed counties (Dombkowski et al.2004, Luman et al. 2002). So the present dissertation also explores the quality of child immunization and its barriers in West Bengal in terms of month-specific vaccine coverage to bridge the gap in literature.
As stated earlier, in a developing country setting, public facilities remain the majority choice for preventive health care. That is also true for services like child immunization. As par DLHS 3 in West Bengal more than 80 percent cases public health center remain the first choice for immunization. Sub centers are the lowest tier government facilities catering to 3000-5000 population at the rural set up (IPHs, MoH&FW, GoI, 2006). Thus they play extremely crucial role in provision of immunization and hence the overall childcare in this state. Their efficiency can expand not only the coverage of full vaccination as per the WHO guidelines, but also improve the quality of immunization process and the child health care on the whole. One can think of improving the performance of sub center in two possible ways: either by increasing the level of resources and infrastructure in sub centers in particular or in aggregate health sector in the gamut or by improving the efficiency of the health centers from the existing resources being utilized.

However, in a country like India where resources are scarce, it is very difficult to increase them substantially in the short run. So it is very important to utilize the existing resources in efficient manner. Also the scarcities of resources make it more crucial to increase the efficiency such that those resources are optimally utilized to deliver the best possible services to the public. Hence, it is necessary to evaluate the performance of the sub centers and to find out the slacks or under utilization of the so called scarce resources being used in these sub centers (SC).

However, so far the measurement of relative technical efficiency has been limited to hospital level only and that too in western countries (Helmig et al. 2011, Pablo and Garcia-Prado 2007, Masiey 2007, Arocena et al. 2007, Nguyen and Thang 2004) and
there are few studies on universities as well (Afonso and Santos 2008). In India, the measurement of relative technical efficiency is limited to industrial sector (Bhandari and Ray 2011) and there are very few studies in health sector which is again limited up to the hospital level (Bhat 2001, Dutta et al. 2011). This dissertation is going to attempt to measure the technical efficiency of the sub centers in West Bengal especially in terms of child immunization service delivery. I discuss the role of SC and auxiliary nurse and midwives in immunization coverage in much detail in the following chapters. I also add an explanation for my choice of West Bengal as a study area in those chapters.

I sum up the research objectives of the dissertation are mentioned below.

1.5. Research Objectives

1. To give a detailed situational analysis of public health in India in general and in West Bengal in particular.

2. To identify the barriers to access child immunization from demand and supply side (Full Immunization, Polio and Non-Polio Immunization).

3. To explore the quality of child immunization in terms of timeliness of immunization and barriers to access it both from demand and supply side.

4. To evaluate the efficiency of health sub centers to provide public health related outputs in general and immunization in specific.

1.6. Methodology

For the first research objective I use descriptive statistics of various public health indicators and economic indicators across major Indian states.
Both, second and third research objective has been addressed by using logistic regression analysis. The detailed methodology of the same has been discussed below.

1.6.1.a. Logistic regression

Logistic regression model is a discrete regression model. When the dependent variable assumes discrete values we called it a discrete regression model (Maddala 1983). The simplest of these models is that in which the dependent variable y is binary, that means can assume only two values. In more complicated cases dependent variable can assume more than two values. Such cases are classified into i) categorical variables and ii) non categorical variables.

For example,

\[ y=1 \text{ if the child is fully vaccinated} \]
\[ y=2 \text{ if the child is partially vaccinated} \]
\[ y=3 \text{ if the child is not vaccinated} \]

An example of non-categorical variable is when y denotes number of patents issued to a company during a year, where y assumes values of 0,1,2,3……., but y is not a categorical variable. However, it is a discrete variable.

Categorical variables can be further classified as a) unordered, b) ordered and c) sequential variables (Maddala, 1983). Some examples are

a) unordered:

\[ y=1 \text{ if mode of transport is car} \]
\[ y=2 \text{ if mode of transport is bus} \]
\[ y=3 \text{ if mode of transport is taxi} \]
b) ordered:

- $y=1$ if mother is earning less than Rs. 3000
- $y=2$ if mother is earning more than equal to Rs. 3000 but less than Rs. 5000
- $y=3$ if mother is earning more than equal to Rs. 5000 but less than Rs. 7000

c) sequential:

- $y=1$ if the mother has not completed primary school
- $y=2$ if the mother completed the primary school but not high school
- $y=3$ if the mother completed high school but not the college

The methods of analysis are different for models with categorical and non-categorical variables. With the dichotomous dependent variable, the assumptions of homo-skedasticity, linearity and normality get violated making ordinary least square estimates misfit.

