THREE ESSAYS ON INTRA-HOUSEHOLD RESOURCE ALLOCATION, THE COST OF ILLNESS MEASURE, AND IMMUNIZATION POLICY

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ABSTRACT

Soyeon Guh: THREE ESSAYS ON INTRA-HOUSEHOLD RESOURCE ALLOCATION, THE COST OF ILLNESS MEASURE, AND IMMUNIZATION POLICY

(Under the direction of Richard N.L. Andrews)

The dissertation comprises three chapters, ranging from health economics to immunization policy analysis. In the first and second chapters I focus mainly on establishing theoretically correct measures of welfare benefit, while in the third chapter I aim to determine which kind of immunization program is best by using better measures of both benefits and costs associated with one episode of typhoid fever.

The objective of the first chapter is to separately derive a mother's versus a father's willingness to spend money and time to save her child from one day of sickness. In order to accomplish this goal, I extend the existing theories of household decision-making by integrating Chiappori (1988)'s household decision-making model and Grossman (1972)'s health production model. All illnesses have financial and time consequences. When a child is sick, the mother and the father may respond differently to the health shock. They may have different preferences toward risk and they may not fully pool their income. They may thus want to allocate different amounts of money and time for improving their children's health. I take account of these differences using an interdisciplinary approach. The novelty of my approach, thus, is in its departure from the unitary household framework on which health valuation studies have relied until now. Finally, I find that maternal/paternal willingness to pay for the child's health is determined by six factors: the income share, the non-labor income, the price of medical care, an individual time value (i.e., wage), and the household's and individual technology for producing the child's health.

In the second chapter, I compare measures estimating the benefits of reduced morbidity in order to answer several questions: what would be the theoretically correct benefit measure for reduced morbidity? How much would the true measure differ from others? What are the determinants of the differences between the true measure and others? In

order to answer these basic questions, I begin with Bockstael and McConnell (2007)'s model, which derives welfare measures for non-marginal changes of morbidity, and then incorporate insurance into it, based on the proposition that insurance may have a significant effect on the magnitude of the discrepancies between the cost-of-illness (COI) and willingness-to-pay measures. Next, I incorporate uncertainty into the model, since an individual does not know what her health will be with certainty (Berger et al., 1987). In doing so, I derive *ex ante* COI and *ex ante* compensating variation measures. Theoretically they are unlikely to be the same. Based on the findings of this study, the COI estimates are not reliable and do not give clear guidance as to the lower bound on the theoretically true estimates in measuring the benefits of reduced morbidity. Therefore, the value of COI estimates in decision-making may be limited.

The third chapter examines school-based immunization against typhoid fever in North Jakarta in order to assess the merits of such a program. Decisions about optimal vaccination programs involve tensions between efficiency and equity (Levy et al., 2007), especially in the developing world. Most vaccination policy analysis, however, mainly takes efficiency into account in order to find the lowest-cost program or the one providing maximum net benefits. Equality in the distribution of benefits is often overlooked (Yitzhaki, 2003) because of lack of data or interest. The absence of a systematic framework to consider both efficiency and equity results in a one-sided immunization policy that disregards or, at worst, enlarges the gap of inequality in children's immunization rate. In order to address this limitation, I incorporate efficiency measures and equity indicators within one framework. I believe that using quantitative indicators of inequality based on parents' level of education will help avoid immunization options that are dominated by efficiency at the expense of equity. The results of the analysis suggest that to strike a fair balance between efficiency and equity, policy makers would be best advised to adopt a school-based typhoid fever immunization program, partially funded by donors (and with plans for sustaining it in the future), in which the typhoid vaccine was simultaneously delivered with the TT booster vaccines. Even this solution, however, leaves unsolved the equity problem of immunizations for children not in school and the question of how such programs would be sustained after the end of the donor funding period (typically five years).

DEDICATIONS

I dedicate this dissertation to my daughter, Aram.

She has been the reason why I have kept on going during tough situations.

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Chapter I

DOES A MOTHER'S WILLINGNESS TO PAY FOR CHILDREN'S HEALTH

DIFFER FROM A FATHER'S?

1.   Introduction

All illnesses have financial and time consequences. When a child is sick, the mother and the father may respond differently to the health shock. They may have different preferences toward risk and they may not fully pool their income. They may thus want to allocate different amounts of money and time for improving their children's health. I take account of these differences by combining the health production model with the collective household model, one of the non-unitary household decision-making models. The unitary household model has been most commonly used to estimate parents' willingness to pay for their children's health, but it is limited in its ability to address the differences between the mother and the father because of its restrictive assumptions. First, it assumes the household is a single unit with homogenous preferences. Second, it assumes that all of the household members pool their resources and maximize a single utility subject to the household's pooled budgetary constraint. In order to counter these restrictive assumptions, non-unitary models take each family member as the unit of analysis and treat household decisions as the outcomes of interactions among family members. They are flexible enough to account for potentially different resource allocations for children's health between a mother and a father.

Non-unitary models, however, are still theoretically and empirically under development, which makes it hard, for example, to include household production of a family public good[1] within their frameworks. First, there are increasing theoretical complexities in deriving both individual preferences and a bargaining-power mechanism with regard to the household production of public goods, here children's health. And second, there is a lack of such data as money *and* time costs associated with children's illness, as well as sufficiently

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[1] "Family public goods" are defined as goods consumed together by all family members and do not necessarily exclude such public goods as education, health, security, housing, and cultural services.

rich socioeconomic data essential to reveal a bargaining power mechanism for empirical analysis.

More recently, however, non-unitary studies have made some promising theoretical progress in extending the framework to include family public goods, and this development may shed some light on the nexus between non-unitary household decision-making models and children's health valuation studies. In particular, Blundell, Chiappori, and Meghir (2005) theoretically extend the collective household model to include family public goods-children's wellbeing- and to identify from observed behavior how much the mother and the father is separately willing to pay for their children's health. While I rely substantially on Blundell, Chiappori and Meghir (2005), I depart from them insofar as I apply their framework to the health production model and I separately derive a mother's willingness to pay to save her child from one day of sickness from a father's.

The novelty of my approach, then, is in its departure from the unitary household framework on which health valuation studies have relied until now. The theoretical implications of intra-household resource allocations for maternal versus paternal willingness to pay have never been explored. This essay introduces three theoretical innovations. First, it expands the health production model within the collective household. Second, it includes a shadow value of health production time in health valuation under an assumption that the resources of the parent are constrained by both money and time. Third, it consistently incorporates two constraints, money and time, in the health-production model as well as in the intra-household bargaining model. As a result of these innovations, I am able to derive maternal willingness to pay for improving children's health separately from paternal willingness to pay.

In section 2 below I review the literature on household decision-making models, both unitary and non-unitary, as well as the empirical findings from children's health valuation studies based on non-unitary models. In section 3, I explain the theoretical framework for separately deriving maternal and paternal willingness to pay for children's health.

2.	*Literature Review*
2.1.	*Unitary Model*

Children's health valuation studies have typically adopted a unitary approach. Assume there are two decision makers in a household. A couple cares about their own consumption of private goods and their own health, as well as the wellbeing of their child. The health of their child is considered a "family public good," which is valued by the mother and the father, denoted *m* and *f*, respectively. The individual utility of either the mother or father is represented by

$$U_i = U_i(X_i, H_i, v_k(X_k, H_k)) \qquad\qquad i = m \text{ or } f \qquad (1\text{-}1)$$

where X_i denotes consumption of private goods consumed by *i*; H_i denotes healthy time of *i*; and v_k denotes a sub-utility of their child, composed of his/her own consumption and healthy time of child *k*.

The household welfare is a function of the individual sub-utilities:

$$U_h = U_h(U_f(X_f, H_f, v_k(X_k, H_k)), U_m(X_m, H_m, v_k(X_k, H_k))) \qquad (1\text{-}2)$$

The unitary model assumes that family members have the same preferences. They pool their incomes and maximize the household welfare function (U_h), subject to the household budget constraint. Under these assumptions the sub-utility function of *i* (U_i) is identical between the mother and the father. Thus in the unitary model either the household is treated as a single unit or there is one family member, a benevolent dictator, who makes all decisions regarding resource allocation. If the unitary model is correct, then children's health outcomes depend not on parents' individual share of resources, but simply on pooled household income (Xu, 2005).

Before discussing the limits of the unitary model, I will summarize the findings from several unitary studies with regard to children's health valuation. First, Salkever (1982) examines the impact of children's health on household medical expenditures for the child, and in particular, the time mothers and fathers spend caring for the sick child. He finds that the production of child health is more time-intensive for mothers than for fathers and that children's chronic health problems have a more pronounced negative effect on both the labor

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supply and earnings of mothers than of fathers. Pitt and Rosenzweig (1990) examine gender differences in the intra-family allocation of caring time when an infant is sick in Indonesia and find significant inequalities in household care activities by sex. Consistently, Salkever (1990), Ettner (1995), Wolfe and Hill (1995), and Powers (2001) find that mothers with a disabled child in the household are less likely to enter the labor market.

Second, Dickie and Salois (2003) compare mothers' willingness to pay (WTP) for avoiding one symptom day for their nine-year-old child to fathers' willingness to pay in U.S.A. Though the measures are not from the same couples, they find that married fathers' willingness to pay for their child's health is approximately 1.6 times greater than married mothers' ($WTP(H_f) = 1.6 \times WTP(H_m)$). However, the marginal rate of substitution of a mother's illness for her child's illness is approximately 1.3 times larger than the MRS of a father's illness for his child's illness $\left(\dfrac{WTP(H_k)}{WTP(H_m)} = 1.3 \times \dfrac{WTP(H_k)}{WTP(H_f)} \right)$. In other words, though a mother's WTP is lower than a father's, probably because of her limited ability to pay, she is more willing to substitute her child's illness with her own than a father is.

Third, Dickie and Salois (2003) report an interesting link between behaviors and perceptions with regard to caring responsibility for sick children by gender in a household. They assume that the spouse with the lower wage will spend more time caring for the child because that would be financially more efficient. However, they find that wives assume the primary responsibility for staying with a sick child and taking the child to the doctor regardless of employment or wage. In marriages where both spouses are employed, the allocation of time caring for the child depends not on wages but on gender. This result suggests that gender disparities in time spent caring for sick children are determined not by concern for efficiency so much as by the contemporary social norm regarding gender roles.

Despite the simple theoretical framework and some successful empirical applications of the unitary approach, the key assumptions of the model— income pooling and homogenous preferences—have proven to be mistaken when tested. The income-pooling assumption is consistently rejected in studies that can be categorized by types of resources in a household:

(1) *Non-labor incomes*: one group of studies has tested the hypothesis that *non-labor incomes* of husbands and wives are pooled and has rejected it. Thomas (1994) shows that children with more powerful mothers—that is, mothers who have more *non-labor income*—are more likely to have less morbidity in Brazil. Schultz (1990) finds that for wives in Thailand an increase in non-labor income reduces fertility.

(2) *Labor incomes*: Qian (2005) in China finds that the more the mother's *income* increases as a result of post-Mao reform, the higher children's survival rates are.

(3) *Premarital assets*: another group of studies uses *premarital assets* to test the resource pooling assumption. Thomas et al. (2002) show that assets, brought to a marriage by the husband, have a different effect on children's health from assets brought by the wife in Indonesia. Quisumbing and Maluccio (2003) also find that the impact of assets on the health outcome of children in Bangladesh, Indonesia, Ethiopia, and South Africa differs by gender. In summary, who controls resources in a family matters for children's health

Second, while the unitary model assumes that family members have homogenous preferences, many studies find that there are different preferences between spouses regarding health risks. Mothers tend to be more concerned about risk than fathers (Flynn, Slovic, and Mertz, 1994; Davidson and Freudenburg, 1996; Byrnes et al., 1999; Finucane et al., 2000). Since risk attitudes affect the form of an individual's utility function, gender differences in risk attitudes could lead to different responses to questions about WTP to reduce risk to children's health (Bostrom, et al., 2006).

Willingness to pay using the revealed preference method

Most of the revealed-preference studies estimating willingness to pay for an additional healthy day for a child (Dickie, 2005; Freeman, 2003) can be summarized as follows: (1) the health production function is a function of medical care use, but not the caring time spent by parents ($H_k = f(M_k, \bullet)$); (2) caring time is determined by the time a child is sick ($T^H = f(H_k)$); and (3) at the optimal provision, the household WTP for an additional healthy day for the child is equal to the marginal cost of producing health, weighted by household technology in producing health. Only the marginal cost of medical care use is considered.

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The WTP estimates derived according to the unitary household model assumption have four potential limits: (1) they may not be accurate measures since unitary household assumptions have been rejected by many non-unitary studies; (2) model specifications under the unitary household model are different from those under non-unitary models and potentially wrong if non-unitary models are assumed to be correct; (3) they neglect the active bargaining mechanism in a household; and (4) time input in producing children's health is totally disregarded. Among children's health production studies, only two (Pitt and Rosenzweig, 1990; and Salkever, 1982) consider that time is a scarce and valuable resource and include caring time in the health production function as one of the inputs. However, neither study goes further and estimates willingness to pay.

Recently, there have been improvements in children's health production studies in that researchers have begun to include shadow values of time in WTP estimates, relying on theoretical progress in home production and shadow wage estimation by Mincer (1962), Becker (1965), DeSerpa (1971), Gronau (1973a, b, 1980), Jacoby (1993). Propper (1990) used stated preference techniques to estimate the value of reducing patients' waiting times in a health care facility. Dalenberg, Fitzgerald, Schuck, and Wicks (2004) have used the same approach to obtain WTP estimates for leisure time. Eom and Larson (2006) assess the value of home production time based on willingness to spend time and money in order to obtain environmental improvements. They develop a new approach to show that WTP can be defined with respect to either time or money when the choices people make are constrained by time as well as money. They prove their joint estimation is consistent with the utility structure.

2.2.   *Non-unitary models*

Non-unitary household models commonly argue that it is not realistic to aggregate individual preferences into one household unit on the assumption that they are homogenous or altruistic (Chiappori, 1997). Non-unitary frameworks relax the restrictions that the traditional unitary model imposes and consider an individual as a unit of study. Non-unitary studies have taken three different directions based on different assumptions of efficient outcomes and bargaining processes (Xu, 2005): (1) the collective household model; (2) the Nash bargaining model; and recently (3) the non-cooperative bargaining model.

A key distinction among these household models lies in how a couple makes resource-allocation decisions. The unitary household model assumes one spouse to have dictatorial power over the allocations, whereas the two bargaining models (i.e., the Nash cooperative and the non-cooperative models) assume that decisions are made through the bargaining process. The collective model assumes that a couple builds fair decision rules for each other and that the final decisions of consumption on goods and times are Pareto efficient. By contrast, the two bargaining models do not assume efficient outcomes within a household. However, in the Nash model a couple finally achieves efficient outcomes through the bargaining process, whereas the non-cooperative model does not necessarily lead to efficient outcomes (Xu, 2005). The assumption of Pareto efficiency can easily be tested empirically for the collective model, but not for the two bargaining models.

Table 1.1 Characteristics of non-unitary models[2]

Model	Bargaining	Efficient Outcomes	Testable hypotheses
Collective Model	No	Assumed	Yes
Nash Bargaining Model	Yes	Yes	No
Non-cooperative bargaining model	Yes	Not necessarily	No

2.2.1. The collective model

Chiappori (1988, 1992) takes the lead in developing an intra-household decision-making model in which family members reach Pareto efficient allocations. A household maximizes the weighted individual utility below:

$$U_h = \pi U_m(X_m, H_m, v_k(X_k, H_k)) + (1-\pi)U_f(X_f, H_f, v_k(X_k, H_k)) , \qquad \text{(1-3)}$$

where π is the power coefficient or Pareto weight. Chiappori's equation explains how a household allocates the resources within a couple. Greater π means more weight on the mother's utility than the father's utility. Suppose accepted rules of fairness result in weights

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[2] Modified from Xu (2005).

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based on relative wages (w_m, w_f), non-labor income, and distribution factors. There is no reason to think $\pi = 1/2$ is more "fair" (Bergström, 2003). The person who earns more may have more decision-making power in a household. Or if females are scarcer in a remarriage market, a wife's bargaining position within a household could increase.

The core problem of the collective model is how to reveal both individual preferences and the Pareto weight from observing labor supplies and the household expenditures. In this model, the household decision regarding resource allocation is made by a two-stage procedure. In the first stage, all family members pool their income and allocate total household income to savings, expenditures on family public goods, and expenditures on private goods for each family member according to the sharing rule (Chaippori, Fortin, and Lacroix, 2002). The income-sharing rule is equivalent to the weights. The more powerful an individual, the bigger the person's share of the pie in the first stage (Thomas et al., 2002). In the second stage family members maximize their own utility given their income share.

To estimate the mother's WTP for children's health separately from the father's, the collective model needs to include home production since parents produce children's health together at home and children's health is a *family* public good. Earlier studies incorporating the collective model with home production (Apps and Rees, 1996, 1997; Chiappori, 1997) investigate whether the presence of home production changes the results obtained in the collective household model and whether it is possible to derive a sharing rule when the collective model includes home production. They conclude that the sharing-rule parameters can be recovered with certain restrictions. Apps and Rees (1997)'s restrictions are (1) household production is linear and homogenous and (2) demands for leisure are independent of the price of the domestic good. Chiappori (1997)'s restriction is (1) a good produced in a household is assumed to be tradable in the market and (2) the production function exhibits constant returns to scale.

Although children's health-valuation studies have been interested in intra-family resource allocation, the difficulties in identifying the model and in recovering the sharing rule have hindered the integration of the collective approach with health-valuation studies. However, recent theoretical (Blundell, Chiappori, and Meghir, 2005) and empirical progress (Fortin and Lacroix, 1997; Aronsson, Daunfeldt and Wikstrom, 2001; Chiappori, Fortin and Lacroix, 2002) has been made within the collective framework. In particular, Blundell,

Chiappori, and Meghir (2005) extend the collective model to include a family public good, which is necessary for separately estimating a mother's and a father's valuation of children's health in a household. First, they introduce the collective indirect utility function and derive marginal WTP of the mother and the father, separately, for children's good by using Samuelson's Pareto optimality condition. They show that if individual consumption of time and money are separable from expenditure on children, then individual preferences on family public goods, as well as Pareto weights, are identifiable. However, while they say it is possible to expand their model to measure time consumption for children, they focus only on the expenditure on children's good. Their study also is purely theoretical.

2.2.2. *The Nash cooperative and the non-cooperative bargaining models*

Manser and Brown (1980) and McElroy and Horney (1981) establish the Nash bargaining approach. The Nash model bargaining in a marriage is similar to that between a firm and a union in a labor market. People choose to get married (employed) and stay in a marriage (a job) as long as their utility in a marriage (their wage rate in a job) is greater than the utility of staying single (the possible wage in another job), which is called the fall-back utility (T_i); otherwise they dissolve their marriage (Xu, 2005). In the bargaining process, just as the possibility of an alternative job plays the role of the threat point to the firm when a firm and a worker do not agree on wage rates, so the high fall-back utility of one partner being single is the "threat point" to the other partner. A household chooses allocations of resources to maximize the Nash maximand (N)

$$N = [U_m(X_m, H_m, v_k(\bullet)) - T_m(w_m, y_m; \alpha_m)][U_f(X_f, H_f, v_k(\bullet)) - T_f(w_f, y_f); \alpha_f)], \quad (1\text{-}4)$$

where T_i is the threat points of i. T_i is a function of wage rates (w_i) and non-labor income (y_i), as well as the extra-household environmental parameters (α_i, EEPs), for example, the male/female ratio in a remarriage market.

However, bargaining within a marriage also is different from bargaining in a labor market. Unlike a firm and a union in a labor market, a couple in a marriage bargains every day, and during their day-to-day marital bargaining they do not usually consider a divorce.

The divorce threat point of the Nash cooperative model therefore may be unrealistic in a marital bargaining situation.

At this point the non-cooperative bargaining model (Rubinstein, 1982; Ulph, 1988; Woolley, 1988; Lundberg and Pollak, 1993; Konrad and Lommerud, 1995, 2000; and Chen and Woolley, 2001) departs from the Nash cooperative model. There are broadly two structures of non-cooperative household models according to an assumption of threat points: an empty (Equation (1-5) below) and a non-empty bargaining set (Equation (1-6) below).

Rubinstein (1982) specifies the generalized Nash product without a threat point in a repeated game of two agents across time periods, i.e., the empty bargaining set, below:

$$N = U_m(X_m, H_m, v_k(\bullet))^{\beta} U_f(X_f, H_f, v_k(\bullet))^{1-\beta}, \tag{1-5}$$

where β is the weight for each agent. In a repeated game, α is determined by each agent's time preference, a function of property rights, institutional practices (e.g. child-support awards or enforcement), or cultural norms that affect individual bargaining power (Xu, 2005).

On the other hand, Binmore, Rubinstein and Wolinsky (1986), Lundberg and Pollak (1993), and Chen and Woolley (2001) propose a non-cooperative model with a threat point (T_m, T_f), i.e., non-empty bargaining set. The definitions of their threat points are various, but they have a common characteristic in the sense that fall-back utilities are interpreted as "utilities during conflict" rather than utilities of divorce (Xu, 2005), as shown below:

$$N = [U_m(X_m, H_m, v_k(\bullet)) - T_m(w_m, y_m; \beta_m)][U_f(X_f, H_f, v_k(\bullet)) - T_f(w_f, y_f; \beta_f)] \tag{1-6}$$

where β_i is the extra-household environmental parameters.

In determining how families allocate resources when children are sick, the assumption of threat points in the non-cooperative bargaining model is more appropriate than in the Nash model, since there is little evidence of divorce occurring because of children's illness.

Although non-unitary models are still under theoretic development, several empirical analyses of these models provide several insights for children's health valuation. First, the mother's WTP for improving children's health may not be the same as the father's for two possible reasons: (1) mothers' marginal rate of substitution between her child's health and her own health is larger than fathers' (Dickie and Salois, 2003); and (2) WTP for a child per the share of non-labor income (WTP_i / Φ_i) differs between the mother and the father (Blundell, Chiappori and Meghir, 2005).

Second, it is feasible to extend the non-unitary model to include household production, but extensive data covering both household expenditures and individual time use is required. Blundell, Chiappori, and Meghir (2005) impose restrictions for identifying the collective model with a family public good, specifying that data on individual labor supply, aggregate household consumption, expenditure on the family public good, and relative wages, as well as time use data of inputs for household production are required. Most studies within the collective framework, however, rely either on data on expenditure or on time-use data but not on both. Those that focus on the intra-family allocation of expenditures rather than time use ususaly show the impact of different levels of power by gender on such outcomes as children's health (Thomas, 1994; Thomas et al., 2002), children's nutrition intake (Breunig and Dasgupta, 2000; Duflo, 2000; Jacoby, 2002), or children's education (Quisumbing and Maluccio, 2003; Xu, 2005; Park, 2006). Other studies focus on the intra-family allocation of time, such as time spent with child (Bourguignon, 1999; Chiuri, 1999) and individual labor-supply decisions (Chiappori, 1988, 1997; Bourguignon and Chiappori, 1992; Aronsson, Daunfeldt, and Wikstrom, 2001; Chiappori, Fortin, and Lacroix, 2002; Blundell, Chiappori, Magnac, and Meghir, 2005). Only one published study (Browning and Görtz, 2006) covers both time use and expenditures within a household using the collective household model.