Linear probability model is used to denote a regression model with binary dependent variable. Usage of such model is very common in social science and medical sciences where the outcome variable is binary in nature. More importantly one is likely to have categorical variable when one is measuring an attribute. For example in the present case I am considering the child immunization coverage as my dependent variable. A child either can be fully immunized or be partially or be not immunized at all.

In the usual regression framework the model with a binary variable as its dependent variable is written as

$$y_i = \beta' x_i + u_i$$

with $E(u_i)=0$ and $E(y_i|x_i)=\beta' x_i$
This has to be interpreted as the probability that the event will occur given the $x_i$. The calculated value of $y$ from the equation $y_i^* = \beta^* x_i$ will then give the estimated probability that the event will occur given the particular value of $x$. In practice these estimated probabilities can lie outside the admissible range $(0,1)$. As $y_i$ takes the value of 1 or 0, the residuals in equation 1 can take only two values $(1 - \beta' x_i)$ and $(\beta' x_i)$. Also given our interpretation of equation 1 and the requirement that $E(u_i) = 0$, the respective probabilities are $\beta' x_i$ and $(1 - \beta' x_i)$.

Hence $\text{var}(u_i) = E(y_i)(1 - E(y_i))$. Given this hetero-skedasticity problem OLS estimates of $\beta$ will not be efficient. This problem has been solved by using logistic regression.

Logistic (or, more commonly, logit) regression is used when the response variable is binary (0 or 1). The predictor variables may be quantitative, qualitative, or both. Logistic regression applies maximum likelihood estimation (MLE) after transforming the response into a logit variable (the natural logarithm of the odds of the dependent occurring or not).

Hence, logistic regression estimates the probability ($P$) of occurrence of an event. Unlike OLS regression, logistic regression does not assume linearity of relationship between the dependent and independent variables, does not require normally distributed variables, does not assume homo-skedasticity, and in general has less stringent requirements.

The multivariate binary logistic model is specified as:

$$P = F(z) = \frac{1}{1+e^{-z}}$$

where

$$z = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k.$$
Here ‘e’ represents the base of natural logarithms, which is approximately equal to 2.718 and P is the estimated probability of vaccination given X_i’s. It is noteworthy that z is not the response variable but a linear function of a set of predictor variables. If \( \beta \) is negative, the curve goes from 1 to 0 instead of 0 to 1 as X increases.

Hence from equation 2
\[
P/(1-P) = e^z = \Omega = \text{odds}
\]

logit P = log P/(1-P) = z = log \( \Omega = \log \text{odds} \)........................3

Hence log \( \Omega = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k \) ..........................4

Thus log \( \Omega \) is calculated first and then log \( \Omega = e^{\log \Omega} \) and then \( P = \Omega/(1+\Omega) \)

P is presented in percentage form that is by multiplying P by 100.

In the present research work I used multinomial logistic model. This model is used when the dependent variable has more than two categories. The ratio of the probability of choosing one outcome category over the probability of choosing the baseline category is often referred to as relative risk and it is also sometimes referred to as odds ratio.

1.6.1.b. Multinomial Logistic Model

Suppose there are m categories and let assume \( P_1, P_2, \ldots, P_m \) be the probabilities associated with those categories. Then the idea is to express these probabilities in binary form.

Let, \( P_i/(P_1+P_m) = F(\beta_i'x) \)

\( P_2/(P_2+P_m) = F(\beta_2'x) \)

\( P_{m-1}/(P_{m-1}+P_m) = F(\beta_m'x) \)..........................5

This implies

\( P_i/P_m = F(\beta_i'x)/1 - F(\beta_j'x) = G(\beta_j'x) \) (j=1,2,\ldots,m-1)..................6
Because
\[ \frac{\sum_{j=1}^{m-1} P_{ij}}{P_m} = \frac{(1-P_m)}{P_m} = \left(\frac{1}{P_m}\right) - 1 \]

We have
\[ P_m = \left[1 + \sum_{j=1}^{m-1} G(P_j|x)\right]^{-1} \]