Third, gender inequalities in terms of who spends time caring for sick children may result not from a concern for efficiency in household decisions of resource allocation, but from social norms. Becker (1981) interprets the customary gender-based division of labor as an efficient response to differences in father and mother endowments. Within the unitary approach, any unequal allocation of resources can be justified on efficiency grounds (Xu, 2005). Norms, however, are almost always more efficient for some groups than for others

(Ullmann, 1977). Several recent studies within non-unitary frameworks shift focus from efficiency to gender ideology (Brines, 1994; Pitt and Khandker, 1994; Kabeer, 1995; Greenstein, 2000; Iyigun, 2002; Bittman et al., 2003; Lundberg and Pollak, 2003; Lundberg 2005) or to developing a dynamic model to explain an endogenous relation between household decision and power which is identified by "gender-specific environmental parameters" (GEPs, introduced by Folbre, 1997: Iyigun, 2002, 2005; Peters and Siow, 2002; Basu, 2004).

2.2.3. Bargaining Power

Proxies for bargaining power have included (1) labor income (Apps and Rees, 1996, 1997; Chiappori, 1997; Chiappori, Fortin and Lacroix, 2002); (2) non-labor income (Schultz, 1990; Thomas, 1990); (3) assets at marriage (Quisumbing, 1994; Guyer, 1997; Thomas, Contreras, and Frankenberg, 1997; Frankenberg and Thomas, 1998; Quisumbing and Maluccio, 2000); (4) remarriage market parameters, such as sex ratio or divorce law (Adam, Hoddinott, and Ligon, 2003; Carlin, 1991; Chiappori, Fortin, and Lacroix, 2002; Folbre, 1997); or (5) welfare benefits (Duflo, 2000; Lundberg, Pollak, and Wales, 1997; Lundberg, 2002; Rubalcava and Thomas, 2000; Ward-Batts, 2003; Zimmermann, 2006).

Economic power

As Lundberg, Pollack, and Wales (1997) have shown, non-unitary models assume that the determinants of the power function are exogenous. However, the most common proxy, labor income, is clearly problematic because it is confounded with time allocation and labor-force participation decisions. Non-labor income may not be independent of time preferences and labor market conditions if much of it comes from unemployment benefits or savings over the life cycle. Current assets may also depend on preferences within a marriage, i.e., asset accumulation decisions. Also, since assets acquired within a marriage may be joint properties, they cannot be clearly assigned to either the husband or the wife. Property rights to assets brought to a marriage are also ambiguous. They may be endogenous to the marriage market (Foster, 1996), but they may be exogenous to decisions made within the marriage.[3]

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[3] See Lundberg, Pollack, and Wales (1997) for further details on the endogenous nature of the various economic proxies.

Extra-household environmental parameters

Characteristics of the environment or the institution are also proxies for bargaining power. For example, Chiappori, Fortin, and Lacroix (2002) include *divorce law* in bargaining power parameters: mutual consent vs. unilateral divorce law, property division, enforcement of support orders, and whether to treat professional degrees or licenses as divisible property at divorce. Lundberg, Pollak, and Wales (1997) look at the effects of *child welfare policy* on bargaining power. They find that after the British government transferred the child benefit from fathers to mothers in two-parent families in the late 1970s, household expenditures on children's clothing increased. Similarly, after rigorously controlling for changes in relative prices of the goods examined, Ward-Batts (2003) finds that expenditures on children (i.e., for toys and pocket money) increased, while expenditures on men's tobacco declined, after the child benefit policy change in the U.K. took effect.

2.3.   *Empirical applications of the non-unitary model to children's health valuation*

The few health valuation studies that adopt a non-unitary framework can be divided into three categories: (1) models that apply the bargaining framework to the health production model; (2) models that extend the collective household model to include the health production function; and (3) empirical studies that compare individual WTP with household WTP.

The Nash cooperative or the non-cooperative bargaining model with health production

By combining the Nash cooperative model with the health production framework, Bolin, Jacobson, and Lindgren (2001) develop a basic dynamic model of the demand for "lifetime health" in which the spouses bargain for the allocation of the family's total resources. They show theoretically how Nash threat points shift Pareto optimality and WTP. By contrast, Strand (2003, 2004) uses the non-cooperative model with the empty bargaining set to compare household members' WTP for a (*pure*) public good on behalf of the household with WTP for the same good on behalf of oneself. Strand (2003) argues that WTP on behalf of the household is on average a correct representation of the sum of individual willingness to pay estimates (i.e., $WTP_f + WTP_m$) if one member does not have a higher or

lower marginal public-good value than another member. In another paper, Strand (2004) specifically focuses on both the individual and the household value of mortality reduction. However, his analysis requires the restrictive assumption that marginal utilities obtained in consuming family public good are equal across family members. Based on that assumption, Strand calculates the marginal rates of substitution between the family public good and private goods (equations (6) and (7) in Strand, 2003) and finds that this ratio is the same as the ratio between household WTP and individual WTP (equation (10) in Strand, 2003). By contrast, several other non-unitary household studies adopt Samuelson (1954)'s condition in order to derive individual WTP for family public good within a couple (Bergstrom, 1996, 2002; Chiuri and Simmons, 1997; and Donni, 2004). Samuelson's condition avoids the condition imposed by Strand, which is more restrictive.

Mount et al. (2001) also develop a model of the value of reduced fatality risk for adults and children in a family using a Nash cooperative bargaining model. They show that the value of a statistical life (VSL) in a Nash model is the same as the VSL in a unitary model. As Dickie and Salois (2003) point out, however, their result hinges on the assumption that the threat points are independent of risk and exogenous factors in the model. Recently, Zimmerman (2006) finds that marriage market factors, especially state divorce laws, significantly contribute to the decision for a child's mental health treatment, as well as the degree of conflict within the marriage. With regard to mental health care, children do best when mothers have relatively more decision-making power, a finding that is consistent with the existing literature based on non-unitary models.

The collective model with health production

Smith and van Houtven (1998) further extend the collective model to consider measurement of Hicksian consumer surplus. They show how two measures of compensating variation can be derived from the model, depending on whether the spouses' shares of income are held constant. Blundell, Chiappori, and Meghir (2005) introduce a family public good (i.e., children) within the collective model and identify how much each parent is willing to pay for their children. They argue that it is not clear that the mother's WTP for children is greater than the father's, but they find that if her WTP is more sensitive to child goods then the demand for expenditure on children in the household increases when her power increases.

Using survey data on family health and nutrition in Brazil, Thomas (1994) empirically tests that households pool their income and maximize household welfare. He finds that who controls the resources within a household matters. The effect of non-labor income in the hands of a mother on child survival probabilities is almost twenty times greater than the effect of non-labor income under the control of a father. Thomas et al. (2002) examine whether in Indonesia parents' assets brought to the marriage have a different effect on a child's health depending on the gender of the child. They find different preferences between mothers and fathers in Java and Sumartra: mothers who are more powerful allocate resources disproportionately towards their sons and so sons have fewer episodes of cough and fever than daughters.

In sum, Smith and van Houtven (1998), Thomas (1994), and Thomas et al. (2002) do not specifically consider the mother's WTP for children's health or safety separately from the father's. Blundell, Chiappori, and Meghir (2005) identify maternal versus paternal WTP, but they focus primarily on expenditures on children, not the mother's and the father's time inputs for children. However, they open up the possibility of extending their theoretical model to include time inputs in household production as well as monetary inputs.

The contingent-valuation method

Direct, stated-preference methods can avoid many of the empirical problems of revealed-preference methods in separately eliciting a mother's WTP for children from a fathers (Bateman and Munro, 2006; Bostrom et al., 2006; and Cockerill et al., 2006), although stated-preference methods are subject to hypothetical bias. Several contingent-valuation studies have elicited separate mothers' and fathers' WTP for child safety in the same household. However, empirical results often are contradictory. Several studies find no significant difference between the mother and the father in the same household in WTP for reduced child injuries (Cockerill, Chilton, and Hutchinson, 2006) or for improved environment in a local harbor (Dupont, 2001). On the other hand, Bateman and Munro (2006) argue that the identity of the respondent does matter for calculating WTP and cast doubt on the assumption that household WTP is the same for all family members. Lampietti et al (1999) test the income-pooling hypothesis of the unitary model in Ethiopia and argue that the nature of the good matters in intra-household resource allocation. They cannot reject

the hypothesis that husbands and wives pool resources to purchase bed nets (a non-exclusive good), but reject the income pooling hypothesis for the hypothetical malaria vaccine (an exclusive private good). It is thus unclear at present whether respondents are providing their own preferences or their appraisal of the outcome of the household decision process (Bostrom et al., 2006), or whether maternal WTP is different from paternal WTP.

The travel-cost method

While not related to health-valuation studies, Dosman and Adamowicz (2006)'s study applying the travel-cost method within non-unitary frameworks provides some insight on time value. Dosman and Adamowicz (2006) combine stated and revealed preference data to examine the impact of family members' relative power on household vacation decisions and find that relative income is a significant determinant and the unitary model is not valid. In addition, they find the value of time is important in decision-making, as well as ideological beliefs and education. Interestingly, the partner with the lower value of time has more influence in the vacation decision because she invests more time in gathering information regarding vacation, which runs counter to the common assumption that the individual with the higher value of time would have more power in family decision-making.

3.   The cooperative health production model

The purpose of this study is to explain how the mother and the father separately allocate resources for their sick child within the collective household model. To do so, I extend the existing literature on household decision making by integrating Chiappori (1988)'s household decision-making model and Grossman (1972)'s health-production model. To my knowledge, this is the first attempt to apply the non-unitary, collective model of household decision making to intra-household health production. My analysis includes refinements to the Grossman health-production model, but not the household decision model. Unless otherwise specified, the model specifications described below are mine.

For my model, which I call the cooperative health-production model, I take one episode of illness as the unit for study. As a result of this assumption, the resource allocations within a family influence the number of sick days, not the stock of health (Dickie, 2005). I assume there are two decision-makers in a conventional household. The mother and the

father each care about her/his own consumption of private goods X_i and her/his own health H_i. For the sake of simplicity I assume the mother and the father are egoistic or self-interested in their relationship. Both the mother and the father also care about the wellbeing of their child v_k. The health of their child H_k is considered a "family public good" that is valued by the mother and the father. However, the utility the child derives from H_k enters the parent's utility function, not H_k itself. Thus, they are purely altruistic for their child. To simplify the analysis, I have assumed that the parents are egoistic in regard to both the utility and consumption of each other.[4]

To simplify the analysis further, I also assume that the mother and the father have a single child. The single-child model avoids the complication of modeling competition for resources among multiple children. Mothers and fathers have their own utility based on their preference, as follows:

$$U_i = U_i(X_i, H_i, v_k(X_k, H_k)) \qquad\qquad i = m \text{ or } f \qquad (1\text{-}7)$$

Since they are married, they also have a household welfare function. A household welfare function U_h is assumed to be a linear increasing function of individual utilities:

$$Max\ U_h = \pi_m U_m\left(X_m, H_m, v_k\left(X_k, H_k\right); \tau_m\right) + \pi_f U_f\left(X_f, H_f, v_k\left(X_k, H_k\right); \tau_f\right) \qquad (1\text{-}8)$$

where τ_i is a vector of preference factors, such as age and education of either the mother or the father and π_i[5] is Pareto weight of i. In Chiappori (1988) π is a relative measure of decision-making power between a mother and a father and the sum of Pareto weights is necessarily unity. π_i departs from Chiappori (1988) in that it avoids having to assume cardinal utility.

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[4] Chiappori (1988) demonstrates that disregarding caring preferences or altruism within the couple has no effect on the conclusions of the egoistic model.

[5] I am grateful to Reed Johnson for the idea of using π_i, insead of π for a mother and $1-\pi$ for a father.

The weight indicates how utility is aggregated in the household welfare function. π_i is influenced by wages and non-labor income, as well as by extra-household environmental parameters (EEPs), which Chiappori, Fortin and Lacroix (2002) call distributional factors. Empirically, EEPs have included divorce laws, sex ratios in remarriage markets, assets brought to the marriage, and welfare-program features.

The household budget constraint is:

$$I = \sum_i w_i T_i + y \geq \sum_i T_i^H w_i + \sum_j X_j + p_M M_k, \qquad i = m \text{ and } f \text{ and } j = m, f, \text{ and } k, \quad (1\text{-}9)$$

where full income (I) is composed of total time (T) evaluated at wage rates (w_i) and any non-labor income (y). Full income is spent on consumption of private goods (X) at the price of unity, as well as on medical care for the child (M_k) at a price p_M. T_i^H is time spent caring for a sick child by either the mother or the father.

I assume that X_j, M_k, and private time consumption (T_i^H, T_i^W, and T_i^L) are directly observable. The total time of either the mother or the father is divided between healthy time (H) and time spent sick (S). Healthy time is allocated among three activities, paid work (T^W), time spent caring for a sick family member (T^H), and leisure (T^L). The time constraint for either the mother or the father is written as follows:

$$T_i = H_i + S_i = T_i^H + T_i^W + T_i^L + S_i \qquad\qquad i = m \text{ or } f. \quad (1\text{-}10)$$

Combining these elements, the household maximization problem can be written as

$$L_h = \pi_m U_m \left[X_m, H_m, v_k \left(X_k, H_k \left(M_k, \cdot \right) \right) \right] + \pi_f U_f \left[X_f, H_f, v_k \left(X_k, H_k \left(M_k, \cdot \right) \right) \right]$$

$$(1\text{-}11)$$

$$+ \lambda_h \left[\sum_i \left(w_i \left(T_i - T_i^H \right) \right) + y - \sum_j X_j - p_M M_k \right]$$

where λ_h denotes the marginal utility of household full income.

3.1.   Two-stage procedures

The collective household model assumes that the mother and the father employ a two-stage procedure to maximize their utility. In the first stage, the mother and the father agree on the allocation of total household income to savings, expenditures on family public goods such as any expenditure for the child, and private expenditures for either the mother or the father. The more powerful an individual, the bigger the person's share of the pie in the first stage (Thomas et al., 2002). In the second stage, the mother and the father each maximizes her/his own utility given her/his income share.

In the first stage the expenditure for family public goods is paid from non-labor income. Either partner can contribute lump-sum transfers out of their own labor income for family public-good expenditures. To avoid distorting incentives, these contributions cannot be linked to the labor-leisure choice of the other partner, and thus are treated as non-labor income.[6] Rearranging Equation (1-9), we get:

$$\sum_i \left(T_i^H w_i + X_i - T_i w_i\right) = y - p_M M_k - X_k \tag{1-12}$$

The right side of Equation (1-12), residual non-labor income after paying for the expenditures of family public goods, is used for private expenditures of the parent. This income, if any remains, is divided between the mother and the father. The mother and the father develop a consensus about how to cooperate with each other. Chiappori calls it the sharing rule. The income share of the mother or the father, Φ_i, is decided as a function of wages, non-labor income, and extra-household environmental parameters (EEPs), which is written below:

$$\Phi_i = \Phi_i\left(w_f, w_m, y, P; \tau_i\right), \tag{1-13}$$

where *P* denotes extra-household environmental parameters.

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[6] It is from a personal communication with Chiappori.

To account for lump-sum transfers out of wage income, the sharing rule Φ_i need not be bounded between 0 and y. If non-labor income is less than the expenditure for the child's health, either the mother or the father would decrease her/his private consumption to pay for the health care treatment for their child. Thus, Φ_i, can be negative or larger than total non labor income.[7] This negative Φ_i reflects the private resources for family public goods—that is, how much she/he is willing to give up her private consumption for the child's health.

In my cooperative health-production model, then, the child's health is produced by a health production function as follows:

$$H_k = H_k\left(\Phi_i, M_k, T_f^H, T_m^H, \mu_k\right), \tag{1-14}$$

where μ_k is the child's long-term health status, including such exogenous factors as the presence of pre-existing chronic diseases (Dickie, 2005).

My model departs from the unitary household framework by including Φ_i in the conventional health production model. The unitary household model is limited in its ability to include the potential impact of a married couple's power distribution on children's health. When the child is sick, the mother and the father adjust to the health shock by allocating money and time to the sick child. The mother, for example, may be more concerned than the father about the health of their child, in which case she would be willing to allocate more resources than he would. The mother's resource-allocation decisions are made based on the resources she has at her discretion, Φ_m. Equation (1-14) helps account for the empirical evidence that children with more powerful mothers are likely to have less mortality or morbidity (Quian, 2005; Quisumbing and Maluccio, 2003; Schultz, 1990; Thomas, 1994; Thomas et al., 2002).

There are two different kinds of inputs committed to the child's health: medical care expenditures and caring time. Expenditures on medical care for the sick child are paid from

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[7] For a transfer only non-labor income is used because a transfer related to labor income would distorts the time-consumption decisions (at Equation (1-49), (1-50) and (1-52), shown later) and violates the efficiency properties of the model. Assume a mother receives 30% of a father's labor income and then his labor supply decision would be made at an inefficient point because it is like taxation on his labor supply. This insight is provided by Chiappori.

income that is treated as a public-input resource, while caring time is an exclusive private input. I propose that the decision on medical care is made in the first stage of the collective household model's process for maximizing the household utility and the one on caring time in the second stage.

The level of the child's medical-care expenditures M_k thus is decided in the first stage where:

$$M_k = M_k\left(w_f, w_m, \Phi_i, \mu_k\right). \tag{1-15}$$

In the second stage, the mother or the father maximizes her/his own utility, given the individual income share, Φ_i:

$$\underset{X_i, T_i^H}{Max} U_i\left[X_i, H_i, v_k\left(X_k, H_k\left(M_k, T_i^H\right)\right); \tau_i\right] \tag{1-16}$$

subject to $\Phi_i = X_i - w_i\left(H_i - T_i^H - T_i^L\right)$.

In the second stage while the mother and the father individually maximize her/his own utility, their individual decisions on consumption or time are Pareto efficient because spouses know each other's preferences well and interact very often (Chiappori, Fortin and Lacroix, 2002). Indeed, the collective household model requires only this one assumption and it can be tested empirically, as will be discussed in the section on empirical strategy.

In other words, the collective household model does not recognize free-riding behaviors where the mother or the father has an incentive not to contribute toward their child's health because she/he benefits from the spouse's contributions without spending any money or time. The non-cooperative model (Rubinstein, 1982; Ulph, 1988; Woolley, 1988; Lundberg and Pollak, 1993; Konrad and Lommerud, 1995, 2000; and Chen and Woolley, 2001), by contrast, has room to take into account such free-riding behaviors within a household. It is beyond the scope of this study to examine such limitations of the collective household model.

As a result of Equation (1-16), the derived supply function for caring time spent by the mother or the father i for their child is defined as follows:

$$T_i^H = T_i^H \left(w_f, w_m, \Phi_i, p_M; \tau_i \right). \tag{1-17}$$

One of the innovations in my model is that the supply of parents' time depends on the parent's share of income. Without taking into account the division of decision-making power between the mother and the father, the caring-time function within the collective household model is identical with the unitary model. For example, Pitt and Rosenzweig (1990), who conducted the only study of caring time for children's health, set up linear equations for caring time. In their unitary model, the individual decision regarding caring time depends on the decision-maker's own wage, her/his spouse's wage, and the price of medical care, which is below:

$$T_i^H = T_i^H \left(w_f, w_m, p_M; \tau_i \right). \tag{1-18}$$

Pitt and Rosenzweig's study therefore does not account for the effect of the decision-making power on her/his caring time decisions.

3.2.   Willingness to pay for child health

Because previous studies of willingness to pay (WTP) for the child's health have concentrated primarily on money, they have essentially been limited to Chiappori's first stage, in which a married couple decides how to allocate total household resources. Time, like money, is a scarce resource, however, and parents cannot produce their child's health with money alone. The two-stage model explains how the mother and the father each determine her/his WTP in terms of both money and time. I thus take the two-stage logic one step further and use it to estimate willingness to pay: willingness to spend money in the first stage and willingness to spend time in the second stage.

To derive the household WTP ($WTP_h^\$$), I apply the logic of Freeman (2003) and Dickie (2003, 2005) to Equation (1-11). The household WTP for one extra healthy day for

the child is given by totally differentiating the indirect household utility function V_h in terms of full household income as follows:

$$WTP_h^{\$} = \frac{dI}{dH_k} = -\frac{\dfrac{\partial V_h}{\partial v_k}\dfrac{\partial v_k}{\partial H_k}}{\dfrac{\partial V_h}{\partial I}} = -\frac{\dfrac{\partial V_h}{\partial v_k}\dfrac{\partial v_k}{\partial H_k}}{\lambda_h} \quad . \tag{1-19}$$

For calculating the numerator of Equation (1-19), take partial derivatives of the household maximization equation (Equation (1-11)) in terms of the medical care and healthy time of the child:

$$\left[\pi_m \frac{\partial U_m}{\partial v_k} + \pi_f \frac{\partial U_f}{\partial v_k}\right]\frac{\partial v_k}{\partial H_k}\frac{\partial H_k}{\partial M_k} = \lambda_h p_M \quad . \tag{1-20}$$

$$\frac{\partial V_h}{\partial v_k}\frac{\partial v_k}{\partial H_k} = \left[\pi_m \frac{\partial U_m}{\partial v_k} + \pi_f \frac{\partial U_f}{\partial v_k}\right]\frac{\partial v_k}{\partial H_k} \quad . \tag{1-21}$$

A simple adjustment of Equation (1-20) gives

$$\left[\pi_m \frac{\partial U_m}{\partial v_k} + \pi_f \frac{\partial U_f}{\partial v_k}\right]\frac{\partial v_k}{\partial H_k} = \frac{\lambda_h p_M}{\partial H_k / \partial M_k} \quad . \tag{1-22}$$

Substituting the left side of Equation (1-21) into the left side of Equation (1-22) gives

$$\frac{\partial V_h}{\partial v_k}\frac{\partial v_k}{\partial H_k} = \frac{\lambda_h p_M}{\partial H_k / \partial M_k} \quad . \tag{1-23}$$

Finally, incorporating Equation (1-23) into Equation (1-19) gives a household WTP of medical care inputs for a marginal reduction in child sick time

$$WTP_h^{\$} = -\frac{\dfrac{\partial V_h}{\partial v_k}\dfrac{\partial v_k}{\partial H_k}}{\lambda_h} = -\frac{p_M}{\partial H_k / \partial M_k}. \qquad (1\text{-}24)$$

$$= -\frac{MC_h}{MP_h} \qquad (1\text{-}25)$$

Equation (1-24) indicates that a household would be willing to pay for the child's medical care up to the point where the household benefit of an additional healthy child day is equal to the marginal cost (*MC*) weighted by a household marginal product of medical care input (*MP*). The productivity of household technologies measured by *MP* — the marginal output for given inputs — are important in the household WTP for medical care use. Low marginal household product in producing child's health (e.g., if the child has a chronic disease as opposed to a cold), results in households being willing to pay more for their child's health.

Equations (1-19) to (1-25) for *household* WTP in the cooperative health production model look similar to the unitary model. I am interested, however, in *separating* a mother's WTP from a father's WTP. If the two WTPs are derived separately, Equation (1-24) in the collective household model should be different from the one in the unitary model. To separately derive a mother's WTP from a father's, Samuelson (1954)'s condition for the Pareto optimal allocation of public-good expenditures is a good starting point.[8] Samuelson derives the optimal level of public-good provision by summing across beneficiaries' willingness to pay. Several non-unitary household studies adopt Samuelson's logic to obtain optimal expenditure shares for a family public good between a couple (Bergstrom, 1996, 2002; Chiuri and Simmons, 1997; and Donni, 2004). I follow their strategy here since the child's health is a family public good and I want to know how much each beneficiary (the mother and the father) would be willing to pay for their child's health.