And hence from 3.7
\[ P_j = G(P_j|x) / \left[1 + \sum G(P_j|x)\right] \]

In the above equation, \( G(P_j|x) \) is nothing but exp \( (P_j|x) \) and thus equation 7 and 8 can be written as
\[ P_j = e^{(P_j|x)/D} \quad (j=1,2,\ldots, m-1) \]

And \( P_m = 1/D \), where
\[ D = 1 + \sum_{k=1}^{m-1} e^{P_j|x} \]

This model is commonly referred to as the multinomial logistic model. For multinomial logistic model we cannot calculate an \( R^2 \), and it is better to define goodness-of-fit measure based on the likelihood-ratio test statistics (Maddala, 1983).

In the fourth objective I used Data Envelopment Analysis (DEA) to measure the efficiencies of health sub centers. The objective of the analysis is to measure the relative efficiency of sub centers to improve cater the basic primary health care facilities. Data Envelopment Analysis (DEA) is a Mathematical Programming technique. DEA is a non-
parametric approach of measuring efficiency of a decision making unit (DMU) as there is no need to assume any specific functional form for production. DEA was first introduced by Charnes, Coopers and Rhodes (1978) in Operation Research where the constant returns to scale assumption was held on the technology. Latter in 1984 Bankers, Charners and Cooper introduced the variable returns to scale (VRS) assumption for technology (Ray 2004). DEA can be input oriented or output oriented. In the present analysis I assume VRS and adopted output oriented method of DEA. It looks at the efficiency of different sub centers, which may be considered as Decision Making Units (DMU) in producing health outcomes by utilizing multiple health care resources (in terms of physical and human infrastructure) as inputs. So, it is an attempt to measure the 'relative efficiency' of health care systems to improve health outcomes. Efficiency score of the health production process is estimated taking into account the data of input and output. Here I add that while looking at the efficiency of the SC, I need not concentrate only on the inputs and outputs in connection to immunization exclusively; rather I focus on the aggregate efficiency of the SC in providing health care to the general mass in reproductive and child health and immunization.

1.6.2. Measurement of Efficiency

Before going into details about the mathematical Linear Programming approach of DEA, it is necessary to discuss about few other related definitions. The efficiency of a firm generally consists of two components: technical efficiency (TE) and allocative efficiency (AE). The technical efficiency shows the ability of a firm to obtain maximum output from a given set of inputs and technology. On the other hand allocative efficiency reflects the ability of a firm to use the inputs in optimal proportions, given their
respective prices. These two measures are combined to give a measure of total economic efficiency. The present study is concerned with the measurement of technical efficiency. Measurement of technical efficiencies can be of two types. Output and input oriented technical efficiency. Input **oriented technical efficiency measure** deals with the maximum amount of input quantities, which can be proportionately reduced without changing quantities produced as output. **Output oriented technical efficiency** deals with the maximum output quantities that can be proportionately increased without altering input quantities. Distinction between the input and output oriented technical efficiency can be illustrated with the help of the Figure 1.1.

**Figure 1.1: Input and output Measure of Technical Efficiency**

In figure 1.1 input $x$ is measured along horizontal axis and output $y$ along the vertical axis. Point A $(x_0, y_0)$ represents the actual input-output bundle of a firm A. Now
\( y^* = f(x_0) \) where \( y^* \) is the maximum output producible from input \( x_0 \). The output-oriented measure of technical efficiency of firm A = \( \frac{y_0}{y^*} \) which is the comparison of actual output with the maximum producible quantity from the observed input. Now for the same output bundle \( y_0 \), the input quantity can be reduced proportionately till the frontier is reached. So, \( y_0 \) can be produced from input \( x^* \). Thus the input-oriented technical efficiency measure for firm A = \( \frac{x^*}{x_0} \).

Obviously measurement of technical efficiency depends on the assumption on returns to scale.

1.6.2. a. Constant and Variable Returns to Scale

Two different assumptions can be made, i.e. constant return to scale (CRS) and variable returns to scale (VRS). The CRS describes the fact that output will change by the same proportion as inputs are changed (e.g. a doubling of all inputs will double output). On the other hand, VRS reflects the fact that production technology may exhibit increasing, constant and decreasing returns to scale. If there are economies of scale then doubling all inputs should lead to more than a doubling of output.