Assuming an interior solution, a Pareto optimum can be obtained by taking the partial derivatives of Equation (1-11).

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[8] For the basic concept of the Pareto efficient allocation of public goods, see Starrett (1988).

$$\pi_m \frac{\partial U_m}{\partial X_m} - \lambda_h = 0,$$ (1-26)

$$\pi_f \frac{\partial U_f}{\partial X_f} - \lambda_h = 0,$$ (1-27)

$$\pi_m \frac{\partial U_m}{\partial v_k} \frac{\partial v_k}{\partial M_k} + \pi_f \frac{\partial U_f}{\partial v_k} \frac{\partial v_k}{\partial M_k} - \lambda_h p_M = 0.$$ (1-28)

Rearranging Equations (1-26) to (1-28) gives the following:

$$\lambda_h = \pi_m \frac{\partial U_m}{\partial X_m},$$ (1-29)

$$\lambda_h = \pi_f \frac{\partial U_f}{\partial X_f},$$ (1-30)

$$\frac{\pi_m \frac{\partial U_m}{\partial v_k} \frac{\partial v_k}{\partial M_k}}{\lambda_h} + \frac{\pi_f \frac{\partial U_f}{\partial v_k} \frac{\partial v_k}{\partial M_k}}{\lambda_h} = p_M.$$ (1-31)

Incorporating Equations (1-29) and (1-30) into Equation (1-31) gives

$$\frac{\frac{\partial U_m}{\partial v_k} \frac{\partial v_k}{\partial M_k}}{\frac{\partial U_m}{\partial X_m}} + \frac{\frac{\partial U_f}{\partial v_k} \frac{\partial v_k}{\partial M_k}}{\frac{\partial U_f}{\partial X_f}} = p_M.$$ (1-32)

Equation (1-32) is the standard result that expenditures on health care should be undertaken to the point where the marginal cost equals the sum of the marginal rates of substitution between medical care and private consumption. Specifically, the first term of the left side in Equation (1-32) represents how much private consumption the mother would be willing to give up in order to add one extra healthy day for her sick child. This is the mother's benefit from a household's supply of the medical care to her child. The second term is the father's benefit. The right side of Equation (1-32) shows the marginal cost of medical care, the numerator of the household WTP (Equation (1-24)). Combining all together, the sum of the benefits the mother and the father each would obtain per her/his giving up private consumption for one extra healthy day of their sick child is equal to the marginal cost of medical care input that the mother and the father would spend together. At this point the mother cannot be made better off without making the father worse off.

Incorporating Equation (1-32) into Equation (1-24) gives maternal ($WTP_m^\$$) and paternal WTP ($WTP_f^\$$) of the medical care input for their sick child,

$$WTP_h^\$ = WTP_m^\$ + WTP_f^\$$$

$$= -\left(\frac{\dfrac{\partial U_m}{\partial v_k} \dfrac{\partial v_k}{\partial M_k} \Big/ \dfrac{\partial U_m}{\partial X_m}}{\dfrac{\partial H_k}{\partial M_k}} + \frac{\dfrac{\partial U_f}{\partial v_k} \dfrac{\partial v_k}{\partial M_k} \Big/ \dfrac{\partial U_f}{\partial X_f}}{\dfrac{\partial H_k}{\partial M_k}} \right). \tag{1-33}$$

The total household willingness to spend money for medical care for their sick child is the sum of the mother's WTP and the father's WTP. The mother's WTP for medical care use, i.e., the first term of Equation (1-33), is the amount of private consumption the mother would be willing to give up in order to prevent one day of symptoms weighted by marginal household product in producing health. The father's WTP is derived similarly. This appears to be a new result not previously reported. Here the marginal household product of medical-

care input is not divided between the mother and the father. That is beyond the scope of this study.[9]

Based on the direct utility function, however, Equation (1-33) does not clearly show the role of decision-making power in the collective household model. Thus, I introduce an indirect utility function in order to show the significant impact that the decision-making power has in deciding the mother's or the father's willingness to pay. An indirect utility function of i (V_i) can be deduced from U_i as follows:

$$U_i\left(X_i, H_i, H_k; \tau_i\right) = V_i\left(w_i, \Phi_i(\bullet, y), p_M; \tau_i\right).$$ (1-34)

After rearrangement, the left side of Equation (1-32) can be rewritten as follows:

$$\frac{\dfrac{\partial U_m}{\partial v_k}\dfrac{\partial v_k}{\partial M_k}}{\dfrac{\partial U_m}{\partial X_m}} + \frac{\dfrac{\partial U_f}{\partial v_k}\dfrac{\partial v_k}{\partial M_k}}{\dfrac{\partial U_f}{\partial X_f}} = \frac{\dfrac{\partial V_m}{\partial p_M}}{\dfrac{\partial V_m}{\partial \Phi_m}} + \frac{\dfrac{\partial V_f}{\partial p_M}}{\dfrac{\partial V_f}{\partial \Phi_f}}.$$ (1-35)

From Equation (1-34) the partial derivative of the indirect utility function in terms of non-labor income can be written as follows:

$$\frac{\partial V_i}{\partial y} = \frac{\partial V_i}{\partial \Phi_i}\frac{\partial \Phi_i}{\partial y}.$$ (1-36)

Incorporating Equation (1-36) into Equation (1-35) gives

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[9] Using a household marginal product, instead of individual marginal product, may result in overestimation of a mother's WTP and underestimation of a father's WTP. Assume a mother is more productive in medical-care input decision-making when a child is sick, i.e., the maternal marginal product is higher than the paternal product. Then, a mother's WTP using her marginal product, which is higher than the household marginal product, could be lower than a mother's WTP using a household marginal product. The opposite could be true for a father's WTP.

$$\frac{\dfrac{\partial V_m}{\partial p_M}}{\dfrac{\partial V_m}{\partial \Phi_m}} + \frac{\dfrac{\partial V_f}{\partial p_M}}{\dfrac{\partial V_f}{\partial \Phi_f}} = \frac{\partial \Phi_m}{\partial y}\frac{\dfrac{\partial V_m}{\partial p_M}}{\dfrac{\partial V_m}{\partial y}} + \frac{\partial \Phi_f}{\partial y}\frac{\dfrac{\partial V_f}{\partial p_M}}{\dfrac{\partial V_f}{\partial y}}. \tag{1-37}$$

Finally, Equation (1-33) is rewritten using the indirect utility function as follows:

$$WTP_m^{\$} + WTP_f^{\$} = -\left[\frac{\dfrac{\partial V_m}{\partial p_M} \Big/ \dfrac{\partial V_m}{\partial \Phi_m}}{\dfrac{\partial H_k}{\partial M_k}} + \frac{\dfrac{\partial V_f}{\partial p_M} \Big/ \dfrac{\partial V_f}{\partial \Phi_f}}{\dfrac{\partial H_k}{\partial M_k}} \right] \tag{1-38}$$

$$= -\left[\frac{\partial \Phi_m}{\partial y}\frac{\dfrac{\partial V_m}{\partial p_M} \Big/ \dfrac{\partial V_m}{\partial y}}{\dfrac{\partial H_k}{\partial M_k}} + \frac{\partial \Phi_f}{\partial y}\frac{\dfrac{\partial V_f}{\partial p_M} \Big/ \dfrac{\partial V_f}{\partial y}}{\dfrac{\partial H_k}{\partial M_k}} \right]. \tag{1-39}$$

Equation (1-38) clearly reveals the characteristics of the collective household model in deriving the mother's WTP and the father's WTP. Parents' WTP for their child's medical care is determined by three factors: (1) the income share (Φ); (2) the price of medical care; and (3) the household's technology in producing a child's health. In other words, the more resources the mother has under her control, the higher her willingness to pay. The lower the marginal product of a household in producing the child's health, the higher both parents' WTP. In addition, Equation (1-39) shows the route by which the individual share affects WTP. For one-dollar increases in non-labor income, the marginal change in an individual share that results from this increase may be different for the mother than for the father. If the mother's share is more sensitive to non-labor income, her WTP is more sensitive when non-labor income changes than the father's WTP.

Next, the mother's or father's WTP in terms of caring time is decided in the second stage. The individual utility maximization problem can be rewritten from Equation (1-16) as follows:

$$\underset{X_i,T_i^H}{L_i} = U_i\Big[X_i, H_i, v_k\big(\bullet, H_k(\bullet, T_i^H)\big)\Big] + \lambda_i\Big[\Phi_i - X_i + w_i\big(H_i - T_i^H - T_i^L\big)\Big], \qquad (1\text{-}40)$$

where λ_i denotes the individual marginal utility of the individual share of i (Φ_i).

The first order conditions of Equation (1-40) are

$$\frac{\partial U_i}{\partial X_i} = \lambda_i, \qquad (1\text{-}41)$$

$$\frac{\partial U_i}{\partial v_k}\frac{\partial v_k}{\partial H_k}\frac{\partial H_k}{\partial T_i^H} = \lambda_i w_i. \qquad (1\text{-}42)$$

Since like money, time is a scarce resource, one can define the standard Hicksian compensating surplus measures with respect to time. If producing a household good takes a significant amount of time, omission of the time cost would produce bias in the demand estimation, which would then lead to an underestimation of consumer surplus (Bockstael and McConnell, 2007). However, the health/environmental valuation studies generally have not accounted for time. Larson and Shaikh (2001) and Eom and Larson (2006) have developed new approaches to deriving willingness to spend time, as well as willingness to spend money, but they do so in the context of the unitary household model. This is the first study to derive willingness to spend time for the child's health within the collective household model.

When child health is improved from an initial level H_k^0 to a subsequent level H_k^1, the Hicksian compensating surplus of WTP_i^T is implicitly defined as

$$V_i\big(w_i, \Phi_i - WTP_i^T, p_M; H_k^1\big) \equiv V_i\big(w_i, \Phi_i, p_M; H_k^0\big) \equiv V_i^0, \qquad (1\text{-}43)$$

where V_i^0 is the initial utility level of i.

In other words, WTP_i^T is estimated by totally differentiating the individual utility function in terms of individual share (Φ_i), as follows

$$WTP_i^T = \frac{d\Phi_i}{dH_k} = -\frac{\dfrac{\partial V_i}{\partial H_k}}{\dfrac{\partial V_i}{\partial \Phi_i}} = -\frac{\dfrac{\partial V_i}{\partial H_k}}{\lambda_i}.$$
(1-44)

Here I apply the basic logic of willingness to spend money to that of willingness to spend time. To estimate the numerator of Equation (1-44), differentiate the Lagrangian (Equation (1-40)) in terms of H_k:

$$\frac{\partial V_i}{\partial H_k} = \frac{\partial U_i}{\partial v_k}\frac{\partial v_k}{\partial H_k}.$$
(1-45)

Finally, after incorporating Equation (1-45) into Equation (1-42) and then into Equation (1-44), an individual WTP_i^T for a marginal reduction in the child's sick time is obtained as

$$WTP_i^T = -\frac{\partial V_i/\partial H_k}{\partial \lambda_i} = -\frac{w_i}{\partial H_k/\partial T_i^H} = -\frac{MC_i}{MP_i}.$$
(1-46)

Equation (1-46) shows that an individual benefit of an additional day available for non-caring activities equals the marginal time cost of producing an additional healthy day of the child, i.e., the market time value of the mother or the father (w_i) weighted by the individual marginal product of each one's caring time input. There are two factors to bear in mind here. First, the caring-time decision of either the mother or the father is made based on the individual share (Φ_i), which is different from the unitary model. Second, an individual

caring-time decision is made at the Pareto-efficient point between the mother and the father, the central assumption of the collective household model.

Combining WTP for medical care usage ($WTP_i^\$$) with WTP for caring time (WTP_i^T) gives us the WTP of the mother and the father for the child's health (WTP_i^k), as shown below:

$$WTP_m^k + WTP_f^k = (WTP_m^\$ + WTP_m^T) + (WTP_f^\$ + WTP_f^T)$$

$$= \left[-\frac{\dfrac{\partial V_m}{\partial p_M} \Big/ \dfrac{\partial V_m}{\partial \Phi_m}}{\dfrac{\partial H_k}{\partial M_k}} - \frac{w_m}{\dfrac{\partial H_k}{\partial T_m^H}} \right] + \left[-\frac{\dfrac{\partial V_f}{\partial p_M} \Big/ \dfrac{\partial V_f}{\partial \Phi_f}}{\dfrac{\partial H_k}{\partial M_k}} - \frac{w_f}{\dfrac{\partial H_k}{\partial T_f^H}} \right] \qquad (1\text{-}47)$$

$$= -\left[\left(\frac{\partial \Phi_m}{\partial y} \frac{\dfrac{\partial V_m}{\partial p_M} \Big/ \dfrac{\partial V_m}{\partial y}}{MP_h(M_k)} + \frac{w_m}{MP_m(T_m^H)} \right) + \left(\frac{\partial \Phi_f}{\partial y} \frac{\dfrac{\partial V_f}{\partial p_M} \Big/ \dfrac{\partial V_f}{\partial y}}{MP_h(M_k)} + \frac{w_f}{MP_f(T_f^H)} \right) \right].$$

$$(1\text{-}48)$$

In sum, by enabling us to separate a mother's WTP in terms of time and money from a father's WTP, the cooperative health-production model that I develop here yields the following results:

(1) There are two kinds of inputs to produce the child's health based on whether the input is exclusive: time inputs, which are exclusive, and monetary inputs, which are not.

(2) There are two different types of technology in producing a child's health: producing one extra healthy day of the child at a household level and one extra day at an individual level.

(3) The willingness to pay for the child's health is the sum of the willingness to pay of the mother or the father for medical care and for caring time.

(4) WTP in terms of each input (i.e., time and money) is determined at its marginal cost weighted by producing one additional healthy day for the child.

(5) Since medical expenditures are expenditures on a family public good, their optimal allocation between the mother and the father is decided at the point at which the sum of the marginal rates of substitution between a family public good and private goods is the same as the marginal cost of medical inputs.

(6) Most importantly, parental WTP for the child's medical care is determined by four factors: income share (Φ), non-labor income, the price of medical care, and the household's technology for producing the child's health.

(7) Parental WTP of caring time is determined by three factors: an individual time value (i.e., wage), an individual technology for caring for the sick child, and income share (since T_i^H is a function of Φ_i).

3.3.   *The Empirical Strategy*

3.3.1.   *From caring-time supply function to income-sharing rule*

The goal of this study, as stated, is to derive the mother's WTP for the child's health separately from the father's WTP. In order to accomplish the goal, Equation (1-47) shows that it is necessary to know the individual indirect utility functions (the numerator of the first term in each bracket), the household health production function (the denominator of the first term in each bracket), and the individual caring-time function (the denominator of the second term in each bracket). Also, the assumption of the collective model — that the decisions of the mother and the father are Pareto efficient — needs to be tested. In these procedures, it is crucial to reveal the income-sharing rule since it is included in all of the functions and is not directly observable.

Non-unitary household studies have taken two approaches to identify the individual share. One is to specify a functional form of the direct or indirect utility and then to derive individual supply equations. Burtless and Hausman (1978) warn that this approach imposes strong restrictions on the utility function. The other is to specify individual supply equations and then to derive the indirect utility function. Chiappori, Fortin, and Lacroix (2002) take the

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second approach within the collective household framework. I follow their procedures, but I augment their empirical equations with family public goods. Chiappori, Fortin, and Lacroix (2002) begin with a semi-log functional form for T_i^H:

$$T_m^H = m_0 + m_1 \log w_f + m_2 \log w_m + m_3 y + m_4 \log w_f \log w_m + m_5 P_1 + m_6 P_2 + m_7 p_M + m_8' \tau_m$$

(1-49)

$$T_f^H = f_0 + f_1 \log w_f + f_2 \log w_m + f_3 y + f_4 \log w_f \log w_m + f_5 P_1 + f_6 P_2 + f_7 p_M + f_8' \tau_f,$$

(1-50)

The collective framework assumes the mother and the father make a joint decision on caring time under Pareto-efficient conditions (Chiappori, Fortin, and Lacroix, 2002):

$$\frac{f_4}{m_4} = \frac{f_5}{m_5} = \frac{f_6}{m_6}.$$

(1-51)

These proportionality restrictions — that the mother and the father jointly decide at the same ratio of influence from the distributional factor — are important since they show which point is chosen on the Pareto frontier. They are also important for testing the collective household model. The constraints are testable by using a joint Wald test after estimating Equations (1-49) and (1-50). If this proportionality restriction holds, the collective household model holds. Furthermore, the constraints play a critical role in identifying the individual shares. The income-sharing rule parameters (Equation (1-13)) are estimated by imposing the proportionality constraints on Equation (1-49) and (1-50). After several mathematical steps,[10] Chiappori, Fortin, and Lacroix (2002) derive the income-sharing rule equation as follows:

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[10] I do not show the technical steps here because I find that the income-sharing rule is the same when family public good is included in Equation (1-49) and (1-50) (see Equation (1-13)) as when it is not included in Chiappori, Fortin, and Lacroix (2002)'s equations. For more mathematical details, see appendix in Chiappori, Fortin, and Lacroix (2002).

$$\Phi_m = \frac{1}{\Delta}\left(f_1 m_4 \log w_m + m_2 f_4 \log w_f + m_4 f_4 \log w_f \log w_m + m_3 f_4 y + f_4 m_5 P_1 + f_4 m_6 P_2\right),$$

$$(1\text{-}52)$$

where $\Delta = m_3 f_4 - m_4 f_3$, conditional on $f_5/f_3 \neq m_5/m_3$.

Each parent's caring time then can be rewritten as follows:

$$T_m^H = \alpha_1 \log w_m + \alpha_2 \Phi_m + \alpha_3 p_M + \alpha_4(\tau_m), \qquad (1\text{-}53)$$

$$T_f^H = \beta_1 \log w_f + \beta_2\left(y - p_M M_k - X_k - \Phi_m\right) + \beta_3 p_M + \beta_4(\tau_f), \qquad (1\text{-}54)$$

where $\alpha_1 = (m_1 f_4 - m_4 f_1)/f_4$, $\alpha_2 = \Delta/f_4$, $\beta_1 = (m_4 f_2 - m_2 f_4)/m_4$, and $\beta_2 = -\Delta/m_4$. α_1 and α_2 are derived by equalizing the derivatives of Equation (1-52) with respect to wages to those of Equation (1-49). Following the same logic, β_1 and β_2 are derived, too.

3.3.2. Indirect utility functions

To estimate each parent's WTP, it is necessary to derive individual indirect utility functions from the caring-time functions (Equation (1-49) and (1-50)). Stern (1986) summarizes various studies that derive indirect utility functions from various functional forms for supply equations and provides a convenient table linking utility and demand functions. The semi-log functional form is commonly used in empirical models. Following Stern (1986), the functional form of the indirect utility functions can be obtained from semi-log caring-time functions as follows:

$$V_m\left(w_m, \Phi_m, p_M; \tau_m\right)$$

$$(1\text{-}55)$$

$$= \left[\frac{exp(\alpha_2 w_m)}{\alpha_2}\right]\left[\alpha_1 \log w_m + \alpha_2 \Phi_m + \alpha_3 p_M + \alpha_4(\tau_m)\right] - \frac{\alpha_1}{\alpha_2}\int_{-\infty}^{\alpha_2 w_m} \frac{exp(t)}{t} dt,$$

$$V_f\left(w_f, \Phi_f, p_M; \tau_f\right)$$

$$=\left[\frac{exp\left(\beta_2 w_f\right)}{\beta_2}\right]\left[\beta_1 \log w_f + \beta_2\left(y - p_M M_k - X_k - \Phi_m\right) + \beta_3 p_M + \beta_4\left(\tau_f\right)\right] - \frac{\beta_1}{\beta_2}\int_{-\infty}^{\beta_2 w_f} \frac{exp(t)}{t} dt.$$

$$(1\text{-}56)$$

Equations (1-53) to (1-56) differ from Chiappori, Fortin, and Lacroix (2002) in that they take into account family public goods.

3.3.3. *Willingness to pay of the mother and the father*

A combination of Equations (1-55) and (1-47) gives, finally, a mother's willingness to spend money and time as follows:

$$WTP_m^k = -\left(\frac{\dfrac{\partial V_m}{\partial p_M}}{\dfrac{\partial V_m}{\partial \Phi_m}}\frac{1}{\dfrac{\partial H_k}{\partial M_k}} + \frac{w_m}{\dfrac{\partial H_k}{\partial T_m^H}}\right)$$

$$= -\left(\frac{\alpha_3/\alpha_2}{\partial H_k/\partial M_k} + \frac{w_m}{\partial H_k/\partial T_m^H}\right)$$

$$= -\left(\frac{\alpha_3/\alpha_2}{MP_h\left(M_k\right)} + \frac{w_m}{MP_m\left(T_m^H\right)}\right).$$

$$(1\text{-}57)$$

Using the same logic, a father's willingness to spend money and time is:

$$WTP_f^k = -\left(\frac{\dfrac{\partial V_f}{\partial p_M}}{\dfrac{\partial V_f}{\partial \Phi_f}}\frac{1}{\dfrac{\partial H_k}{\partial M_k}} + \frac{w_f}{\dfrac{\partial H_k}{\partial T_f^H}}\right)$$

$$= -\left(\frac{\beta_3/\beta_2}{MP_h(M_k)} + \frac{w_f}{MP_f(T_f^H)} \right). \qquad (1\text{-}58)$$

Equation (1-57) shows that a mother's willingness to spend money is obtained by dividing the optimal amount a mother would spend on her child's medical care (α_3/α_2) divided by a household marginal product of medical inputs ($MP(M_k)$). Parents' willingness to spend time to avoid one day of school loss for their child is equal to their time value spent for caring for the sick child, divided by the individual marginal product of time ($MP(T_i^H)$). These two marginal products can be obtained from the health production functions (Equations (1-14) and (1-15)).

Next, in Equations (1-57) and (1-58), α_2 and β_2 show the characteristics of the collective household model. They are the coefficients of individual shares in the indirect utility functions. The individual share is a function of a parent's own wage, her/his spouse's wage, non-labor income, and EEPs (Equation (1-52)). The individual share is determined at the Pareto efficient point (Equation (1-51)). Thus, α_2 and β_2 are affected by the ratio of distributional factors ($f_4, f_5, f_6, m_4, m_5, m_6$), as well as non-labor income (f_3, m_3). In other words, the magnitude of the difference between a mother's and a father's WTP is partially determined by distributional factors. If the ratio of distributional factors is unity, it is possible that a mother's WTP is close to a father's WTP.

4.   Conclusion

The objective of this essay is to separately derive a mother's willingness to spend money and time to save her child from one day of sickness from a father's. In order to accomplish the goal, I use the collective household model to shed light on the health production model and in so doing advance a theoretical model of my own, which I call the cooperative health production model. To identify both the collective model and the health production model, empirically, one must have the rich data in six categories: (1) individual characteristics such as wage, educational attainment, age, race, etc.; (2) individual time use

for producing the child's health, or if that is not available, individual time use for work in the market ; (3) medical care expenditures for the child; (4) family characteristics such as non-labor income, number of children, etc.; (5) children's health; and (6) extra-household environmental parameters.

The full analysis would take the following four steps: (1) test the assumption of the collective model; (2) estimate the caring time supply model and the income-sharing rule in order to check whether the assumption of the collective model holds; (3) estimate marginal products of medical care and caring time using a health production function; and finally (4) estimate WTP of mothers and fathers.

Therefore, several hypotheses can be tested in the empirical analysis: (1) extra-household environmental parameters have an impact on the distribution of decision-making power between the mother and the father; (2) EEPs have an impact on the consumption decisions of time and money for improving the child's health; (3) children with more powerful mothers have fewer days of school loss due to illness or injury; and (4) a mother's willingness to pay for an additional healthy day of a child is greater than a father's.

In this essay I expanded the health production model by reframing it along the lines of a promising intra-household model, the collective household model. I begin with the two-stage procedure in the collective household model and consistently use it to estimate willingness to pay, that is, willingness to spend money in the first stage and willingness to spend time in the second stage. Finally, I find that maternal/paternal WTP for the child's health is determined by six factors: the income share (Φ), the non-labor income, the price of medical care, an individual time value (i.e., wage), and the household's and individual technology for producing the child's health.

For the last two decades, health/environmental valuation studies have questioned whether to combine the two models, as well as how much a mother's WTP differs from a father's, if any. Here an inter-disciplinary approach such as mine opens up the possibility of a separate estimation of a mother's WTP from a father's. This possibility in turn raises several important issues. If a mother's WTP is different from a father's WTP, does it mean that a household WTP is not an accurate welfare measure for saving a child from one extra day of a symptom? What are the policy implications of these separate estimates?

At the very least, separate estimates would have implications on targeting policies. Since non-unitary models include various extra-household environmental parameters in the models themselves, they suggest various policy tools. For example, several studies use the characteristics of welfare programs or health insurance programs as extra-household environmental parameters and show the impact of EEPs on consumption for child goods, child's health, or child's nutritional status. Since non-unitary models also make agents (mothers and fathers) in a household visible, they are able to specify which parent is more sensitive between mothers and fathers to children's welfare. Such findings would be valuable to the framers of a targeting policy. Understanding the mechanism of intra-household bargaining may lead to accurate benefit estimates and better prediction about the impact of public programs for children. If a mother showed more concern than a father for their children's welfare and her WTP for that health were greater than his WTP—information that is obtainable from the cooperative health-production model proposed here— then a government considering a program for improving children's health, nutrition, or educational attainment would be well advised to target the program toward mothers as recipients of the subsidies, rather than fathers.

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CHAPTER II

A SKEPTICAL VIEW OF THE COST-OF-ILLNESS MEASURE

1.   Introduction

Diarrhea is a leading cause of disease and death from communicable disease in developing countries. Diarrheal diseases are a global problem, but they are especially prevalent in developing countries, which are more likely to have poor environmental sanitation, inadequate water supplies, poverty, and limited public health education (Kosek, Bern, and Guerrant, 2003). In areas where basic interventions to combat these problems cannot be implemented in the near future, efforts have been directed towards disease prevention through vaccines. If immunization programs are to be subjected to close analysis, it is necessary to have accurate benefit measures of reduced morbidity.

The most widely used measure for estimating the benefits of reduced morbidity is the cost-of-illness (COI) approach[11], which measures the sum of medical expenses and opportunity costs in terms of lost wages.[12] Another is the willingness-to-pay measure, which determines individual welfare change associated with a disease by measuring the maximum amount of income that an individual would be willing to give up to be healthy. Although there is little basis in economic theory for the cost-of-illness measure, it has been commonly used in policy analysis[13] because of Harrington and Portney's (1987) result that COI

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[11] Numerous cost-of-illness studies have been conducted (Segal, 2006) since the work of Rice (1966) 40 years ago. A 2001 systematic literature review of cost-of-illness studies identified a total of 1,725 publications (Bloom, Bruno, Maman, et al., 2001).

[12] The COI approach may be used to estimate the "public" costs to a community or society of treating infected individuals, or "private" (out-of-pocket) costs to individuals, or both. The present study is concerned exclusively with private costs (Guh et al., 2008).

[13] For example, the 1996 Amendments to the Safe Drinking Water Act require the US Environmental Protection Agency and the Centers for Disease Control and Prevention to develop a national estimate of waterborne infectious disease cases that are attributable to public drinking water systems (US EPA 1996 [see Section I458 (d)]). Such disease-burden estimates usually rely on the cost-of-illness measure (Rice, Heberling, et al., 2006).

estimates are lower bounds on theoretically correct measures of willingness to pay (WTP). Harrington and Portney (1987) show that the *marginal* WTP to avoid one unit of illness is the sum of monetized pain or suffering from illness and defensive expenditures, as well as medical expenses and lost opportunity costs due to illness. In other words, WTP estimates are more comprehensive than COI.

Several empirical studies support Harrington and Portney's argument by reporting that WTP is 1.6 to 8.0 times higher than COI (Rowe and Chestnut, 1985; Chestnut et al., 1988, 1996; Dickie and Gerking, 1991; Alberini and Krupnick, 2000; and Cropper et al, 2004). These theoretical and empirical studies have played a role in justifying the use of COI measures in policy analysis. If the conservative benefit estimates (COI) exceed the cost of a program, the program is guaranteed to pass the benefit-cost test using a comprehensive benefit measure (WTP). Policy makers also prefer COI estimates because of their interest in the budgetary effects of health policy interventions, their lack of understanding of welfare-based estimates of economic benefits, and their skepticism about the accuracy of stated preference techniques (Guh et al., 2008).

One limitation of Harrington and Portney's study is that it pertains to marginal changes, while it is non-marginal changes that we are most often interested in evaluating. However, recently Bockstael and McConnell (2007) have clarified the confusion in interpreting Harrington and Portney's study by distinguishing a welfare measure for *non-marginal* changes from a measure for *marginal* changes. Bockstael and McConnell show that COI estimates can either overstate or understate non-marginal WTP estimates. Thus, I revisit the comparisons between private COI and WTP estimates for diarrhea diseases in the context of developing countries in order to answer several questions: what would be the theoretically correct benefit measure for reduced morbidity? How much would the true measure differ from others? What are the determinants of the differences between the true measure and others?

I begin with Bockstael and McConnell (2007)'s model and articulate the underlying factors that create potential differences between the true and other benefit measures in developing country contexts. In developing countries, people lack health insurance and public expenditure on health is low. Thus, most illnesses impose great financial burdens on poor households. I therefore incorporate insurance into Bockstael and McConnell's model,

because I propose that insurance may have a significant effect on the magnitude of the discrepancies between the COI and WTP measures. Medical insurance could either shift the marginal cost of treatment away from the sick individual (Freeman, 2003) or alter individuals' choices of averting activities and days of illness (Harrington and Portney, 1987). For example, a 100% coverage insurance plan reduces the price of medical treatment to zero (Freeman, 2003). In other words, the social risk pooling system, insurance, is a key factor in determining the magnitude of the difference between COI and WTP measures. By incorporating insurance into Bockstael and McConnell's model, I show that *ex post* COI tends to overstate *ex post* WTP because of income effects in developing countries, which are different from those in developed countries.

Next, I incorporate uncertainty into the model, since an individual does not know what her health will be with certainty (Berger et al., 1987). In doing so, I derive *ex ante* COI and *ex ante* compensating variation (CV) measures. The *ex ante* COI measures how much a program prevents in terms of the expected value of the loss from an adverse event. The loss is calculated as the actual loss (*ex post* COI) multiplied by the probability of the occurrence of an adverse event. The *ex ante* CV, on the other hand, measures expected changes in an individual's utility as the result of a public program and assumes that an individual maximizes her expected utility. Thus, the difference between *ex ante* COI and *ex ante* WTP lies in the difference between expected utility and expected value. Theoretically they are unlikely to be the same unless an individual is risk neutral (Freeman, 1989; and Johannesson, 1996). The literature on decision-making under uncertainty shows that the difference between expected utility and expected value is a risk premium. That is, a risk averse individual is likely to pay more than the expected loss (here *ex ante* COI) in order to avoid a risk (Friedman, 2002).

In section 3, I compare the four different measures of the economic benefits of avoiding one episode of diarrhea diseases. I base my empirical comparison on a combined epidemiological and economic study conducted in China, Indonesia, Vietnam, Bangladesh, and Thailand between 2001 and 2005 by the Diseases of the Most Impoverished (DOMI) program. The epidemiological component of the study had been previously conducted through a population-based surveillance study. In the economic part of the study, patients with laboratory-confirmed illness (or their caregivers) were asked to answer questions about

their out-of-pocket expenditures and lost earnings associated with diarrhea and the results were used to calculate *ex post* COI. In order to measure *ex post* WTP, the study asked respondents about their willingness to pay to avoid another, similar episode of diarrhea. Next, the *ex ante* COI was calculated by multiplying the incidence rate by *ex post* COI estimates. *Ex ante* WTP estimates were also obtained from another contingent valuation study measuring the benefit of avoiding one episode of diarrhea by a hypothetical vaccine.

To the best of my knowledge, all four measures (*ex post* COI and WTP, and *ex ante* COI and WTP) have been neither theoretically discussed together nor empirically assessed using consistent methods across multiple countries. In this study I find that there is no clear evidence that *ex post* COI is a lower bound on *ex post* WTP. The *ex post* COI associated with one episode of diarrheal diseases is close to, lower than, or higher than *ex post* WTP in the Asian countries. On the other hand, *ex ante* COI measures understate the benefits of reduced morbidity in developing countries because of their disregard for risk premiums. Furthermore, the discrepancy between *ex ante* measures is not within a reasonable range. In sum, COI measures are unreliable proxies for true WTP measures, especially in developing countries. Therefore, the value of COI estimates as welfare benefit measures may be limited in a policy analysis.

2.   *Theoretical basis for comparing cost-of-illness and willingness-to-pay measures*

Knowledge of the economic burden of a disease can help policy makers to decide which diseases need to be addressed first with public health interventions (Segel, 2006). In this section, I extend Bockstael and McConnell (2007)'s model for comparing *ex post* COI and *ex post* WTP measures for one avoided episode of illness by incorporating the effects of insurance and uncertainty.

2.1.   *Ex post CV versus ex post COI*

The health *S* is produced as a function of the effect of pollution, averting activity (A_i), and medical treatment (M_i):

$$S_i = s(b, A_i, M_i; \mu_i),$$ (2-1)

where health is measured by the number of sick days S. b is the quality of public bad and μ_i is the genetic endowment of an individual i.

Utility depends on the consumption of a numeraire (X), the leisure time (T^L), and the amount of time spent ill with diarrhea diseases (S) of an individual i, conditional on the quality of public bad:

$$U_i = u\left(X_i, T_i^L, S_i; b\right). \tag{2-2}$$

An individual maximizes her utility subject to her budget constraint,

$$y_i = I_i + w_i\left(T - T_i^L - S_i\right) = X_i + p_A A_i + p_M M_i, \tag{2-3}$$

where I is non-labor income and T is the total time available. This budget constraint indicates that the expenditures on the numeraire, averting activity, and medical treatment cannot exceed the sum of her unearned and earned income. p_A and p_M are price of preventive goods and medical care, respectively.

The utility maximization model can be written as

$$\max\ u_i(X_i, T_i^L, S_i) + \lambda_i\left[I + w_i\left(T - T_i^L - S_i\right) - X_i - p_A A_i - p_M M_i\right]. \tag{2-4}$$

Restating the model for expenditure minimization yields

$$e_i\left(b, w_i, p_A, p_M, T, u_i\right)$$

$$= \min_{X, T^L, A, M}\ w_i\left(T_i^L + S_i\right) + X_i + p_A A_i + p_M M_i - Tw_i + \tau_i\left[u_i - u_i(X_i, T_i^L, S_i)\right]. \tag{2-5}$$

Using the expenditure function in equation (2-5), the welfare measure for a non-marginal increase in the public bad from an initial level b^0 to a subsequent level b^1, while holding the utility constant, is

$$ex\ post\ CV_i = e_i\left(b^0, w_i, p_A, p_M, T, u_i^0\right) - e_i\left(b^1, w_i, p_A, p_M, T, u_i^0\right)$$

$$= X_i^H + p_A A_i^H + w_i S_i^H + p_M M_i^H, \tag{2-6}$$

where a superscript *H* represents the Hicksian demand.

Equation (2-6) is just a simple version of Bockstael and McConnell's equation (8.52). The compensating variation is the total amount of income required to keep the utility constant once the quality of the environment degrades. Equation (2-6) allows for four behavioral responses to one episode of illness. An individual actively responds to changes in public bad by either altering consumptions of other goods (*X*) or leisure (T^L) or purchasing preventive goods (A_i, e.g., bottled water or vaccines), while taking days (*S*) off and seeking medical treatment (M_i). All are decisions made to maintain the same level of well-being at the occurrence of environmental degradation. For example, a person might buy bottled water at the announcement of water pollution or get a flu vaccine. She might reduce or increase consumptions of other goods based on her ability to pay for health costs for an episode of illness.

On the other hand, the cost of illness can be simply written as follows:

$$ex\ post\ COI_i = w_i S_i^M + p_M M_i^M, \tag{2-7}$$

where a superscript *M* represents the Marshallian demand.

It is worth noting that Equation (2-7) makes no allowance for individuals to have control over their health by actively adjusting consumptions of other goods or leisure to changes in public bad. Equation (2-7) also makes no allowance for any preventive behaviors that would produce better health, by definition (Bockstael and McConnell, 2007). In other words, health status is not a choice variable, but exogenous in COI estimates.

2.1.1. A model without insurance

Equations (2-6) and (2-7) are used to calculate the difference between the compensating variation and the cost of illness estimate below:

$$ex\ post\ CV_i - ex\ post\ COI_i = \underbrace{X_i^H + p_A A_i^H}_{only\ in\ CV} + \underbrace{p_M\left(M_i^H - M_i^M\right)}_{Difference\ in\ M} + \underbrace{w_i\left(S_i^H - S_i^M\right)}_{Difference\ in\ S} \ . \qquad (2\text{-}8)$$

The difference between non-marginal willingness to pay (CV) for an improvement in health outcomes and actual loss due to illness (COI) is composed of four elements in Equation (2-8): consumption of other goods (the first term of the left side), averting expenditures (the second), and the differences between expenditures on Marshallian and Hicksian medical (the third) and health demand (the fourth). The first two terms are included only in the CV measure.

Bockstael and McConnell (2007) assume that an individual would consume more X and adopt more preventive activities after experiencing degradation in the environment. However, this is not always true. Especially in developing countries, the responses of the poor to health shocks may differ from those expected by Bockstael and McConnell. For example, poor households may cut their consumption of other goods in the market (X) when the treatment cost for a sick family member places a heavy burden on their tight household budgets.[14] The poor often live on a daily wage that is barely enough to provide for minimum health care expenditures (Russell, 2003). Even minor illness can have a great impact on their budgets. In order to cope with this financial shock, the poor would reduce consumption first of non-essential and then essential items. Thus, the first term of equation (2-8) could be more often negative in developing countries.

The third and fourth terms are the difference between the Marshallian and the Hicksian cost of illness. As the public bad changes, the Hicksian and Marshallian demand functions diverge. The difference between Marshallian demand and Hicksian demand is commonly explained by income effect. Willig (1976) shows that the magnitude of differences between Marshallian and Hicksian demands depends on income elasticity, as well as the budget share of a good relative to income. The smaller the income elasticity or the

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[14] The empirical evidence of decreasing consumption associated with illness in developing countries is well documented in the consumption against illness literature (Gertler and Gruber, 2002; Morduch, 1995, 1999; Townsend, 1995; and World Bank, 1993, 1995).

smaller the budget share of a good (here medical care expenditures and lost wages) relative to income, the closer the demand curve of the compensated (i.e., Hicksian) to the uncompensated (i.e., Marshallian). Therefore, the third and fourth terms of equation (2-8) could be negative or positive. The magnitude of discrepancies between the two measures can be explained by income effects.

The second term, preventive expenditures, is important in explaining the disparity between COI measures and WTP measures (Dickie, 2003; Dickie and Gerking, 1991; and Harrington et al., 1989). However, this term raises a measurement issue. It is not clear how to measure the cost(s) of averting a single episode of diarrhea. Activities to prevent diarrhea might include personal hygiene (careful hand-washing after using the toilet, or washing hands with soap), safe food preparation, boiling drinking and cooking water, protecting sources of food and water from contamination, and practicing hygienic disposal of household wastes (Guh et al., 2008). Computing such expenditures is problematic because preventive actions have joint products (see Dickie and Gerking, 1991). For instance, hand washing reduces the risk of more than one diarrheal disease. The cleanliness and freshness that come from hand washing also increase individual utility. It is not possible, therefore, to measure preventive expenditures separately for only one episode of diarrhea diseases.

The third terms of Equation (2-8), $p_M \left(M^H - M^M \right)$, raises an additional measurement issue. In COI estimation researchers typically use average costs rather than marginal costs (Byford, Torgerson, and Raftery, 2000; and Songer et al., 1998). Moreover, costs are not determined in competitive markets.[15] Thus, the average costs estimated by cost-of-illness studies are likely to be higher than the marginal costs. In other words, typical COI estimation may cause overestimations of $p_M M^M$ in the third term of Equation (2-8).

In summary, given the signs of the first term, the third and fourth terms in Equation (2-7), *ex post* CV may be close to, lower than, or higher than *ex post* COI under a wide range of circumstances, while the second term is assumed as indeterminable. In addition, income effect could be one of the key factors in the difference between *ex post* COI and *ex post* CV.

2.1.2. A model with insurance

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[15] I am grateful to Reed Johnson for this observation.

In this section I incorporate insurance into Equation (2-8) and explore whether the availability of health insurance decreases the magnitude of the difference between the Marshallian and the Hicksian demand in Equation (2-8), and subsequently decreases the gap between CV and COI.

Assume that everyone in a society has identical preferences toward risk and a monthly income of USD200.[16] The probability that each would become ill (π) is 1/100. Without insurance, if an individual became ill, s/he would pay USD100 for medical care. For those who are insured, the insurance is assumed as fair, so $\pi \times p_M M = P$ [1/100×100=1], where P is the insurance premium. The individual who is insured and becomes ill pays the fair premium of USD1 and receives USD100 of medical care (K), paid for entirely by insurance. K is the insurance payoff.

Since the probability of illness is 1 in 100, for each person who becomes ill, there are ninety-nine others who transfer USD1 to the person who becomes ill (Newhouse and Phelps, 1976). As a result, this transfer decreases the out-of-pocket expenditures for treatment paid by the patient. This is incorporated into Equations (2-6) and (2-7), putting π aside,[17] and mathematically written below:

$$Ex\ post\ CV_i = X_i^H + p_A A_i^H + w_i S_i^H + p_M M_i^H + P_i^H - K_i, \tag{2-9}$$

$$Ex\ post\ COI_i = w_i S_i^M + p_M M_i^M + P_i^M - K_i. \tag{2-10}$$

It should be noted that Equation (2-9) measures the welfare benefit in non-marginal changes in public bad using Bartik's bound (1988) (for further details, see Bockstael and McConnell, 2007).

If an individual purchases full insurance coverage that pays the entire medical expenditure for treatment K, then $p_M M = K$. Equation (2-8) can be rewritten below:

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[16] Adapted from Newhouse and Phelps (1976).

[17] A discussion of *ex ante* measures takes into account π in the next section.

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$$\text{ex post CV}_i \text{ - ex post COI}_i = \underbrace{X_i^H + p_A A_i^H +}_{only\ in\ CV} \underbrace{\left(P_i^H - P_i^M\right)}_{Difference\ in\ P} + \underbrace{w_i\left(S_i^H - S_i^M\right)}_{Difference\ in\ S}. \quad (2\text{-}11)$$

Equation (2-11) with insurance shows that the difference in *M* is different from Equation (2-8) without insurance. The difference in premiums ($P^H - P^M$) would be much smaller than the difference in the actual medical care expenditures ($p_M(M^H - M^M)$). Therefore, from an individual perspective,[18] being insured decreases a patient's out-of-pocket expenses in the event of illness and also decreases income effects. Finally, the gap between *ex post* COI and CV decreases.

Instead of a simple illustration explaining the effect of insurance on the difference between *ex post* CV and *ex post* COI, Willig's approximation equation can be used below:

$$\frac{CS}{CV} \approx 1 \bigg/ \left(1 - \frac{\eta}{2}\frac{CS}{y}\right), \quad (2\text{-}12)$$

where η is income elasticity and CS is consumer surplus.

Assume consumer surplus as a direct cost of illness and income elasticity as 1.4. If the budget share of medical care relative to income (CS/y) is 0.8 without insurance, then the consumer surplus overstates CV [$CS/CV = 1/(1 - (1.4/2) \times 0.8) = 2.5$]. However, at the same income elasticity, if the budget share of medical care decreases to 0.2 with insurance, then CS is 116% of CV [$CS/CV = 1/(1 - (1.4/2) \times 0.2) = 1.16$]. Therefore, the differences in *M* in Equation (2-11) decrease from 150% (without risk pooling) to 16% (with risk pooling).

In summary, the difference between *ex post* CV and *ex post* COI is at some level determined by the extent of medical insurance coverage.

2.2. *Ex ante CV versus ex ante COI*

Both *ex post* COI and *ex post* WTP measures, discussed in the previous section, assume certainty in estimating the benefit of health improvement. However, an individual does not know what her health will be with certainty (Berger et al., 1987). In this section, I

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[18] The aggregate societal perspective in taking insurance into account is out of scope of this study.

incorporate uncertainties into *ex post* COI and *ex post* WTP expressions. To my knowledge, this is the first attempt to compare *ex ante* CV to *ex ante* COI for non-marginal change in public bad.

2.2.1. A model without insurance

An individual faces illness with probability π and good health with probability $1-\pi$. She seeks to maximize an expected utility function as

$$\max(1-\pi)u(X_h, T_h^L, S_h) + \pi u(X_s, T_s^L, S_s),\tag{2-13}$$

where the subscripts h and s represent a healthy and an ill state, respectively. π is a function of preventive actions and the level of public good given individual genetic endowment $(=\pi(A, b; \mu))$.

Anyone in the population j could be sick or healthy and anyone could also be the beneficiary of the reduction of illness through a public intervention. The *ex ante* compensating variation for the reduction in probability of illness corresponds to Equation (2-6) and is written below:

Ex ante CV_j

$$= (1-\pi)\underbrace{\left(X_{jh}^H + p_A A_{jh}^H + w_j S_{jh}^H + p_M M_{jh}^H\right)}_{CV_h} + \pi\underbrace{\left(X_{js}^H + p_A A_{js}^H + w_j S_{js}^H + p_M M_{js}^H\right)}_{CV_s}\tag{2-14}$$

$$= (1-\pi)\left(X_{jh}^H + p_A A_{jh}^H\right) + \pi\left(X_{js}^H + p_A A_{js}^H + w_j S_{js}^H + p_M M_{js}^H\right)\tag{2-15}$$

where CV_h and CV_s are the *ex post* compensating variation in a health and an ill state, respectively. For the sake of simplicity, it is assumed that $S_h = 0$ and $M_h = 0$ in a healthy state in Equation (2-14). Equation (2-15) means that an individual's willingness to pay is determined as the sum of the utility in a healthy state and in an ill state multiplied by the probabilities of each state.

Ex ante COI of patients i can also be simply written as follows:

$$\text{Ex ante COI}_i = (1-\pi)\left(w_i S_{ih}^M + p_M M_{ih}^M\right) + \pi\left(w_i S_{is}^M + p_M M_{is}^M\right) \qquad (2\text{-}16)$$

$$= \pi\left(w_i S_{is}^M + p_M M_{is}^M\right), \qquad (2\text{-}17)$$

Here assume that $S_h = 0$ and $M_h = 0$, too. *Ex ante* COI is calculated as the *ex post* COI in the ill state multiplied by the probability of illness.