Following the methodology developed by Fare et al. (1994), the best achievable configuration of population health (outcomes) for a particular health producing system (or DMU) is constructed, given its input resources on health care and the performance of health systems. Thus, a ‘best-practice’ frontier is constructed, which is a piece-wise linear envelopment of the health input and health output (outcome) data for the DMUs under
consideration. This frontier creates a standard for comparison as it describes the most efficient performance conditions within the group of units under judgment. For each unit, efficiency in the production of primary health care is measured relative to such a frontier. The health care systems of the units, which are operating on the frontier, are termed efficient, while units operating off the frontier are considered to be relatively inefficient. An unit operating below the frontier is considered as technically inefficient because its output falls short of what could have been produced given the input usage.

Figure 1.2 illustrates the basic ideas behind DEA and return to scale. Four data points (A, B, C, and D) are used here to describe the efficient frontier and the level of capacity utilization under VRS and CRS assumptions. In a simple one output and one input DEA problem, A, C and D are found to be efficient, while B is an inefficient DMU. So unit B can produce more output at point B' on the frontier (which is equal to theoretical maximum) utilizing same level of input at X_i. With constant returns to scale, the frontier is defined by point C for all points along the frontier, with all other points falling below the frontier (hence indicating capacity underutilization). With variable returns to scale, the frontier is defined by points A, C and D, and only B lies below the frontier i.e. shows capacity underutilization (Dutta et al. 2011). So capacity output corresponding to VRS is smaller than the capacity output corresponding to CRS. Following the analytical methodology presented by Afonso and Aubyn (2007) for their pioneering study on the health production process of OECD countries, the methodology used in the present study is described below.
The present chapter employs output oriented measure of technical efficiency and has tried to solve a linear programming problem which assumes variable return to scale. Here, DEA assumes the existence of a convex production frontier and the word *envelopment* emanating from the fact that the production frontier envelops the set of observations.

1.6.2.b. Output Oriented TE

It is supposed that there are $N$ firms. Each of them are producing $g$ outputs using $h$ inputs. The input bundle used by firm $t$ is $x^t = (x_{t1}, x_{t2}, ..., x_{tn})$ and the output bundle produced is $y^t = (y_{t1}, y_{t2}, ..., y_{tn})$. In order to compute the average productivity of the firm, together with input and output, price data is also needed. If no price data is available, 'shadow' prices of inputs & outputs are needed in this situation. Let $a^t = (a_{t1}, a_{t2}, ..., a_{tn})$ be defined as the shadow price vector of inputs and outputs.
as the shadow price vector of outputs. Two restrictions are imposed on the shadow prices. First, the shadow prices must be non-negative, however individual input and output prices can be zero. Secondly, the shadow prices have to be such that when they are used for aggregation, no firm’s input-output bundle results in average productivity greater than unity.

Technology can either follow constant returns to scale (CRS) or variable returns to scale (VRS).

Under CRS, if \((x, y)\) is feasible then for any \(\alpha \geq 0\), \((\alpha x, \alpha y)\) is also feasible. The production possibility set corresponding to CRS can be defined as

\[
T^{\text{CRS}} = \left\{(x, y) : x \geq \sum_{j=1}^{N} \lambda_j x^j; y \leq \sum_{j=1}^{N} \lambda_j y^j; \lambda_j \geq 0; (j = 1, 2, \ldots, N)\right\}
\]

Similarly, the specific production possibility set under VRS is given by

\[
T^{\text{VRS}} = \left\{(x, y) : x \geq \sum_{j=1}^{N} \lambda_j x^j; y \leq \sum_{j=1}^{N} \lambda_j y^j; \sum_{j=1}^{N} \lambda_j = 1; \lambda_j \geq 0; (j = 1, 2, \ldots, N)\right\}
\]

The output oriented measure of TE of any firm \(t\) under VRS technology requires the solution of the following LP problem

\[
\text{max} \phi
\]

Subject to \(\sum_{j=1}^{N} \lambda_j y^j \geq \phi r_n; \quad (r = 1, 2, \ldots, g)\);
\[ \sum_{j=1}^{N} \lambda_j x_{ij} \leq x_i; \quad (i = 1, 2, \ldots, h); \]

\[ \sum_{j=1}^{N} \lambda_j = 1, \quad \lambda_j \geq 0; \quad (j = 1, 2, \ldots, N) \]

Knowing \( \phi^* \), the maximum value of \( \phi \), by solving equation (3), output oriented TE of firm \( t \) can be determined by using equation (4).

\[ \text{TE}^o = \frac{1}{\phi^*} \]

Where \( y^* = \phi^* y \) and \( y^* \) is the maximum output bundle producible from input bundle \( x' \).