The difference between *ex ante* CV and *ex ante* COI recalls Equation (2-8) and can be written as follows:

Ex ante CV$_j$ - Ex ante COI$_i$

$$= (1-\pi)\underbrace{\left(X_{jh}^H + p_A A_{jh}^H\right)}_{CV_h} + \pi\underbrace{\left(X_{js}^H + p_A A_{js}^H + w_j S_{js}^H + p_M M_{js}^H\right)}_{CV_s} - \pi\underbrace{\left(w_i S_{is}^M + p_M M_{is}^M\right)}_{only\ in\ COI} \qquad (2\text{-}18)$$

$$= (1-\pi)\left(X_{jh}^H + p_A A_{jh}^H\right) + \pi\left[\left(X_{js}^H + p_A A_{js}^H\right) + p_M \underbrace{\left(M_{js}^H - M_{is}^M\right)}_{Difference\ in\ M} + \underbrace{\left(w_j S_{js}^H - w_i S_{is}^M\right)}_{Difference\ in\ S}\right] \qquad (2\text{-}19)$$

Equation (2-19) shows that the sign and the magnitude of the difference between *ex ante* COI and *ex ante* CV depend on:

   (1)   the difference in socioeconomic characteristics between the general population and the patient population (w_j, w_i, M_j, M_i);

   (2)   the impact of illness on consumption of other goods and averting expenditures; and

   (3)   the curvature of utility with respect to income.

First, if there is a relationship between an incidence of an illness and socioeconomic status, there will be a difference in wages and medical care expenditures between the general and patient population. In other words, if there is a higher incidence rate of an illness in the

poor than in the rich, then w_j and M_j in Equation (2-19) would be different from w_i and M_i, respectively.[19]

The second terms, $\pi\left(X_{js}^{H} + p_A A_{js}^{H}\right)$, are explained in the previous section.

Finally, an obvious difference between Equation (2-8) and Equation (2-18) lies in the first terms in Equation (2-19), which are related to the expected utility theory. In comparing *ex ante* CV and *ex ante* COI, the key factor is the shape of utility function associated with risk preferences. Several studies (Arrow, 1971; Freeman, 1989; and Johannesson, 1996) provide a clear distinction between *ex ante* CV and *ex ante* COI: the logic of converting *ex post* COI to *ex ante* COI corresponds to the concept of the expected value of a risky situation, while *ex ante* CV reflects the expected utility function.

Figure 2.1 draws *ex ante* CV and *ex ante* COI assuming risk averse preference.
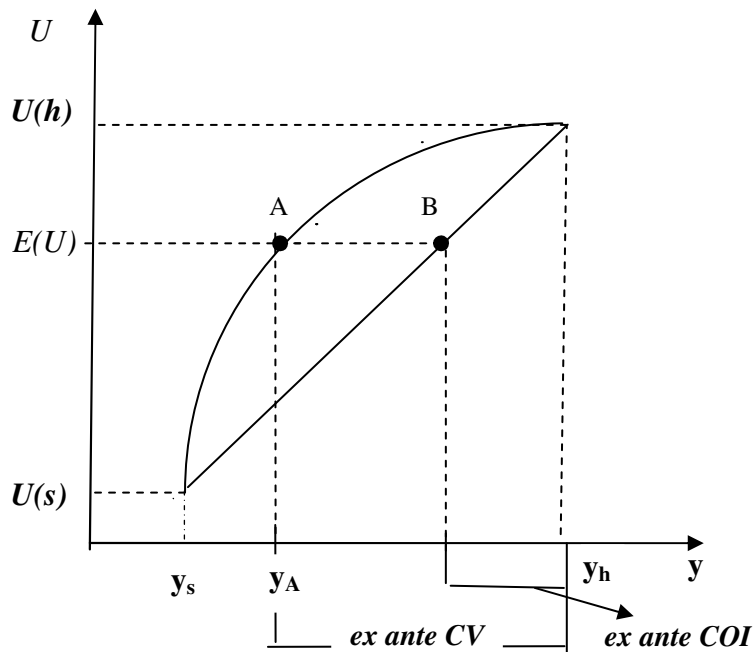
Figure 2.1 *Ex ante* CV vs. *ex ante* COI, assuming risk averse preference [20]

In Figure 2.1, the *x*-axis shows an individual's income in a healthy state and in an ill state as y_h and y_s, respectively. If she were infected by diarrhea diseases, she would lose her income, $y_h{-}y_s$ [=*ex post* COI]. Assume $\pi = 0.3$. Her *ex ante* COI is $y_h{-}y_s$ multiplied by the probability of contacting typhoid fever, i.e., one third of $y_h{-}y_s$.[20]

By contrast, the curve in Figure 2.1 shows the individual's utility as a function of income. The *y*-axis shows her utility in a healthy state and in an ill state as *U(h)* and *U(s)*, respectively. Assume an individual is risk averse with respect to income, i.e., a concave curvature of utility function with respect to income (for further details, see Friedman, 2002). If a government considers introducing a vaccination program against typhoid fever, an individual's *ex post* willingness to pay would be the maximum income she would be willing to give up to be healthy (Johannesson, 1996), which is equal to $y_h{-}y_s$ in Figure 2.1. Her *ex ante* WTP is decided at the point A [= $y_h{-}y_A$], at which she maximizes her expected utility.[21] Therefore, *ex ante* COI is lower than *ex ante* CV in this case, because she is risk averse. The difference between *ex ante* CV and *ex ante* COI (i.e., $\overline{AB}$) is a conventional risk premium — someone averse to risk will pay more than the expected value of the loss in order to avoid a risk (Friedman, 2002).

If one allows different risk preferences, more deviations can be considered. So far it is assumed that people are risk averse. Figure 2.2 illustrates different curvatures of the utility function that reflect different attitudes toward risk.

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[20] Adapted from Johannesson (1996) and Friedman (2002).

[21] If one adopts non-linear probability weighting (Tversky and Kahneman, 1992; Bleichrodt and Pinto, 2000; Starmer, 2000; and Johnson, Houtvan, and Hauber, 2008), instead of the linear weighting of expected utility theory, the discrepancy [= $y_h{-}y_A$] would be greater with small probabilities of getting sick, since people tend to overweight small probabilities and underweight large probabilities. I am grateful to Reed Johnson for this insight.
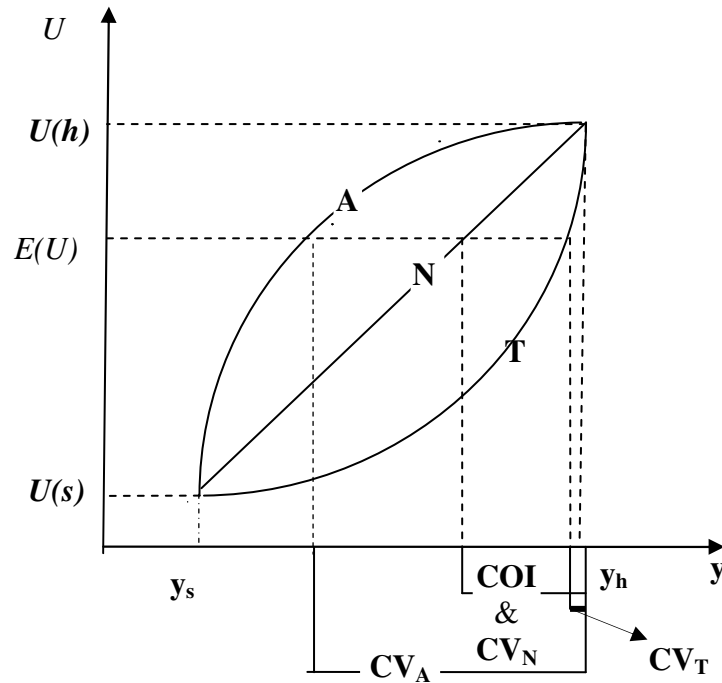
Figure 2.2 *Ex ante* CV vs. *ex ante* COI by different risk attitudes

If the utility function with respect to income is concave, the individual is risk averse and the slope of the curve *A* is diminishing. If she is risk neutral, her utility function is a straight line, *N* (*i.e.*, constant marginal utility), and her *ex ante* CV is the same as the *ex ante* COI. Finally, if she is risk taker, her utility function *T* is convex, i.e., increasing the marginal utility of income (Friedman, 2002). In this case, her *ex ante* CV is lower than the *ex ante* COI. Thus, it is theoretically impossible to generalize the relationship between *ex ante* CV and *ex ante* COI without knowing the curvature of the utility.

In summary, *ex ante* cost-of-illness estimates and the *ex ante* compensating variation are likely to be different. *Ex ante* COI may either overstate or understate *ex ante* CV. However, if one assumes that people are risk averse, *ex ante* COI tends to understate *ex ante* CV because of the significant role that the probability of illness plays. The terms in the square bracket of Equation (2-19) are exactly the same as those in Equation (2-8). As discussed in the section on *ex post* COI versus *ex post* CV, the bracket in Equation (2-19) can be positive or negative. However, here I am interested in the sum of the weighted value at two states (ill and healthy). Assuming the probability of illness is 0.01, then $1 - \pi$ is 0.99.

Finally, it is possible that the first terms of Equation (2-19), if any exists, determine the sign of Equation (2-19).

In section 2.2.1, I mainly focus on the probability term and the curvature of the expected utility function because they are the key differences between *ex ante* measures and *ex post* measures. Otherwise, everything is the same, as explained in the section 2.1.1. In the equation of *ex ante* CV, health status is a choice variable, while in the *ex ante* COI equation, S is not. In other words, the *ex ante* CV equation allows for behavioral responses to illness, but in the *ex ante* COI equation S is exogenously determined.

2.2.2. A model with insurance

The difference between *ex ante* COI and *ex ante* CV with insurance can be written by incorporating insurance into Equation (2-18):

Ex ante CV$_j$ - Ex ante COI$_i$

$$
= (1 - \pi)\left(X_{jh}^H + p_A A_{jh}^H + P_j\right) + \pi\left(X_{js}^H + p_A A_{js}^H + w_j S_{js}^H + p_M M_{js}^H + P_j - K_j\right)
$$
$$
- \left[(1 - \pi)P_i + \pi\left(w_i S_{is}^M + p_M M_{is}^M + P_i - K_i\right)\right]
$$

(2-20)

If an individual purchases full insurance coverage, then Equation (2-20) can be rewritten as follows:

$$
\underbrace{(1 - \pi)\left(X_{jh}^H + p_A A_{jh}^H\right)}_{only\ in\ CV_h} + \underbrace{\pi\left(X_{js}^H + p_A A_{js}^H\right)}_{only\ in\ CV_s} + (P_j - P_i) + \underbrace{\pi\left(w_j S_{js}^H - w_i S_{is}^M\right)}_{Difference\ in\ S}
$$

(2-21)

Again, the difference in premium ($P_j - P_i$) would be smaller than the weighted medical care expenditures by $\pi\left(\pi\left(p_M\left(M_{js}^H - M_{is}^H\right)\right)\right)$. Therefore, with insurance income effects in medical care expenditures decrease and then the gap between *ex ante* CV and *ex ante* COI decreases, too.

3.   *Study design*

In order to measure the economic benefits of preventing diarrheal diseases (e.g., typhoid fever, cholera, and shigellosis), the DOMI program conducted three different studies (of *ex post* COI using the cost of illness method, and of *ex post* WTP and *ex ante* WTP using the contingent valuation method) in seven study sites in China, Vietnam, Bangladesh, Indonesia, and Thailand.

First, the data on private costs of illness were collected in the course of a combined epidemiological and economic study. Laboratory-confirmed patients (or their caregivers) were asked to answer questions about their out-of-pocket expenditures and lost earnings associated with one of the diarrhea diseases 7, 14, and 90 days after onset of illness.

Second, at the end of the follow-up COI interview (on the 14th or 90th day after onset), respondents were asked about their willingness to pay to avoid another episode of the disease like the one they had just experienced. The respondents were asked to mark two prices on a sliding-scale payment card, a lower bound on WTP (WTP^L), and an upper bound on WTP (WTP^U).[22] This measures *ex post* WTP.

There are two aspects of this interviewing method that are important to mention. First, the responses to open-ended questions, if truthful, are direct expressions of value and would be interpreted as measures of compensating surplus (Freeman, 2003) or compensating variation. Second, the WTP estimates from the sliding-scale questions are *ex post* measures. Therefore, these two studies offer a chance to explore the relationship between *ex post* COI and *ex post* CV for morbidity reduction from the perspective of one set of individuals able to offer insight on both measures.

Third, at the same study or neighborhood sites as the above, another contingent valuation study was conducted using the discrete choice question format. People were asked directly via in-person interviews whether they would purchase a hypothetical vaccine (e.g., the typhoid vaccine or the cholera vaccine[23]) for themselves and for other members of their household if it were available to them at a specified price. Descriptions of vaccines with different levels of efficacy and duration and with different prices were randomly assigned to respondents in order to investigate how private individual or household demand for a

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[22] For further details, see Guh et al. (2008).
[23] Since the development of a shigellosis vaccine is under study, the contingent valuation study for investigating shigellosis vaccine demand was not conducted.

hypothetical vaccine changes with variations in these vaccine characteristics (Malik et al., 2005). The responses to this discrete choice question were used to derive *ex ante* willingness-to-pay estimates for a hypothetical vaccine.

4.   Results

4.1.   Sample size and characteristics

In the economic study, a total of 1,786 patients (or caretakers) completed several rounds of face-to-face interviews in seven study sites in Thailand, China, Vietnam, Indonesia, and Bangladesh between 2001 and 2005 (see Table 2.1).

Table 2.1 Comparisons of *ex post* COI and *ex post* WTP in China, Indonesia, Vietnam, Thailand, and Bangladesh for shigellosis, cholera, or typhoid fever (2005US Dollars)

Study site (Sample size)	COI†	WTP^U	Monthly wage^a	WTP^L/ COI	COI > WTP^U	t-value^b
Shigellosis						
Kaengkhoi, Thailand (N=127)	3	14	92	1.9	29%	-2.27 (p=0.99)
Zhengding, China (N=307)	6	6	55	0.5	52%	-0.07 (p=0.53)
Nha Trang, Vietnam (N=279*)	7	14	37	1.3	43%	0.07 (p=0.47)
N. Jakarta, Indonesia (N=425)	23	11	73	0.4	59%	5.54 (p=0.00)
Cholera						
Matlab, Bangladesh (N=234**)	12	1	46	0.001	98%	15.09 (p=0.00)
N. Jakarta, Indonesia (N=176)	40	16	99	0.4	61%	4.41 (p=0.00)
Typhoid fever						
Hue, Vietnam (N=17)	38	11	31	0.1	88%	3.52 (p=0.00)
Hechi, China (N=49***)	141	49	68	0.3	75%	3.08 (p=0.00)
N. Jakarta, Indonesia (N=107)	106	17	81	0.2	80%	5.40 (p=0.00)

Note: † denotes the average COI for hospitalized and non-hospitalized cases, weighted by hospitalization rate. *279 out of 291, **234 out of 278, and ***49 out of 58 adult patients and caretakers answered willingness-to-pay questions. a. Some adult patients, mostly wage earners, provided information on their wages.
b. The null hypothesis is that the mean private cost of illness is equal to the mean upper bound on WTP. The alternative hypothesis is that COI > upper bound on WTP, on average.

Out of the sample, 65 observations were unusable for the comparison between *ex post* COI and *ex post* WTP because they were incomplete for *ex post* WTP questions. Due to the limited socioeconomic information on the sample, an illustrative empirical analysis is conducted below.

4.2.   Ex post CV versus ex post COI

Table 2.1 shows the mean estimates of *ex post* WTP and COI for three diseases in seven different study sites. It immediately reveals several tendencies:

1. The COI estimates for shigellosis tend to be lower than those for both cholera and typhoid fever.

2. The upper bound on WTP estimates on average show a narrower range (USD1-17[24]) regardless of disease or country (except for one extreme case [typhoid fever in Hechi]), while the *ex post* COI estimates have a wider range (USD3-106).

3. Contrary to other empirical results, *ex post* WTP^L estimates are 0.001 to 0.5 times lower than *ex post* COI estimates, except for Kaengkhoi (the fifth column).

4. The high percentage of cases (43-98%) indicates that *ex post* COI estimates exceed the upper bound on WTP, except for Kaengkhoi (the sixth column).

The sixth column of the first panel shows that of the total 1138 WTP^U-COI pairs [=127+307+279+425], around 30 to 60% of patients (or caretakers) gave an upper bound on willingness to pay that was lower than their actual losses. Berger et al. (1987) investigate WTP-COI pairs and report strikingly different results: in the United States, (1) less than 25% of their WTP-COI pairs indicate higher COI than WTP for light symptoms, and (2) the ratio of WTP to COI ranges from 3 to 79.

In the DOMI studies, only Thailand shows the same tendency as reported by Berger et al. (1987). The lower bound on WTP in Thailand is around twice as much as COI on average, and 30% of patients indicated higher WTPs than COIs. This result probably reflects the fact that the public expenditure on health in Thailand covers 60% of the total expenditure

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[24] In this study the currency is 2005US dollars.

on health, whereas the other countries in the study have low health insurance coverage, from less than 10% of the population in Vietnam and Indonesia to 30% in China. Thus, for 29-59% of the sample, the actual expenses associated with shigellosis are higher than the upper bound on WTP.

However, the one-sided t-test (H_0: COI = WTP^U; and H_1: COI > WTP^U) shows that the difference between the upper bound on WTP and COI for shigellosis is not statistically significant in China, Vietnam, and Thailand. In these countries *ex post* COI on average is lower (< USD10) than in Indonesia. In Indonesia, with a higher COI (USD23) for shigellosis, the average COI estimates are higher than the upper bound on WTP. The difference is statistically significant ($p <.001$). Thus, one tentative conclusion at this point is that statistically *ex post* WTP may be close to *ex post* COI when *ex post* COI is lower. However, when *ex post* COI increases, *ex post* WTP does not increase at the same rate, because of more restrictive budget constraints on WTP, and so *ex post* WTP is lower than *ex post* COI. In *ex post* COI estimates, medical care expenditures, especially for hospitalized cases, tend to exceed individual income, while *ex post* WTP estimates show that people are not likely to pay more than their incomes regardless of hospitalization.

The second panel shows the same comparisons for cholera. In North Jakarta, the average COI estimates are high (USD40). One episode of cholera costs patients almost 40% of their monthly income (USD99). Almost 60% of cases express their upper bounds on WTP as lower than the private COI. In Bangladesh all patients were hospitalized for cholera. They lost USD12 on average, but they would be willing to pay only USD1 in order to avoid one episode of cholera. Even more strikingly, almost all patients in Bangladesh answered that their upper bounds on willingness-to-pay measures were lower than their cost-of-illness estimates ($p <.001$).

In the third panel of Table 2.1, the COI estimates for typhoid fever are much higher, on average, than those estimates for shigellosis and cholera. When COI estimates are higher, one can see that WTP estimates do not proportionally increase. Then, the ratio of the lower bound on WTP to COI ranges only from 0.1 to 0.3, which is opposite to the results from other empirical studies.

WTP-COI pairs for typhoid fever show similar results to those for cholera. Of the 172 WTP-COI pairs in Vietnam, China, and Indonesia, more than 75% of patients or caretakers

gave an upper bound on WTP that was lower than their actual losses due to typhoid fever. These comparisons of the paired estimates are statistically significant at a .001 level.

From the broad comparisons, one can see that *ex post* COI estimates are equal to, lower than, or higher than the upper bound on WTP, on average, as predicted in the theory section. COI estimates are also out of proportion in relation to WTP estimates. These results vary by disease as well as by country, specifically, by the insurance mechanisms in the different countries.

Recent studies—macro-level (Preker et al., 2002) and micro-level multi-country studies (Doorslaer, et al., 2007; O'Donnell et al., 2008; and Xu, et al., 2003)—give empirical support to the hypothesis that risk-sharing in health financing affects the level and distribution of financial protection against the cost of illness. In other words, national health financing systems can have a significant impact on the magnitude of private burden resulting from illness. There are also clear differences in financing health care between developed and developing countries. Out-of-pocket payments are the principal means of financing health care in Asia (Doorslaer, et al., 2007), while a combination of general taxation, insurance, and limited out-of-pocket user charges is the preferred instrument for health financing in middle- and high-income countries (Schieber and Maeda, 1997).

Given the effect of insurance on the discrepancies between COI and CV measures, shown in Equation (2-11), how health care is financed at the national level may reduce the magnitude of the difference between CV and COI estimates. However, insurance is not the only important determinant of discrepancies between the two measures across countries. Others include different levels of health-service delivery and use as well as differences in healthcare markets, healthcare technologies, and basic socioeconomic development between developing and developed countries. Nonetheless, I propose that the discrepancies between COI and CV are likely to be much more pronounced in countries where the provision of a public health financing system is weak. There is no study that examines the impact of macro-economic factors on the discrepancies between COI and CV. This study is the first attempt to introduce the variation in insurance mechanisms across countries, a macro-economic factor, as an explanatory variable in comparing COI to WTP estimates.

Table 2.2 shows the national health care financing systems of the five Asian countries by main source.

Table 2.2 Private expenditure on health and national health care system*

| Country | Private expenditure on health per capita per month (2005 USD) | % of total health expenditure | | |
| | | Public | Private | |
		General government	Prepaid & risk-pooling plans	Out-of-pocket payment
Bangladesh	0.6	37	6	56
China	4.3	42	4	54
Indonesia	1.6	35	4	49
Thailand	3.2	64	6	27
Vietnam	2.4	32	2	61

*Sources: National Healthcare Account-World Health Organization (http://www.who.int/nha/country/en/)

Public health care financing coverage is low for most of these countries. Governments cover approximately 32-42% of the total health expenditure. Only Thailand's government provides wider public coverage on health (64%). In other countries out-of-pocket expenses play a significant role, while pooling instruments contribute a negligible share (2-6%) of the total expenditure on health.

Without a social risk-pooling system, people with low incomes face serious financial hardship when a family member falls ill. The first column of Table 2.2 summarizes average private expenditures on health per capita per month. For example, in Indonesia an individual spends USD1.6 on health per month, but one episode of typhoid fever costs seventy times as much (USD106). People can therefore fall into an illness-poverty trap due to only one episode of typhoid fever. Poor households may be pushed down to a poverty level when faced with severe typhoid fever symptoms that require hospitalization.

At the same time, a poor household's willingness to pay is constrained by its limited budget. When a significant portion of the financial burdens associated with diarrhea is imposed on the poor, the difference between *ex post* COI and *ex post* WTP increases. The patients from Matlab, Bangladesh, who had had cholera, for example, lost USD12 but said that they would be willing to pay only USD1. This gap makes sense when one considers that people in Matlab spend an average of 60 cents per month on health care.

For a close examination of the financial burdens associated with one episode of diarrheal disease, Table 2.3 presents the budget share of *ex post* direct COI and WTP out of the monthly income of adult patients. Out of a total of 828 adult cases, only 229 patients reported their earned income.[25] Table 2.3 refers only to these 229 cases. Thus, the analysis using 229 patients is not representative of the total number of patients in the study sites.

Table 2.3 Budget share of direct COI and WTP out of income, and percentage of families borrowing money or selling items in order to cover the treatment cost of diarrhea diseases*

Study site (sample size)	Budget share of direct COI	Budget share of WTP[U]	Families that adopted coping strategies
shigellosis			
Kaengkhoi, Thailand (n=54)	1%	7%	0%
Nha Trang, Vietnam (n=44)	38%	26%	4%
N. Jakarta, Indonesia (n=81)	13%	22%	14%
cholera			
Matlab, Bangladesh (n=32)	19%	1%	13%
N. Jakarta, Indonesia (n=43)	35%	36%	14%
typhoid fever			
Hechi, China (n=27)	169%	120%	14%
N. Jakarta, Indonesia (n=18)	224%	11%	24%

*Sources: The DOMI cost-of-illness studies in each country.