Under CRS, \( \max \phi, \phi^* \), can be determined by solving equation (3) along without the constraint \( \sum_{j=1}^{N} \lambda_j = 1 \), taking into account the CRS frontier (equation 1). Knowing \( \phi^* \), technical efficiency of the firm can be determined.

In problem (1), \( \phi \) is a scalar satisfying \( \phi_i \leq 1 \), which is the efficiency score that measures technical efficiency of the \( i \)-th unit in terms of the distance to the efficiency frontier. With \( \phi_i < 1 \), the output of the decision making unit (DMU) is inside the frontier and inefficient. But, \( \phi_i = 1 \) implies that the output of the ‘DMU’ is on the frontier and efficient. The vector \( \lambda \) is a \((n \times j)\) vector of constants, which measures the weights used to calculate the location of an inefficient DMU, if it is to be converted as efficient. The inefficient DMU is projected on the production possibility frontier as a linear combination of its peers utilizing those weights. The ‘peers’ are other DMUs that are more efficient and therefore used for the comparison and \( n \) is a \( n \)-dimensional vector of
ones. The restriction \( \sum_{j=1}^{N} \lambda_j = 1 \) implies the convexity of the frontier, with variable returns to scale. If this restriction is dropped then, returns to scale is constant. The problem has to be solved for each of the \( n \) DMUs in order to obtain \( n \) efficiency scores.

There are potential advantages and disadvantages of measuring efficiency using non-parametric methods. The strengths of DEA are: (i) it can handle multiple input and multiple output models, (ii) it doesn't require an assumption of a functional form relating inputs to outputs, (iii) DMUs are directly compared against a peer or combination of peers, (iv) inputs and outputs can have very different units. There are also some limitations of using DEA. The limitations of DEA are: (i) since DEA is an extreme point technique, measurement error can cause significant problems, (ii) DEA is good at estimating relative efficiency of a DMU, but it converges very slowly to absolute efficiency. Thus, it can tell how well a state is performing compared to its peers but not compared to a theoretical maximum, (iii) as DEA is a nonparametric technique, statistical hypothesis tests are difficult, (iv) a standard formulation of DEA creates a separate linear program for each DMU, it may creates large computational problem.

1.6.2.c. Identifying the local measures of returns to scale

The test whether the data supports CRS or VRS technology for each of the firm is based on the dual approach of Banker, Charnes and Cooper (BCC) (1984). In turn with BCC (1984), the input-oriented efficiency measure corresponding to VRS technology for firm \( t \) can be specified as
min $\theta$

Subject to

\[ \sum_{j=1}^{N} \lambda_j x_{rj} \geq y_{r}, \quad (r=1,2,\ldots,g) \]

\[ \sum_{j=1}^{N} \lambda_j x_{ij} \leq \alpha_k, \quad (i=1,2,\ldots,h) \]

\[ \sum_{j=1}^{N} \lambda_j = 1; \quad \lambda_j \geq 0 \quad (j=1,2,\ldots,N) \]

The corresponding dual LP problem is given by

\[ \max \sum_{r=1}^{g} a_r y_{r} - a_o \]

Subject to

\[ \sum_{r=1}^{g} a_r y_{rj} - \sum_{i=1}^{h} b_{ij} x_{ij} - a_o \leq 0, \quad (j=1,2,\ldots,N) \]

\[ \sum_{j=1}^{b} b_j x_{ij} = 1 \]

\[ a_r, b_i \geq 0; \quad (r=1,2,\ldots,g; i=1,2,\ldots,h) \]

\[ a_o \quad \textit{free} \quad \ldots.6 \]

BCC (1984) have shown that

a) locally CRS holds if $a_o^* = 0$

b) locally DRS holds if $a_o^* > 0$

c) locally IRS holds if $a_o^* < 0$
Since the multiple solution are possible a conclusive findings requires that (a), (b) or (c) must hold at all possible optimal solutions.