The budget share of income spent on direct COI varies by disease and country, between 1% for shigellosis in Kaengkhoi and 224% for typhoid fever in N. Jakarta. By comparison, the budget share of *ex post* WTP seems reasonable, between 1% and 36%, except for the cases of typhoid fever in Hechi (120%).

In order to cope with the private financial burden of treating diarrhea diseases, some families borrowed money or sold items. On average, an episode of typhoid fever imposed the heaviest burden on families in North Jakarta, Indonesia. Twenty-four percent of adult patients adopted coping strategies because of typhoid fever. In other countries, approximately

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[25] Almost 75% of adult patients did not report their wages, mostly because they were not employed in the labor market (e.g., housewives).

14% of patient families reduced their consumption of other goods or borrowed money because of diarrhea diseases. These percentages may reflect the national health care financing system in each case. In Thailand, with wider public health care financing coverage, no one borrowed or sold items because of shigellosis. In order to hold the household utility constant, the first strategy for meeting treatment costs would be to reduce consumption of other goods, followed by selling items or borrowing money. From the figures presented in Table 2.3, it is safe to say that in developing countries people tend to decrease consumption of other goods when a family member contracts diarrhea disease, contrary to the expectation of Bockstael and McConnell for the consumption of other goods (the first term) in Equation (2-8). According to the consumption against illness studies (Gertler and Gruber, 2002; Morduch, 1995, 1999; Townsend, 1995; and World Bank, 1993, 1995), in developing countries families with sick members do not insure their consumptions because of the lack of insurance. Those who are better off are more likely to spend a large fraction of total household resources on health care (Doorslaer, et al., 2007) in developing countries where few individuals are covered by formal health insurance. Even small costs for common illnesses can be financially disastrous for poor households with no insurance coverage (Xu et al., 2003). Spending a large fraction of household resources on health care means that current consumption of other goods and services must be sacrificed (Doorslaer et al., 2007).

After the analysis of the first component in Equation (2-8), the next step is to examine the third and fourth components, income effects, by using Willig's approximation equation (Equation (2-12)). The data on income elasticity of health care is necessary for Willig's equation. Studies on income elasticities of health care yield two contradictory results. The one using cross-section data shows that income elasticities of health care are less than one (Di Matteo & Di Matteo, 1998; and Hitiris & Posnett, 1992), which means that medical care is a necessity. Income elasticities vary from country to country. In the United Sates, they are very low, ranging from below 0.1 to 0.4.[26] In urban China, on the other hand, the estimated income elasticity ranges from 0.44 to 0.52, according to a recent study by Mocan, Tekin and Zax (2004) of the determinants of the demand for medical care in urban households of China.

The studies using cross-country data, on the other hand, report that income elasticities of health care are greater than one (Gerdtham, Søgaard, Andersson, & Jönsson, 1992;

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[26] For further details see Andersen and Benham, 1970; Newhouse and Phelps, 1976; and Phelps, 1975.

Kleiman, 1974; Newhouse, 1977; Parkin et al., 1987), ranging from 1.15 to 1.31. This result means that medical care is a luxury good, in stark contrast to the result from the cross-sectional data. One possible explanation is that in developing countries equity in health care has not been achieved and so medical care may indeed be a luxury (Gerdtham, Søgaard, Andersson, & Jönsson, 1992). Newhouse (1977) also finds that estimated income elasticities tend to be higher in countries with lower per capita GDP. While the income elasticity of health care is still under debate, it is safe to say that it ranges from 0.4 to 1.4 in developing countries.

I set income elasticities equal to 0.4, 0.6, 0.8, 1.0, and 1.4 and apply Willig's approximation equation to the observations including wage information. Figure 2.3 shows that the ratio of direct COI (a measure of CS) to CV is a function of the budget share of direct medical care expenditures out of income, especially when income elasticity is greater. The reference line shows the acceptable range of using CS instead of CV, which is 10% of the range.
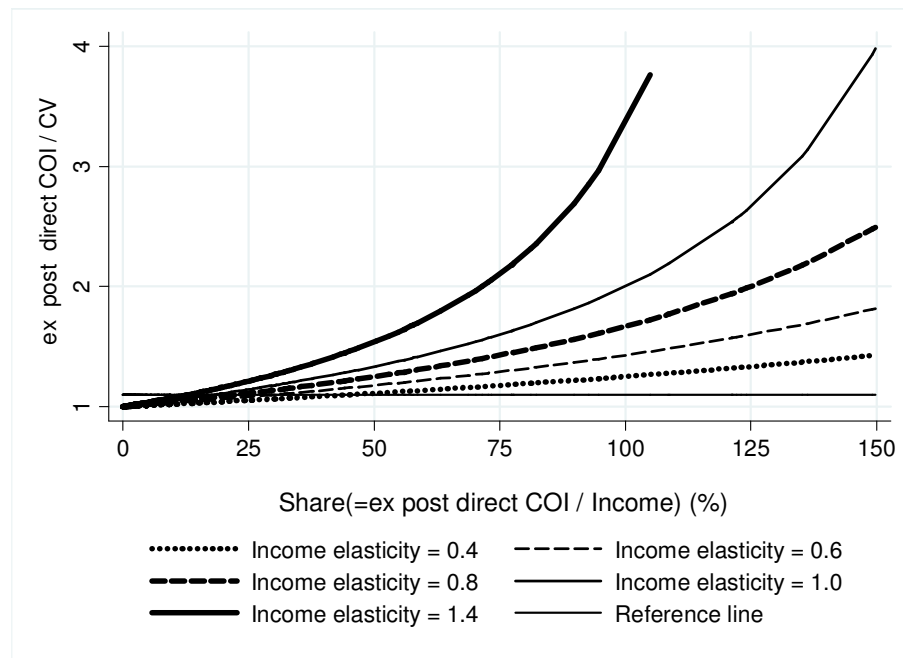
Figure 2.3 Consumer surplus over compensating variation related to the budget share of direct COI by various income elasticities

*For the purpose of presentation, this figure excludes 27 observations with high budget share (>150%) or the larger ratio of *ex post* direct COI to CV (> 4).

If the errors from using CS, instead of CV, are within the 10%, the results are considered reasonable because there are also errors involved in estimating the Hicksian demand and CV.

In Figure 2.3, if income elasticity is 0.6 (i.e., $\eta = 0.6$), COI falls within a reasonable range (90% of WTP-110% of WTP) only for the cases in which the budget share of direct COI is less than 15% of income. If income elasticities increase from 0.4 to 1.4, the budget share decreases within Willig's acceptable range. Except for the cases in which the patients spent a small portion of income on medical treatment for diarrhea, the gap between direct COI and CV is not negligible. More specifically, when both income elasticity and budget shares of medical treatment are not small, the consumer surplus of medical care demands tends to overstate CV by factors of 45 at maximum.

In order to summarize the results of this study, Table 2.4 shows the simple comparisons between *ex post* COI and *ex post* WTP.

Table 2.4 *Ex post* COI vs. *ex post* WTP in the DOMI studies

	shigellosis	cholera	typhoid fever
China	$COI = WTP^u$	n.a.	$COI > WTP^u$
Vietnam	$COI < WTP^u$	n.a.	$COI > WTP^u$
Thailand	$COI < WTP^u$	n.a.	n.a.
Bangladesh	n.a.	$COI > WTP^u$	n.a.
Indonesia	$COI > WTP^u$	$COI > WTP^u$	$COI > WTP^u$

A quick look at Table 2.4 reveals that there is no clear indication that COI is the lower bound on WTP. When a consistent method is used in estimating *ex post* COI and *ex post* WTP associated with diarrhea diseases across several Asian countries, COI estimates are equal to, lower than, or higher than the upper bound on WTP, on average. The results using multi-country data are inconsistent with those of empirical studies based on single-country data, which tend to disregard macroeconomic factors. This study suggests that future research should consider macroeconomic factors as one explanation for the discrepancies between COI and CV estimates.

4.3.   Ex ante COI versus ex ante CV

The comparisons between *ex ante* COI and *ex ante* WTP are conducted only for cholera cases. In order to estimate *ex ante* COI, the incidence rate is multiplied by *ex post* COI. *Ex ante* WTP estimates are obtained from contingent valuation studies (Islam et al., 2007; Malik et al., 2005; and Whittington et al., 2007).

As shown in Table 2.5, the incidence rate of cholera is between 0.3 and 9 per 1000 persons per year. Multiplying that rate by *ex post* COI gives an estimated *ex ante* COI ranging from 1 cents to 7 cents in 2005US dollars.

Table 2.5 *Ex post/ex ante* COI and *ex ante* WTP estimates for cholera

Site	Parameters	Estimates (2005 USD)		Incidence rate[c] Ratio (=*ex ante* WTP/*ex ante* COI)	
		Children	Adults	Children	Adults
Matlab, Bangladesh	*ex post* COI[a]	24	33	0.003	0.001
	ex ante COI	0.07	0.03	10	35
	ex ante WTP[b]	0.7	1.2		
N. Jakarta, Indonesia	*ex post* COI[a]	56	62	0.0009	0.0003
	ex ante COI	0.05	0.02	25	30
	ex ante WTP[b]	1.2	0.5		
Kolkata, India	*ex post* COI[a]	20	12	0.004	0.009
	ex ante COI	0.07	0.01	27	84
	ex ante WTP[b]	1.9	1.0		

Sources: [a] the DOMI cost-of-illness studies; [b] the DOMI contingent valuation studies; [c] the DOMI epidemiology studies

The healthy respondents were willing to pay from 50 cents to 1.9 U.S. dollars for hypothetical cholera vaccines in order to be protected from cholera for one year. *Ex ante* WTP is 10 to 84 times higher than *ex ante* COI for cholera, which is consistent with the experimental results of Freeman (1989). Freeman (1989) simulates comparisons for a range of each parameter and finds that *ex ante* CV for risk reduction can exceed *ex ante* CS by factors of 0.1 to over 50. However, it is not certain whether most of the ratios (i.e., 10-84) in this study are inherited from risk premium ($\overline{AB}$ of Figure 2.1) or income effect. Further interrogation is required with appropriate socioeconomic information about the patients. For

example, in examining income effect or deciding the shape of utility function it is critical to obtain data on income and medical care expenditures associated with a given illness, as well as socioeconomic information about patients.

5. *Conclusion*

Although the problems of a cost-of-illness approach are well known, there continues to be theoretical confusion about whether the cost-of-illness estimate is the lower bound on the compensating variation.

However, Bockstael and McConnell (2007) have recently clarified the source of confusion and explained the possible disparities within the context of non-marginal changes. Though they shed light on the comparisons, their lack of macroeconomic perspective makes their explanations relevant specifically to the context of developed countries. In order to apply their logic to developing countries, I incorporate insurance into Bockstael and McConnell's model and then I empirically find that when *ex post* COI estimates are higher compared to income, *ex post* WTP estimates for diarrhea diseases are more likely to be constrained by income. Thus, the magnitude of discrepancy between the two measures increases with higher *ex post* COI. This result due to income effect tends to be significant in developing countries because of their lack of a risk-pooling system.

The responses to one episode of diarrheal disease in developed countries are different from those in developing countries, where people lack health insurance and the coverage of public expenditures on health is lower, between approximately 12% and 35% of the total expenditures on health. These macroeconomic factors determine the share of direct COI out of household income. With a larger budget share of direct COI relative to income, the income effects in explaining the difference between *ex post* COI and CV tend to be greater. In that case, the differences between COI and WTP do not look negligible. In developing countries, the income effects result in higher *ex post* COI estimates relative to *ex post* WTP estimates.

When incorporating uncertainty, *ex ante* COI estimates (=*ex post* COI × incidence rate) substantially underestimate the true individual benefits of reduced morbidity. It is mostly because the *ex ante* compensating variation reflects the expected utility, while the *ex ante* cost of illness corresponds to the expected value of adverse events. Thus, healthy and risk-averse people are more likely to be willing to pay more for a hypothetical vaccine than

their expected COI because of the curvature of the utility function. Empirically, *ex ante* cost-of-illness estimates tend to be 3 to 84 times lower than *ex ante* WTP. The observed discrepancy between the two measures in the empirical studies is far too wide for COI to be used as a lower bound on WTP estimates.

Based on the findings of this study in developing country contexts, the COI estimates are not reliable and do not give any guidance as to the lower bound on the theoretically true estimates in measuring the benefits of reduced morbidity. Therefore, the value of COI estimates in decision-making may be limited (Freeman, 1989; Rice, 1994; and Wiseman and Mooney, 1998).

These findings are, of course, preliminary due to lack of information, especially on household income. In order for these findings to be definitive, the following recommendations are made. Future studies need to collect information on household income, changes in household consumption of other goods, and any preventive expenditures associated with illnesses, as well as macroeconomic data from several sources on national health insurance coverage and the percentage of public expenditure on health out of the total expenditure. Researchers should also look to macroeconomic cross-country regressions for valuable insight into the discrepancies between COI and WTP measures derived from microeconomic studies, since, as this study has shown, macroeconomic factors may be one of the explanations for these differences.

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CHAPTER III

TRADE-OFF BETWEEN EFFICIENCY AND EQUALITY IN SCHOOL-BASED TYPHOID

VACCINATION PROGRAMS IN NORTH JAKARTA, INDONESIA

1.   Introduction

Typhoid fever has caused more than 21 million illnesses and more than 200,000 deaths in the year 2000 (Crump et al., 2004). The incidence rates are highest in South and Southeast Asia, which account for an estimated 91% of the global typhoid fever disease burden (Crump et al., 2004). Children living in endemic areas are at particularly high risk (Sinha et al., 1999; Saha et al., 2001).

In Indonesia, there are an estimated 1.08 million new cases of typhoid fever every year, causing up to 20,000 deaths (Punjabi, 1998). Typhoid fever imposes an economic burden on a society through subsidized treatments in public health care facilities as well as the private medical care paid by individuals or families. Typhoid fever is also responsible for lost productivity from those who are sick or are taking care of ill family members.

In the absence of public interventions to improve water and sanitation in the near future in developing countries, efforts have been directed towards disease prevention through vaccines. The WHO recommends routinely immunizing school-aged children with available new-generation vaccines in areas where the disease burden is high (WHO, 2003a). The Indonesian National Institute of Health Research and Development (NIHRD) is considering immunization for the most impoverished children living in typhoid fever-endemic areas (e.g., Jakarta) with the Vi polysaccharide vaccine (Agtini et al., 2006), one of the new-generation vaccines against typhoid fever.

This paper examines school-based immunization against typhoid fever in North Jakarta in order to assess the merits of such a program. Two vaccine delivery modes and three financing schemes are examined. The typhoid vaccines would be administered either as a single injection

or together with the tetanus toxoid (TT) booster that is currently administered in Indonesia under the schoolchildren immunization program (BIAS).[27] The BIAS program has been conducted in primary schools for the past 11 years. Each November, health workers visit all schools nationwide to administer one dose of diphtheria-tetanus toxoid (Td) or tetanus toxoid vaccine. The safety and immunogenicity of Vi polysaccharide, when given simultaneously with TT vaccine booster, is under study (Agtini et al., 2006). In this paper I compare two administration modes under an assumption that administering the typhoid vaccines along with the TT booster vaccines is safe. I also examine three financing schemes for the immunization: the government scheme in which the Indonesian government pays all of the immunization costs, the procurement assistance scheme financed by external donors, and a user fee scheme.

Decisions about optimal vaccination programs involve tensions between efficiency and equity (Levy et al., 2007), especially in the developing world. Immunization is one of the most cost-effective interventions to prevent a series of major illnesses (World Bank, 1993). Immunization in developing countries, however, does not equally cover children from all socioeconomic strata of society. Children in the poorest quintile are less likely to be fully immunized than those in the wealthiest quintile. Given the fact that immunization services are largely the domain of the public sector and that immunization services tend to favor the wealthy at the expense of the poor, finding ways to improve access to immunization services for the poor is a significant policy challenge, especially in developing countries (Nichter, 1995; Pande and Yazbek, 2002; Bonu, Rani, and Baker, 2003; and Schwartz and Bhushan, 2004).

Most vaccination policy analysis, however, mainly takes efficiency into account in order to find the lowest-cost program or the one providing maximum net benefits. Equality in the distribution of benefits is often overlooked (Yitzhaki, 2003) because of lack of data or interest. The absence of a systematic framework to consider both efficiency and equality results in a one-sided immunization policy that disregards or, at worst, enlarges the gap of inequality in children's immunization rate.

In order to address this limitation, I incorporate efficiency measures and equality indicators within one framework. I believe that using quantitative indicators of inequality based

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[27] The primary immunizing course of three doses of DTP (diphtheria-tetanus-pertussis) is given in the first month of life. For the full protection, at least three more doses of vaccine containing tetanus toxoid should be given to females before childbearing age (Galazka, 1993). The WHO considers the optimal time for boosting boys and girls to be at 6, 7, and 8 years of age. School-based programs for administering booster doses of tetanus toxoid may be the best strategy against tetanus (WHO, 1995).

on parents' level of education will help avoid immunization options that are dominated by efficiency at the expense of equality.

There is another limitation to current immunization policy analysis that this paper seeks to address. It has been assumed that vaccination delivery costs through school systems might be cheaper than the costs through other delivery modes, but there are no data or studies to support such an assumption. Here I examine the rich experience and the data on school-based immunization in Indonesia to show that the delivery cost through school-based immunization is approximately two thirds that of other modes.

The next section of this essay contains a brief review of the literature on equality in immunization. Section 3 discusses methods to measure inequality and efficiency. Then the three following sections explain the background of the study sites, 12 immunization schemes to be examined, and data sets used in the analysis. In section 7, I separately present the empirical results in terms of equality and efficiency as well as trade-offs between equality and efficiency according to different vaccination schemes; here I also conduct the Monte Carlo probabilistic sensitivity analysis in order to test the robustness of the results. In section 8, I present my conclusions.

2.   *Literature Review*

Immunization is one of the most cost-effective interventions to prevent a series of major illnesses, particularly in environments where children are undernourished and many die from preventable diseases (World Bank, 1993). Immunization in developing countries, however, tends not to cover children from the poor in a society. Children in the poorest quintile are less likely to be fully immunized than those in the wealthiest quintile (Gwatkin, Nichter, 1995; WHO, 1999; Gwatkin and Deveshwar-Bahl, 2000; Gwatkin and Garima, 2001; Rutstein, Johnson, Pande, & Wagstaff, 2000; Vandemoortele, 2001; Pane and Yazbeck, 2002; and Delamonica, Minujin, and Gulaid, 2005).

Gwatkin and Deveshwar-Bahl (2000) use household data collected by the Demographic and Health Survey program for 41 countries and overview the information about socioeconomic inequalities in full immunization coverage. They find that virtually everywhere full immunization rates (BCG, measles, DPT, and polio) are considerably higher among the rich than among the poor. On average, the rate is 25-75% greater in the richest than in the poorest quintile

of a country's population. Since diseases that can be prevented through vaccines are generally thought to be concentrated primarily among the poor, Gwatkin and Deveshwar-Bahl conclude that there is a significant mismatch between the population groups that most need immunization and the population groups that immunization programs most frequently serve.

Pande and Yazbeck (2003) use data from the India National Family Health Survey and analyze socioeconomic inequalities in immunization in India. They find that wealth and regional inequalities are correlated with overall levels of immunization. On one hand, there is a basic system failure that leaves even the wealthiest children with high levels of no immunization. On the other hand, any initial improvements in the degree of full immunization result in a significant increase in the immunization rate of wealthy children, causing wealth inequality to increase also. However, once performance has reached a critically good level (low no immunization and high full immunization), the immunization rate for the poor increases and inequalities decrease. Victoria et al. (2000, 2001) report similar patterns for immunization in Brazil.

Schwartz and Bhushan (2004) examine immunization equity through a public-private partnership in rural areas of Cambodia. In the mid-1990s, the Cambodian primary health care system was not able to deliver an adequate level of services (Bhushan, Keller, and Schwartz, 2002). Only 39% of children were fully immunized in 1998 (NIS, 2000). Thus, the Ministry of Health collaborates with international nongovernmental organizations (NGOs) to deliver primary health care services. Schwartz and Bhushan find that whether a child is fully immunized is affected by household wealth, as well as other factors such as whether the household lives in an urban or rural area, the mother's level of education, the mother's age, and the child's sex. They also find that children in the poorest households in the districts served by NGOs are more likely to be fully immunized than poor children living in districts served by the government.

Indonesia's immunization program shares these characteristics. Nationally, the vaccine coverage rate for BCG, measles, DPT, and polio differs by income: 43% for the poorest population quintile vs. 72% for the richest quintile (Gwatkin and Deveshwar-Bahl, 2000; and Gwatkin and Garima, 2001).

However, all of the existing studies were conducted after the mass immunization campaign (post-campaign studies). There are no studies that examine the expected effect of immunization programs on inequalities in vaccine coverage that are associated with pre-campaign socioeconomic status (pre-campaign studies).

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3.   Methods

3.1.   *Measuring socioeconomic status*

Immunization inequalities have been defined in socioeconomic terms, and the few studies examining inequalities in immunization rates have mostly used household income or consumption to measure socioeconomic status. However, several studies that examine inequalities in health but do not focus on immunization have used a variety of different measures of socioeconomic status, including income (van Doorslaer, Wagstaff, and Bleichrodt et al., 1997), consumption (Wagstaff, 2000), size or ownership of household assets (Gwatkin, Rutstein, Johnson, Pande, & Wagstaff, 2000; and Koenig, Bishai, and Ali, 2001), as well as educational attainment (Kunst and Mackenbach, 1994; and Schwartz and Bhushan, 2004). Educational attainment and income are the most common proxy measures of human capital, [28] and a higher level of education ought to be correlated with increased earning power (Muller, 2002). In addition, more schooling, especially of mothers, seems to correlate with better health for families. In this study I use the level of parental education as an indicator of socioeconomic status in measuring immunization inequalities.

3.2.   *Measuring inequalities by parents' education*

There are several indexes of inequality in the literature on the measurement of inequality. They are the mean of the distribution, the coefficient of variation, the variance of logs, the Gini coefficient, the Theil index (1967), and the Atkinson index (1970, 1975) (see Levy et al., 2006 for further details of each index). The Gini coefficient (*G*), a well-known measure for the magnitude of inequalities in health, is applied for the analysis, whose simple formula (Brown, 1994) is shown below:

$$G = \left| 1 - \sum_{k=0}^{n-1} \left(X_{k+1} - X_k \right)\left(Y_{k+1} + Y_k \right) \right|, \tag{3-1}$$

where *X* is the cumulative proportion of the population variable and *Y* is the cumulative proportion of cases expected or avoided.

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[28] See Barro and Sala-i-Martin, 1995; Barro and Lee, 1996; Barro, 1998; and Kalaitzidakis, Manuneas, Savvides, and Stengos, 2001.

All children in the sample are ranked by the educational attainment of the household heads (usually their mother or father). The Gini coefficient ranges from 0 to 1, with 0 representing perfect equality and 1 representing total inequality. The Gini coefficient is defined as twice the area between the Lorenz curve and the diagonal (area *A* of Figure 3.1).
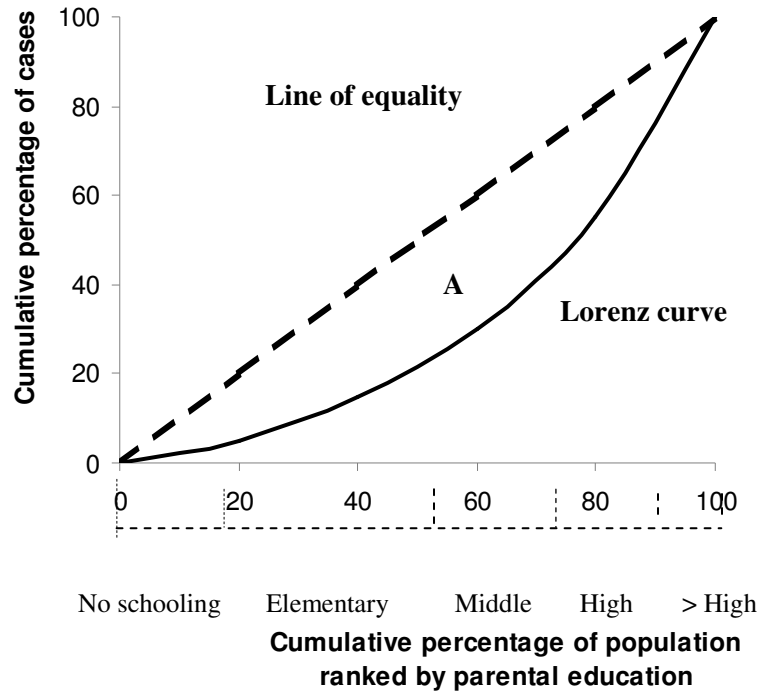
Figure 3.1 An example of the Lorenz curve

The Lorenz curve shows the percentage of immunized children (*y*-axis) against the cumulative proportion of children (*x*-axis, beginning with those whose parents have not finished elementary school and ending with those whose parents have more than a high school education). If immunization is distributed equally among children from all parental educational attainment levels, then the Lorenz curve meets the diagonal. In a perfectly equal society, the 18% of children with the least educated fathers would account for 18% of all immunized children. The 55% of children whose fathers did not go to middle school would account for 55% of the total

immunized cases, and so on. The further the curve is from the diagonal (area *A*), the greater is the degree of inequality in immunization.

3.3. *Measuring efficiency*

The results of economic analyses (e.g., cost-effectiveness analysis or cost-benefit analysis) will vary depending on the perspective assumed by the analyst (Drummond et al., 2005), since that perspective determines which costs should be included and how they should be valued (Szucs, 2005). For example, a health care providers' perspective focuses on the number of cases prevented by immunization programs. From a public-sector budgetary perspective, public-sector costs that are avoided or costs borne by healthcare providers are important criteria. From a comprehensive societal perspective, all costs and benefits should be identified, regardless of who incurs the costs and who receives the benefits (Szucs, 2005).

Net benefits

In justifying an immunization program, positive social net benefits would be one of the necessary conditions. Assuming that all or most benefits and costs of an immunization program can be quantified, the criterion of positive net benefits dictates that the benefits of introducing typhoid vaccines outweigh the costs. In the analysis I focus on two different measures of net benefits based on two different perspectives: a net public budgetary perspective and a net societal perspective.

The first net benefit measure is taken from a public-sector budgetary perspective and subtracts the vaccine cost from the public-sector treatment cost savings,

Net public benefits = [Avoided public COI$_i$]-[Total vaccine cost$_i$]

$$= \sum_i \sum_{t=0}^{2} \left[c_i \times (public\_COI_i) \big/ (1+r)^t \right] - \sum_i Q_i V_c^S \qquad (3\text{-}2)$$

where c_i is the number of cases prevented by an immunization program in group *i* and *r* is a social discount rate, assumed as 3%. Q_i denotes the number of individuals vaccinated by the program in group *i* and V_c^S denotes the cost of the Vi vaccine per immunized child, including the

procurement and delivery cost, as well as the private cost of obtaining the vaccine (i.e., transportation cost and travel/waiting time).

The second net benefit measure is taken from a societal perspective and adds willingness to pay (WTP) estimates to the first net benefit. WTP measures include pain, suffering, preventive expenditures associated with illness, and the value of reduced mortality risk, as well as actual costs associated with illness.

Net societal benefits = [WTP_i + public COI_i]-[Total vaccine $cost_i$]

$$= \sum_i \sum_{t=0}^{2} \left[\left(Q_i \times WTP_i + c_i \times public\_COI_i \right) / (1+r)^t \right] - \sum_i Q_i V_c^S \qquad (3\text{-}3)$$

Cost-effectiveness measures[29]

While the cost-benefit analysis helps a decision-maker determine whether to pursue a particular goal, the cost-effectiveness analysis helps a decision-maker who has already decided to pursue the goal determine the lowest cost approach (Hinman, 1999). Assessing the cost-effectiveness of a vaccination program can help guide decisions about introducing vaccines versus other health interventions.

Since the early 1990s, standard cost-effectiveness methods have been developed by the Disease Control Priorities Project (Jamison et al., 2006) and WHO's CHOICE project (WHO, 2003b).[30] It is useful to compare the "cost-effectiveness" (the cost per unit of effect) of a particular intervention either to those of alternative interventions that produce a similar effect or to a standard cut-off value (Evans and Hurley, 1995). If an intervention's cost-per-unit effect is less than that of one or more alternative interventions, it will be judged the "more cost-effective." If its cost-per-unit effect is less than a cut-off value, it may simply be judged "cost-effective." Either result provides support for using the intervention as part of a health program, ensuring that the desirable effect is maximized subject to the constraint of a fixed budget (Bobadilla et al., 1994).

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[29] The basic analysis tool for cost-effectiveness measures is developed by the UNC-DOMI economic team.

[30] For more information on the DCP, see http://www.dcp2.org; for CHOICE, see http://www.who.int/choice.

The third measure of efficiency in this study, the incremental cost-effectiveness ratio, is again taken from a public-sector budgetary perspective. It is the public dollars spent on vaccination minus the public-sector cost savings per disability-adjusted life years (DALY) averted:

$$\frac{\sum_i Q_i V_c^S - \sum_i \sum_{t=0}^{2} \left[c_i \times (public\_COI_i)/(1+r)^t \right]}{DALY \ averted} \ . \tag{3-4}$$

The DALY measure includes two components: years of life lost due to premature mortality (*YLL*) and years lived with disability (*YLD*). The DALY loss from mortality is calculated on the basis of the standardized life expectancy for children.

In order to compare the "cost-effectiveness" of the Vi vaccination with the cut-off value, I use the common threshold, per capita gross domestic product (GDP). A "very cost-effective" intervention is one with a cost-effectiveness ratio less than the per capita GDP, while a "cost effective" intervention is one with a ratio less than three times the per capita GDP. To determine whether typhoid immunization competes with other important interventions, one would examine cost-effectiveness estimates (per DALY averted) of those other health interventions.

4.   Background

Jakarta is the capital city of Indonesia and consists of five municipalities (South Jakarta, East Jakarta, Central Jakarta, West Jakarta, and North Jakarta). The total area is approximately 662km^2. In 2001 the population of Jakarta was about 9.7 million, with a growth rate of 0.52% (Statistics DKI Jakarta, 2002, see Figure 3.2). But the population rises up to 11 million during the day, when people commute into the city from suburban areas for work. The monsoon-type climate is characterized by two seasons, with the dry season running from June to September and the rainy season from December to March.
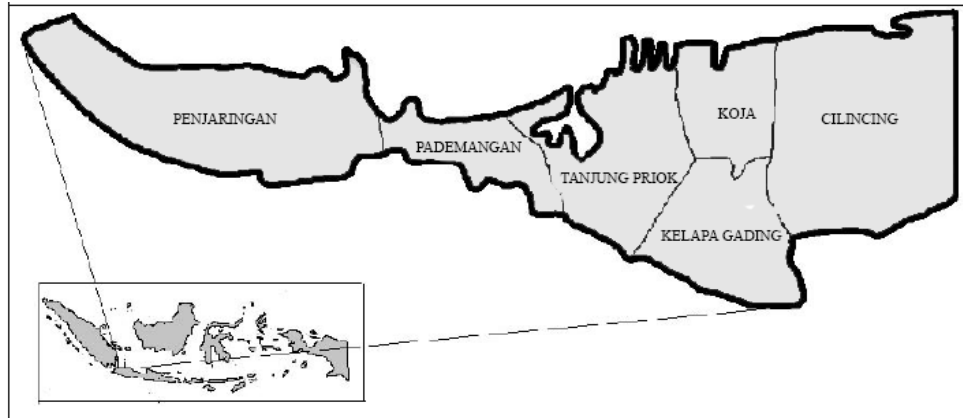
Figure 3. 2. North Jakarta and Jakarta Bay, Indonesia

In Indonesia, diarrhea is the third leading cause of overall morbidity and infant mortality (Nazir et al., 1985; Simanjuntak et al., 1998; UNDP, 2005). It is widely acknowledged that various diarrhea diseases are spread via fecal-oral routes, and that these routes are far more heavily traveled where water supplies and sanitary conditions are inadequate (McGranahan et al., 1997).

The sources of the existing water supply system in Jakarta are surface water, ground water, and spring water (Shofiani, 2003). In 2001 only about 25% of households in Jakarta had piped water supplied to the dwelling (Demographic and Health Survey, 2003). The average domestic water consumption is about 77l/capita/day for a household, which is lower than other mega-urban regions in Southeast Asia (ADB, 2005; Yulinawati 2005). The problem with drinking water in Jakarta is not only scarcity, but also inefficient allocation, inequitable pricing, and microbial contamination.

The households with piped water connections are those of relatively high-income families, which spend 2% of their incomes on water (ADB, 2005). Another 25% of households, with neither house connections nor shallow wells, rely upon public wells and standpipes or have their water delivered by water vendors. Most of them are low-income families, and they spend 7% of their incomes on water.[31] The remaining population (half of the households) draws its

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[31] The vendor water costs approximately USD3-5/m^3, which is 10-25 times higher than the cost of piped water, USD0.3/m^3 (ADB, 2005)-USD0.6/m^3 (UN-HABITAT and Annan, 2003). Water vendors buy water at USD0.4/m^3 from public taps and sell at USD3-5/m^3.

water supply from shallow wells. Groundwater is accessible within a few meters of the surface in most of Jakarta. However, most of this groundwater is not potable.

Most urban dwellers rely on on-site sanitation rather than a sewer network to dispose of human waste. The on-site septic tank and cesspits are often connected to street drains with no waste treatment.

Jakarta's government attempted to solve the clean water supply problem by privatization. Despite this governmental intervention, however, safe water and better sanitation do not seem to be achievable in the near future in Jakarta. Therefore, the prevention of water-transmitted diseases through vaccines, as recommended by the WHO, is considered to be the second-best measure.

New-generation typhoid vaccines

There are two licensed and internationally available typhoid vaccines. The currently licensed liquid formulation of Ty21a has shown protective efficacy of 53-78% in children for at least five years. The Vi polysaccharide vaccine has efficacy of 64-72% in children and adults for at least three years (Ivanoff et al. 1994; Levine 1998; and Hessel et al. 1999). Both vaccines are licensed for use in persons two years and older, although data are limited on the clinical protection conferred by the vaccines to children under five years of age. These new-generation typhoid fever vaccines are licensed by the national Food and Drug Control Organization (POM) in Indonesia, too.

Currently vaccines against typhoid fever (e.g. Vi polysaccharide and Ty21a) are available in Indonesia. However, they cost between USD6 and USD26 per dose. Since about 86% of Indonesians are not covered by any form of health insurance scheme (Thabrany, 2001);[32] most of the typhoid vaccine cost is paid by clients out of pocket. With approximately 56% of Indonesians living on less than USD2 per day (WHO, 2006b), the vaccine is too expensive for anybody but the rich.

Health sector financing and immunization

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[32] Two main insurance companies, Askes and Jamsostek, cover 10% of the Indonesian population, while commercial insurance covers 4% (Thabrany, 2001, 2003; Hidayat et al., 2004; WHO, 2006b).

By the mid-1990s Indonesia had recorded high Expanded Program in Immunization (EPI) coverage, with at least 80% of all children receiving basic EPI vaccines before their first birthdays (WHO, 2007b). But in 1997 the Asian financial crisis, the end of the Soeharto government, and the decentralization of health services negatively affected the immunization program (USAID, 2008). During the crisis, only 52% of children were immunized against the six major vaccine-preventable diseases targeted by the EPI program (USAID, 2008). The formerly high-performing immunization program has fallen to dangerously low levels, leaving many infants and young children seriously exposed to the risk of disease and death (USAID, 2008).

In addition, the government's health care budget has been tight. During 2005, total expenditures for health were only 2.7% of gross domestic product, equivalent to USD34 per capita (WHO, 2006a). These are far below the average health expenditure for developing countries, 4.5% (WHO, 2006b). Out of the total health expenditures in Indonesia, 65% (USD22 per capita) was spent by the private sector, whereas only 35% (USD12 per capita) was spent by the government (WHO, 2006a). Half of the total expenditure is out of pocket (USD17 out of USD34 per capita).[33] The Ministry of Health (MOH) covered only 10% of the total health expenditure (USD3 per capita in 2005USD).

However, Indonesia had recovered by 2000 from the economic crisis of 1997 (Tjiptoherijanto and Remi, 2001; Cogneau and Grimm 2004; and Strauss et al., 2004). In addition, external donors have buffered the profound impacts of the crisis and the decentralization of the health sector by increasing funding targeted to the poor. Michaud (2005) tracked the external resource flows to the health sector in Indonesia and found that USD188 million of external funds were spent in the health sector in 2002. There was no significant change in health sector spending before and after the economic crisis, according to the WHO (2006a).

Recently the GAVI/Vaccine Fund committed USD40 million over five years (2002-2007) to support immunization services (USD16 million), injection safety (USD10.7 million), and Hepatitis B vaccines (USD13.2 million) (GOI, 2001, 2004, 2006; and Michaud, 2005). USAID also provided a USD20 million grant in order to increase the EPI immunization coverage for two years, beginning in 2007. Both projects have committed to building the capacity to sustain

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[33] The author's calculation using WHO (2006a).

immunization programs. These recent efforts may provide a better environment for the school-based immunization project against typhoid fever that is considered here.

5.   *Immunization scheme*

The school-based immunization program considered in this paper would be conducted in two impoverished sub-districts, Koja and Tanjung Priok, in North Jakarta with a combined population of 580,234.[34] The Vi vaccine would be administered at schools. In the two sub-districts, there are 204 primary schools and 90 junior high schools. Children who do not attend school are encouraged to go to the nearest school for immunization.

Initial informational meetings would be held a couple of months before the immunization campaign. Posters and information leaflets on prevention of typhoid fever, the project's aims, and immunization dates would be distributed to the puskesmas (community health center), schools, and households (through students). The vaccines would be delivered from a local cold room to the logistics office at NIHRD on daily basis, and then transported to the schools in project vehicles. Vi polysaccharide vaccine must be stored at a temperature of 2-8˚C (Agtini et al., 2006).

The Vi polysaccharide vaccine is assumed to be locally produced. One vial contains 10-20 doses. Given the Indonesian policy of discarding opened vials of vaccine at the end of a day, the vaccine wastage rate is assumed as 10%.[35]

The immunization programs are categorized by vaccine delivery mode, the financing method, and target group. The vaccine would be delivered either by single injection or simultaneous administration. "Simultaneous vaccination" is when multiple vaccines are administered, usually in separate limbs (e.g., one in each arm). The single injection of the Vi vaccine is a baseline scenario in case administering it simultaneously with the TT booster turns out to be unsafe. However, there is usually no contraindication to simultaneous administration of any vaccines, except in the case of cholera and yellow fever or two live vaccines at the same

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[34] The population figure from SUSENAS 2003 is updated to 2007 using the growth rate of population in Jakarta, 0.52% (Statistics DKI Jakarta, 2002).

[35] It is worth noting the opposite relationship between vial format and wastage rate. Multi-dose vials, in general, sell at a lower per-dose price and occupy less cold-chain capacity than single-dose formats. However, higher wastage rates of multi-dose vials may offset these benefits (for further details see Drain, Nelson, and Lloyd, 2003). In order to immunize more children at a minimum cost, the best strategy would be to use 20-dose vials and single-dose vials together.

time (Nafarrete, 2007). Giving a child several vaccines at the same time offers two practical advantages. First, more children can be immunized. Second, it means fewer visits to health care facilities, which saves both time and money for parents as well as for the public sector.

It is worthwhile distinguishing "simultaneous vaccination" from "combination vaccine." A combination vaccine consists of two or more separate vaccines that have been combined into a single shot. Examples of combination vaccines in current use are DTaP, trivalent IPV (three strains of inactivated polio vaccine), MMR (measles-mumps-rubella), DTaP-Hib, and Hib-hepatitis B (Hep B). Individual vaccines should not be mixed in the same syringe unless they are licensed for mixing. The safety and immunogenicity of the Vi vaccine when given simultaneously with the TT booster in separate syringes or when combined in a single syringe is under study. The combination vaccine is not examined in this analysis because its licensing may take longer and there is a great degree of uncertainty as to the cost of manufacturing it.[36]

There are two target groups. The first is only the students who attend primary or junior high schools, ages 5-14. The second is all children who are old enough to receive the vaccine safely (2 years) but under 15 years old.

There are three financing schemes for the immunization. In the government scheme, the Indonesian government would pay all of the immunization costs. The procurement assistance scheme represents a cost-sharing arrangement. The vaccine procurement cost would be financed by external donors and the vaccine delivery cost by the Indonesian government. Indonesia is eligible for five-year (in most cases) time-limited grants from the GAVI Alliance (2006) to introduce new vaccines.[37] This cost-sharing scheme is the same as that of the ongoing DTP-Hepatitis B vaccination program. The last financing scheme is a user fee system. In this financial scheme, parents pay a user fee for their children's vaccination against typhoid

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[36] The price of a hypothetical combination vaccine depends on whether the cost of research and development is absorbed by the vaccine price. The information on the prices of combination vaccines is somehow contradictory. The experience of the PAHO revolving fund in procuring a pentavalent vaccine (DPT, HBV, Hib) shows that combination vaccines would have only a negligible effect on the overall cost of vaccination; that is, the cost of the combined vaccine was slightly more than the sum of the components (UN, 2002). However, the combined TT-typhoid vaccine is new and plenty of research costs may be built into the vaccine procurement cost. Like Hep B, it may be costly. The price of DTP and Hep B was USD0.14 and USD0.28 in 2004, respectively. The sum of the two vaccine prices is only USD0.42, but at USD1.2 the price of the combination vaccine is 3.6 times higher. See http://www.who.int/immunization_delivery/new_vaccines/GAVI_Product_Menu.pdf.

[37] All countries below the $1000 GNI/capita threshold and with immunization coverage of 50% or higher would be given equal access to grant resources (GAVI Alliances, 2006).

fever. The user fee is charged at the revenue-neutral point, i.e., at the point that the net program cost (total program cost−public COI−revenue) is zero.

6. *Data*

The Diseases of the Most Impoverished (DOMI) program conducted a series of epidemiological and economic studies in North Jakarta between 2002 and 2003. These include: 1) a population-based surveillance study to measure the incidence of typhoid fever in two sub-districts of Jakarta (Tanjung Priok and Koja); 2) a public and private cost-of-illness study of typhoid patients identified by blood culture in the surveillance study in Tanjung Priok and Koja; 3) a survey carried out in the four other sub-districts of North Jakarta (Penjaringgan, Kelapa Gading, Cilincing, and Pademangan) on household willingness to pay for hypothetical typhoid vaccines using the contingent valuation method (855 respondents); and 4) vaccine cost studies.

6.1. *Burden of disease*

The Indonesian government has a surveillance system to detect diarrhea cases; however, public health data are likely inaccurate because of misdiagnosis, self-treatment, and the fact that only about 30% of provinces regularly provide disease reports to the central government (Malik et al., 2005). The DOMI research conducted the most recent study for measuring typhoid fever incidence in slum areas of North Jakarta from August 2002 to July 2003. Typhoid cases in the study area were identified through passive surveillance at participating government health facilities. During that year, 16,872 people presented at the health care facilities with three or more loose bowel movements within a 24-hour period and/or a fever ($\geq 37.5°C$) for three or more days.

One hundred thirty-one cases of typhoid fever were identified by blood culture, resulting in an estimated incidence of 1.6 per 1,000 (Ochiai et al., 2007).[38] Children were at considerably higher risk of typhoid fever in the slum area of North Jakarta than adults, i.e., 3.5 per 1,000 versus 1.0 per 1,000. Children aged five to fourteen years were at the highest risk of getting typhoid fever.

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[38] Since several studies have shown blood cultures to be only around 50% sensitive as compared to bone marrow cultures, a multiplier of two is applied to the adjusted number of cases.

Still, laboratory data have fortunately shown that antibiotic resistance against *S. typhi* is not evident yet in Indonesia (Arjoso and Simanjuntak, 1998)

6.2.   *Economic burden of typhoid fever*

Of 1,342 blood-culture-confirmed cases among children (aged 2-15 years), 72 were identified as typhoid fever in the DOMI surveillance study. These cases were enrolled in the DOMI cost-of-illness (COI) study to measure both the private and the public (or governmental) costs of a typhoid fever episode. The private COI includes both direct and indirect costs. The private direct COI consists of out-of-pocket costs incurred by patients for treatment, hospital stays, medicines, laboratory tests, transportation, and the food and lodging of patients and those accompanying them. The private indirect costs include lost wages of caretakers while looking after ill children as well as lost productivities of patients due to typhoid fever. The public COI measures the direct financial costs of providing treatment, the estimated depreciation cost of capital items (buildings and equipment), and a step-down allocation of indirect costs, such as administration and support.

6.3.   *Willingness to pay (WTP) and predicted vaccine coverage rate*
Willingness to pay

In the contingent valuation survey, 855 respondents were told about a hypothetical typhoid vaccine and asked if they would purchase the vaccines for their children at one of five randomized prices. The data of the contingent valuation survey include the level of parental education and whether each school-aged child attends school or not. First, the household's WTP for young children aged 2-4.9 years, school-aged children (5-14 years) who attend school, and school-aged children who do not attend school are estimated by parental educational level if a 70% effective/3-year typhoid vaccine were available (see the column of WTP before adjustment in Table 3.1 below).[39] Second, the WTP estimates are adjusted for the time-to-think effect for each group of children (see the column of WTP after adjustment in Table 3.1). Several studies of private demand for typhoid or cholera vaccines find that respondents who were given more time to think about the hypothetical vaccine overnight indicated they were willing to pay 8-10% less

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[39] The codes for estimating WTP developed by Cook, J., Maskery, B., and Jeuland, M. are adapted using information on school enrollment in the data of the contingent valuation survey.

than before they were given the extra time (see Cook et al., 2007; Lucas et al., 2007; Whittington et al., 2007; and Islam et al., 2008).

Table 3.1. Vaccine coverage rate for free vaccine and WTP for children by age group and enrollment as well as parental education, with and without adjustment for time-to-think and uptake in TT booster project

Parental education	Before adjustment		After adjustment	
	Coverage rate	WTP (2007 USD)	Coverage rate	WTP (2007 USD)
Panel A: Young children (2-4.9 yrs)				
No schooling	38%	$7	34%	$6
Elementary school	52%	$9	46%	$8
Middle school	76%	$11	68%	$10
High school	100%	$13	89%	$12
> High School	100%	$16	89%	$15
Panel B: School-aged children who do not attend school				
No schooling	36%	$6	30%	$6
Elementary school	48%	$8	40%	$8
Middle school	63%	$9	53%	$8
High school	89%	$14	75%	$12
> High School	100%	$29	84%	$26
Panel C: School-aged children who attend school				
No schooling	53%	$12	64%	$11
Elementary school	61%	$13	74%	$12
Middle school	71%	$15	86%	$14
High school	77%	$18	93%	$16
> High School	88%	$21	107%	$19

Source: the data of the DOMI-contingent valuation survey.