1.6.2.d. Output and input slacks

In linear programming models radial measures of efficiency is obtained. Here efficiencies are measured along a ray from the origin to the observed production point. In such a radial projection of an observed input-output bundle onto the frontier, sometimes the output is not optimally expanded and also all the inputs used are not potentially reduced. The horizontal or vertical portion of an isoquant or product transformation curve accounts for inefficiency in usage of inputs or output production.

Among the output produced by firm t, the largest output bundle with the same output mix as \( \left( y'_1, y'_2 \right) \) that can be produced from the input bundle \( \left( x'_1, x'_2 \right) \) is \( \left( \phi y'_1, \phi y'_2 \right) \). It is sometimes possible to expand individual outputs by a factor larger than \( \phi^* \). It is also possible that firm t may not entirely use up all the individual components of the input bundle to produce the expanded output bundle.

So the output slack variables can be defined as

\[
s_r^+ = y_n - \phi y_n, \quad (r = 1, 2, \ldots, g)
\]

And the input slack variable can be defined as

\[
s_i^- = x_u - x_u^*, \quad (i = 1, 2, \ldots, h)
\]
The concept of output and input slack can be illustrated with the help of the following diagrams. Consider a two output example of an output oriented DEA which could be represented by a piecewise linear production possibility curve, as represented by a piecewise linear production possibility curve as depicted in Figure 1.3.

**Figure 1.3: Radial and Slack of Output**

![Diagram showing radial and slack of output](image)

*Source: Adopted from Dutta et al. (2011)*

Suppose the actual observation corresponds to point P. The point P is projected to the frontier P' which is on the frontier but not on the efficient frontier, because the production Y₁ could be increased by the amount AP' without using any more inputs. **Hence output slack is AP'**. So in this case radial movement in output is PP' and Slack movement is AP'. Therefore whenever any output slack is strictly positive, it is possible
To expand particular output by the amount of output slack even after the radial expansion have been taken into account.

To illustrate the concept of input slack, I consider Figure 1.4 where the DMU’s using input combinations C and D are the two efficient DMU’s which define the frontier and DMU’s A and B are inefficient. The Farell (1957) measure of technical efficiency gives the efficiency of DMU’s A and OA/OA and OB/OB, respectively. However, it is questionable as to whether the point A’ is an efficient point as one could reduce input $X_2$ used by the amount $CA'$ and still produce the same output. Hence $CA'$ represents the slack in input $X_2$.

Figure 1.4: Input Slack

Source: Adopted from Dutta et al. (2011)
1.6.2.e. The Group and Meta-Frontiers

Before one proceeds to construct the production frontier using the DEA in order to measure the technical efficiency of a firm, it is necessary to recognize that all of the observed firms may not have access to the same technology. Rather, different firms or categories of firms may face different production technologies. A variety of geographical, institutional, or other factors may give rise to such a situation. Constructing a single production frontier based on all the data points would, in such cases, result in an inappropriate benchmark technology. A way to measure the impact of technological heterogeneity across groups is to construct a separate group frontier for each individual group alongside a single grand or meta-frontier that applies to firms from all the groups.

In order to construct different production possibility sets for different groups, we first group the observed input-output bundles by the locations of the corresponding firms. Suppose N firms are observed and these firms are classified, according to some criterion, into H number of distinct and exhaustive groups, g
th group containing N
 g number of firms

\[ N = \sum_{g=1}^{H} N_g \]

Define the index set of observations \( J = \{1, 2, \ldots, N\} \) and partition it into non-overlapping subsets

\( J_g = \{j : \text{firm } j \text{ belongs to group } g; (g = 1, 2, \ldots, H)\}. \)

In this case, the production possibility set for group g will be

\[ T^g = \left\{ (x, y) : x \geq \sum_{j \in J_g} \lambda_{jg} x^j; y \leq \sum_{j \in J_g} \lambda_{jg} y^j; \sum_{j \in J_g} \lambda_{jg} = 1; \lambda_{jg} \geq 0 \right\} \quad (g = 1, 2, \ldots, H) \]
The set $T^g$ is the free disposal convex hull of the observed input-output bundles of firms from group $g$. Suppose, that the observed input-output bundle of firm $k$ in group $g$ is $(x^k_g, y^k_g)$. A measure of the within-group (output-oriented) technical efficiency of the firm $k$, is

$$TE^g_k = \frac{1}{\varphi^g_k}$$

where $\varphi^g_k$ solves the following linear programming (LP) problem:

$$(P^g_k) \quad \varphi^g_k = \max \varphi$$

s.t. $\sum_{j \in J_i} \lambda_{ij} y^j_s \geq \varphi y^k_s$;

$$\sum_{j \in J_i} \lambda_{ij} y^j_s \leq x^k_s; \sum_{j \in J_i} \lambda_{ij} = 1;$$

$$\lambda_{ij} \geq 0 (j = 1,2,...........,N_s); \varphi \text{ unrestricted}$$

The above LP problem is solved for each firm $k$ in the $g^{th}$ group.

Next we consider the technical efficiency of the same firm $k$ from group $g$ relative to a grand technological frontier, or what is called the meta frontier. The meta frontier is the outer envelope of all of the group frontiers. It consists of the boundary points of the free disposal convex hull of the input-output vector of all firms in the sample. The (grand) technical efficiency of the firm $k$ from group $g$ is measured as

$$TE^g_k = \frac{1}{\varphi^g_k}$$
Where \( \phi^k_G = \max \phi \)

\[
\begin{align*}
  &\text{s.t. } \sum_{i=1}^{H} \sum_{j \in I_k} \lambda^k_{ij} y^k_{ij} \geq \varphi y^k_z; \\
  &\sum_{i=1}^{H} \sum_{j \in I_k} \lambda^k_{ij} y^k_{ij} \leq x^k_z; \sum_{i=1}^{H} \sum_{j \in I_k} \lambda^k_{ij} = 1; \\
  &\lambda^k_{ij} \geq 0 (j = 1, 2, \ldots, N_g; g = 1, 2, \ldots, H); \varphi \text{ unrestricted}
\end{align*}
\]

In view of the fact that the grand production possibility set contains every group production possibility set, it is obvious that \( \phi^k_G \leq \phi^k_g \) and, hence, \( TE^k \geq TE^k_G \), for every k and g. In other words, firms cannot be more technically efficient when assessed against the meta-frontier than when evaluated against a group frontier.

### 1.6.2.f. Technology Closeness Ratio

When, for any firm k in group g, the group efficiency and the grand efficiency measures are close, we may argue that evaluated at the input bundle \( x^k_g \), the relevant group frontier is close to the meta-frontier. Instead of evaluating the proximity of the group frontier to the meta-frontier at individual points, it is useful to get an overall measure of proximity for the group as a whole. For this, we first define an average technical efficiency of the firms in the group (i.e., relative to the group frontier) by the taking a geometric average of such individual technical efficiencies. For the group g this will be given by

\[
\text{...}
\]
Similarly, the average technical efficiency of group \( g \), measured from the meta-frontier, will be

\[
TE_x(g) = \left( \frac{N_g}{\sum_{k=1}^{N_g} N_k} \right)^{1/N_g}
\]

For group \( g \), an overall measure of proximity of the group frontier to the meta-frontier is its technology closeness ratio

\[
TCR(g) = \frac{TE_0(g)}{TE_x(g)}
\]

TCR increases if the group frontier shifts towards the meta-frontier, ceteris paribus, and is bounded above by unity which would be realized if and only if group frontier coincides with the meta-frontier.

1.7. Chapterization plan

Given the detailed background, research objective and methodology in Chapter 1, Chapter 2 addresses the first research objective by doing a situational analysis of public health in India. This chapter extends from a brief historical account of evolution of public health in India to description of the status of present public health scenario in terms of important public health indicators across the major Indian states. This exercise helps to justify the necessity to focus on West Bengal among the other Indian states.

Chapter 3 addresses the next two research objectives together. Starting with a brief discussion on available literature on barriers to access immunization in Indian
context, the chapter then explores the demand and supply side barriers to access child immunization in West Bengal. Considering the ‘immunization coverage’ as the proxy variable for ex-post access the chapter finds out the significant factors which act as barrier to immunization. Then the same exercise has been used to find out the barriers to timely immunization.

The chapter 4 evaluates the relative technical efficiency of sub centers as it is the most commonly used service delivery point not only for child immunization but for other public health services as well. Chapter 5, following the technical difference across the districts of West Bengal, revisits the barriers to access immunization for two groups of districts. The last chapter concludes the dissertation with plausible policy directions.