Predicted vaccine coverage rate

The vaccine take-up rates (i.e., how many people would get vaccinated) for a free vaccine are also estimated for the same three groups of children according to parental education, using the data from the contingent valuation study. Then, for more accurate estimation the take-up rates are adjusted in two ways: the time-to-think effect for children who do not attend school and the school-delivery effect for children who attend school.

Panel A and B before adjustment in Table 3.1 present the predicted vaccine take-up rate for children who do not attend school (including young children). When the estimates of vaccine take-up at a zero price are adjusted to account for the effect of giving respondents time to think about their answers. Thus, the coverage level goes down 10-15%. The coverage rates of children who do not attend school are estimated to be, on average, 59% (2-4.9 years) and 50% (5-14 years) for a free typhoid vaccine. In addition, 80% of people are assumed to have heard about the immunization campaign. In the sensitivity analysis these adjusted estimates are ranged by +/− 20% of their base value.

Next, the coverage rate for children from the contingent valuation survey who attend school is adjusted for the field evidence, that is, the coverage levels of the current school-based immunization programs in Indonesia. The coverage rate of the school-based TT booster program, which has been in operation for almost a decade in Indonesia, ranges by district from 80-89% at its highest to 50% at its lowest (WHO, 2007b). In Jakarta the BIAS program achieved a coverage rate of more than 90% between 2002 and 2004 (MOH, 2002). In addition, the DOMI Vi immunization project conducted in Jakarta in 2004 randomly selected 18 out of 105 public primary schools in Koja and Tanjung Priok (nine in each sub-district). The target population was 5,303 students aged 5-11 years who attended the randomly selected schools. The demonstration project achieved an 84% coverage rate at the first visit. After additional contacts with unvaccinated children, the final coverage was 91% (Agtini et al., 2006). The immunization plan in this paper targets the same population in the same area through the same vaccine delivery strategy as the demonstration project. Therefore, based on the field evidence the coverage rates for children who attend school are adjusted 20% higher to 80% (see Panel C), compared to 50-59% for children who do not attend school.

6.4. *Total vaccine cost*

Deriving the vaccination cost poses a significant challenge, as many studies have demonstrated. For example, Walker et al. (2000) and Pegurri et al. (2005) show that published cost studies lack information and transparency in the costs of currently available vaccines, making it more difficult to estimate the costs of a hypothetical vaccine. Within this limitation, I discuss two components of vaccination costs: the procurement cost and the delivery cost.

6.4.1. *Vaccine procurement cost*

During the demonstration campaign, the Vi polysaccharide typhoid vaccine was supplied by GlaxoSmithKline from Belgium. However, if the vaccine were locally produced, the procurement cost would be lower. Vietnam has locally produced Vi at the price of USD0.54 per dose packaged in a 20-dose vial. Assuming 10% wastage and an estimated cost of USD0.04 per syringe, the cost of vaccine and syringe per vaccinated individual is hypothesized at USD0.60 (Lauria and Stewart, 2007).

6.4.2. *Vaccine delivery cost*

The incremental costs of adding a new vaccine vary depending on the vaccine delivery mode, the capacity of the current immunization system,[40] the size of the immunization program,[41] and the volume of the packages for the vaccine.[42]

In order to derive vaccine delivery costs in Indonesia, I begin with the financial records of the demonstration project for typhoid immunization in North Jakarta as well as data on 94 other immunization programs in Indonesia from the available literature (Anwar, 2001; Simbolon, 2001; Malik et al., 2004; Mardiati et al., 2004; Stewart, 2005; and WHO, 2006c). Mardiati et al. (2004) use the richest data on vaccine cost in Indonesia. From 2001 through 2003, the vaccine costs per fully immunized child (FIC) for administering the traditional EPI6 vaccines (DTP, measles, polio, and BCG) were on average USD5.6 in four districts (Bangka, Belitung, Banjarnegara, and Pekalongan). In order to estimate the costs of delivering vaccines specifically in Indonesia, first, total vaccine costs per FIC and total vaccine costs per dose are calculated. Second, procurement costs of vaccines per dose are estimated based on certain assumptions and limited available vaccine price data. Finally, vaccine delivery costs are calculated by subtracting procurement costs from total vaccine costs per dose, since total vaccine costs per dose are the sum of procurement costs and delivery costs (see Appendix A for further details).

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[40] For further details, see Martin, 1984; Creese, 1986; Shepard, Sanoh, and Coffi, 1986; Feilden, 1990; Brenzel, 1990, 1994; Monath, 1993; Parent, Gessner, and da Silva, 2001; Waters et al., 2002, 2004; and WHO, 2004.

[41] See Cook, 2007; and Lauria and Stewart, 2007.

[42] See Hall et al., 1993; Edmunds et al., 2000; and Griffiths, Hutton, and das Dores, 2005.

After excluding the two extreme cases of typhoid Vi in North Jakarta and cholera in Aceh, I characterize the programs by (1) EPI versus non-EPI and (2) BIAS versus non-BIAS and present the average delivery cost with each program, as shown in Table 3.2.

Table 3.2. Vaccine delivery costs per dose by delivery mode (2007USD)

Category	Characteristics of program	Mean (Range)	No. of observation
EPI	EPI	0.9 (0.1-3.3)	69
	Non-EPI	0.7 (0.2-2.2)	24
BIAS	BIAS	0.6 (0.2-1.2)	12
	Non-BIAS	0.9 (0.1-3.3)	81

Note: BIAS includes only the TT booster. Non-BIAS includes all of EPI vaccines and TT.
Source: Anwar (2001); Simbolon, (2001); Malik et al. (2004); Mardiati et al. (2004); and Stewart (2005).

EPI versus non-EPI

In Table 3.2 the category of non-EPI includes the administration of routine TT vaccines and the TT booster. There is a slight difference in the cost between EPI (USD0.9) and non-EPI (USD0.7) delivery.

The EPI category includes the Hep B vaccines, which is delivered through the EPI program within seven days of birth to all newborns (MOH, 2002). Since most newborns in Indonesia are delivered at home (79% in the 1990s) (CBS, 1997), the Hep B vaccines are administered by midwives, making their delivery costs more expensive than other EPI vaccines, which are usually provided in health care facilities. The wastage rate of Hep B vaccines (31%) is also higher than the wastage rate of other EPI vaccines (5-10%) in Indonesia. Thus, the delivery cost of Hep B vaccines is on average USD1.4, higher than other EPI vaccines (USD0.7). If Hepatitis B programs are excluded from the category of EPI, the delivery cost of EPI vaccines is the same as non-EPI, on average.

BIAS versus non-BIAS

The BIAS category includes only TT booster vaccines, whereas the non-BIAS category includes all EPI and TT vaccines. The costs of delivering TT booster vaccines through the school-based platform (USD0.6) are lower than other vaccine delivery modes (USD0.9). The

range of delivery costs through the non-BIAS program is also wider than the one through the BIAS program, probably because the school-based program delivers the vaccines more efficiently and consistently.

For the purpose of this paper, I make the conservative assumption that the average delivery cost is USD0.6 per dose for a vaccine administered singly (rather than simultaneously with other vaccines) through schools. Soendoro (2007), NIHRD staff, assumes the cost of typhoid vaccine delivery through the schools to be USD0.4 in Jakarta.

This delivery cost is almost half of Lauria and Stewart (2007)'s recommendation for Indonesia. They review data from six vaccine cost studies (four single-country studies and two multi-country studies) and unpublished cost data from DOMI vaccine trials. They recommend USD1.0 for middle-income developing countries. However, they rely on the cost data from Chile, Israel, Argentina, South Africa, and others, rather than on data from Indonesia, which the present study uses exclusively. In addition, Lauria and Stewart do not distinguish between school-based and mass immunization programs. Indonesia has a rich experience with school-based immunization, and the unique data from its programs clearly shows that the vaccine delivery cost of school-based immunization is lower.

On the other hand, the data on the vaccine costs used in this study (Anwar, 2001; Simbolon, 2001; Malik et al., 2004; Mardiati et al., 2004; and Stewart, 2005) do not provide enough information on whether the costs include economic costs. Therefore, in order to account for the uncertainty, I allow the vaccine delivery cost to range from USD0.2 to USD1.2 per dose, which covers the range of the BIAS data in Table 3.2, as well as Lauria and Stewart (2007)'s recommendation.

In the immunization schemes for North Jakarta that I propose in this study, the typhoid vaccine would also be simultaneously delivered along with TT vaccines through an existing BIAS program. Since the TT booster program is already established for the primary school students, the only additional costs of delivering the typhoid vaccine would be in the additional volume of typhoid vaccine and additional administration time. The simultaneous administration of vaccines is expected to be especially cost efficient in personnel costs, often the largest cost in immunization programs. Based on several studies (for further details, see Appendix B), the delivery cost through simultaneous administration is assumed to be USD0.45 for the primary school students. Table 3.3 summarizes the parameters and the data in detail.

Table 3.3. Description of model parameters with ranges of uncertainty, except for WTP and coverage rate

Parameters	Value	Uncertainty range[a]
Site characteristics		
Child population[1]	325,261	
Minimum wage/month (2007USD)[2]	96	(72-120)
Enrollment rate[3]: Primary school (5-11 yrs)	93%	(90-98)
Junior high school (12-14 yrs)	72%	(70-83)
Disease of burden		
Incidence(/1000)[4]: Young Children (2-4.9 yrs)	3.0	(1.8-5.0)
School-aged Children (5-14 yrs)	3.8	(4.1-6.8)
Average duration of case (days)[5]	16	(10-21)
Assumed case fatality rate (CFR)[6] (%)	1%	(0.5-3)
Vaccine characteristics and costs		
Vaccine effectiveness (%)	65%	(55-75%)
Vaccine duration (years)	3	(2-4)
Delivery cost per dose (2007USD)		(0.4-1.5)
Single administration.	$0.6	
Simultaneous administration		(0.2-1.2)
Primary school students	$0.45	(0.4-1.5)
Non-primary school students	$0.6	
Acquisition cost per dose (2007USD)	$0.6	(0.4-0.8)
Cost-of-illness (2007USD)[5]		
Public COI per case	$25	(19-32)
Private COI per case: Young Children	$66	(50-83)
School-aged Children	$55	(41-69)
Total COI per case: Young Children	$98	(74-123)
School-aged Children	$78	(59-98)
Other parameters		
Discount rate	3%	
DALY weight[7]	0.27	(0.075-0.471)

Note: [a] In the sensitivity analysis the base value is adjusted within a range of +/- 20%.
Sources: [1] 2003 Census population in N. Jakarta, Indonesia. [2] In 2006 the minimum wage per month in Jakarta was Rp 819,100 (USD95.5 in 2007 dollars). See http://www.indonesia-ottawa.org/economy/Economicissues/wage-minimum-jkt-06.htm. [3] UNICEF fact sheet, http://www.unicef.org/indonesia/girls_education_fact_sheet_final_ENG_1_.pdf for Indonesia. [4] The DOMI epidemiology study. [5] The DOMI cost-of-illness data. [6] According to the WHO, the CFR for typhoid fever is about 1% assuming treatment with antibiotics. In Indonesia most people (84%) know how to treat typhoid fever and get antibiotics (Marlik et al., 2005). Several studies (Crump, Luby, and Mintz, 2004; and Parry et al., 2002) also assume 1% of CFR as a conservative estimate. Therefore, in the analysis CFR is assumed as 1%, ranging from 0.5% to 3% in order to deal with uncertainty. [7] Available online at: http://www3.who.int/whosis/discussion_papers/pdf/paper54.pdf. For general discussion of calculating DALYs see http://www.who.int/healthinfo/boddaly/en

7.   *Results*

7.1.   *Equality*

The educational level of a parent is used to examine inequality. All of the DOMI data sets, including the epidemiology data, the cost-of-illness data, and the data using the contingent valuation method, have consistent information on the educational level of children's care givers, usually parents.

This section answers several questions below:

(1) Are children with less educated parents more likely to suffer from typhoid fever?
(2) Do households in which household heads have lower educational attainment incur a greater economic burden if their children have typhoid fever?
(3) If the immunization program is launched, would the program reduce cases associated with typhoid fever equally across parents' educational level?
(4) Are the immunization rates of children the same whether or not there is a user fee?

Are children with less educated parents more likely to suffer from typhoid fever?

Panel A of Table 3.4 shows private COI for typhoid fever cases among children by parents' educational attainment without the programs. Panel B represents the percentage vaccinated also by parental educational attainment.

Table 3.4. Number of cases and cost-of-illness estimates due to typhoid fever with/without an immunization program in North Jakarta

Parameters		No schooling	Elementary school	Middle school	High school	> High School
% of Population [a]		18%	37%	21%	20%	4%
Monthly household income (2007USD)[b]		124	153	174	219	360
Panel A: Without a program						
Typhoid fever cases [c]		**25%**	26%	18%	**23%**	**8%**
Private COI (2007 USD) [c]		44	79	57	55	57
% of private COI out of income [c]		36%	51%	33%	25%	17%
Panel B: With a program						
Percentage vaccinated [b]	Without user fee	60%	65%	71%	79%	80%
	With user fee ($1)	35%	42%	53%	65%	71%

Sources: [a] UNICEF fact sheet http://www.unicef.org/indonesia/girls_education_fact_sheet_final_ENG_1_.pdf for Indonesia.
[b] The DOMI data of the contingent valuation study. [c] The DOMI cost-of-illness data.

The first, fourth, and fifth columns of Panel A in Table 3.4 show that children with the least educated (≤ elementary school graduation) and more educated parents (high school) tend to have more typhoid fever cases, compared to the rest of the population by parental education. There is also clear evidence that children with the most educated parents (>high school) are least likely to suffer more from typhoid fever.

Do households in which household heads have lower educational attainment incur a greater economic burden if their children have typhoid fever?

With regard to the economic consequences of typhoid fever cases, the private economic burden associated with typhoid fever in children is in general heavy for any educational group. In Jakarta, typhoid illness costs a family, on average, the equivalent of between 17% (>high school) and 51% (elementary school) of monthly household income, according to the DOMI COI study and the DOMI contingent valuation study. Several studies assume that an economic burden of illness greater than 10% of household income is likely to be catastrophic for the household

economy.[43] Thus, the economic burden associated with typhoid fever in children can be considered catastrophic for all Jakarta households. This is mainly because of the national health care financing structure. Poulos et al. (2008) find that the great majority of the total (public plus private) costs of typhoid illness were paid from private funds (60% for hospitalized patients and 74% for outpatients), while according to the DOMI COI study the government paid only 40% of the costs for hospitalized patients and 26% for outpatients. The COI study shows that nearly all of these private direct costs were paid by families themselves (90%), and only a fraction were paid by insurance companies (1%), employers, or others.

Nonetheless, it is clear that less educated groups (36-51%) bear significantly more economic burden than more educated groups (17-25%). At first glance, the proportion of private COI burden to household income does not look different across parental education level.[44] However, it is worth noting that the poor often live on a daily wage that is barely enough to meet minimum food requirements (Russell, 2003). In terms of coping with the budgetary shock or mobilizing assets to pay for treatment, 36 to 51% of household income spent on private COI may feel very different to the less educated groups than 17 to 25% will feel to the more educated groups ($\geq$ high school graduation). For hospitalized cases, families paid the equivalent of nearly two months of their household income (USD210), five times more than for non-hospitalized cases (USD41). It is hard to imagine how less educated groups or the poor (if one assumes that less educated people earn less and are poorer, as shown in the second row of Table 3.4) cope with the catastrophic burden of having their children hospitalized for typhoid fever. They would first cut their consumption of other minimum necessities, then sell productive assets or borrow money (Townsend, 1995; Morduch, 1995, 2002; Gerbtler and Gruber, 2002; and Russell, 2003). Twenty percent of the sample households in the cost-of-illness datasets sold assets or borrowed money in order to provide treatments for their children. Therefore, the private economic burden of hospitalized cases associated with typhoid fever might push less educated groups toward impoverishment.

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[43] This 10% figure is somewhat arbitrary, because it may not be catastrophic for high-income households that can cut back on luxuries to pay for treatment (Russell, 1996).

[44] The Kruskal-Wallis equality test was conducted. The null hypothesis is that the average percentage of household income spent on private COI burden is the same across parents' educational level. The hypothesis is rejected at 10% of significance (p=.62).

If the immunization program is launched, would the program reduce cases associated with typhoid fever equally across parents' educational level?

If vaccines against typhoid fever were delivered without a user fee (Panel B), children with more educated parents would be more likely to be vaccinated, from 60% in the least educated group to 80% in the most educated group. If a user fee were charged at the revenue-neutral point (i.e., when the net program cost is zero) of USD1, the percentage vaccinated would decrease most in less educated groups, while the percentage would not change significantly in more educated groups. In sum, less educated parents have lower demand for vaccines against typhoid fever and are more sensitive to the price of the vaccine than more educated parents.

Are the immunization rates of children the same whether or not there is a user fee?

Figures 3.3 and 3.4 show the vaccination rate of school-aged children who attend school and those who do not, according to parental educational level. The vaccine coverage rate is estimated using the data of the contingent valuation study regarding the enrollment of each school-aged child. The sum of percentages across parental educational attainments is 100% in each figure. In 2002 the enrollment rate of schools in Indonesia was approximately 93% for primary schools and 72% for junior high schools.[45]

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[45] See UNICEF fact sheet http://www.unicef.org/indonesia/girls_education_fact_sheet_final_ENG_1_.pdf
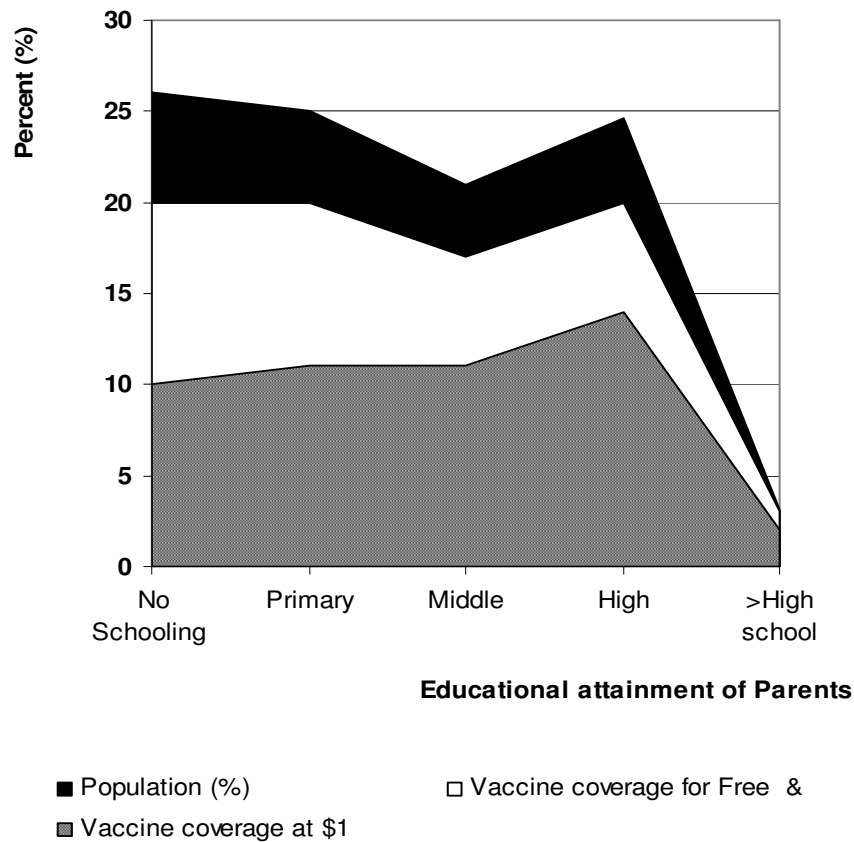
Figure 3.3 Vaccination rate: school-aged children who enroll in school

If one looks at Figure 3.3, 26% of children who attend school have parents who have not graduated from elementary school. Their vaccination rate is 20% if the vaccine is free but 10% if it costs USD1, i.e., the revenue neutral user fee. Children with more educated parents (>high school) comprise only 4% of children who attend school, and their vaccine take-up rate is the highest as well as not sensitive to price. The white area in Figure 3.3 shows the difference in coverage rate between a free vaccine program and one with a user fee. Thus, the larger the white area, the more the vaccine demand is sensitive to price.

However, Figure 3.4 for school-aged children who do not attend school shows vaccine demand failure (Pande and Yazbeck, 2003). For children who do not attend school, there is significantly lower demand even for free vaccines against typhoid fever across any parental educational level. Also, their demand is not affected by vaccine price.
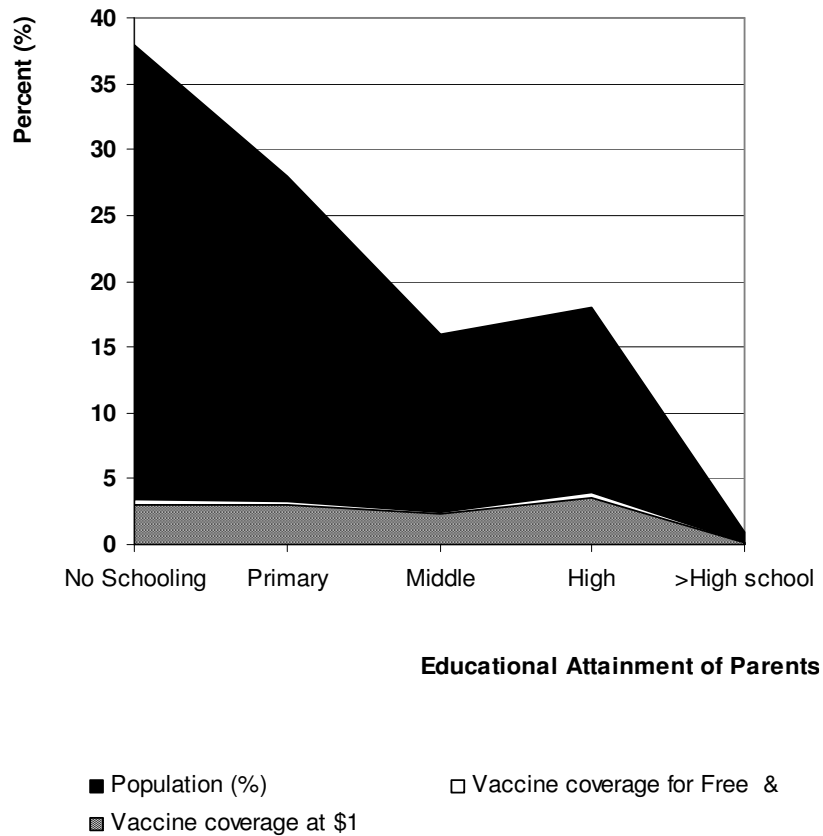
Figure 3.4 Vaccination rate: school-aged children who do not enroll in school

Another way of answering the question is to look at the Lorenz curve of typhoid fever cases illustrated in Figures 3.5 and 3.6. Figure 3.5 shows the inequality of current typhoid fever cases and Figure 3.6 the inequality of avoided cases. The Lorenz curve represents the cumulative percentage of typhoid fever cases against the cumulative percentage of the population. The *x*-axis is ordered by the educational attainment of parents. If one focuses on the Lorenz curve for young children in Figure 3.5, the first 18% of children (whose parents have no schooling) have only 6% of the total typhoid fever cases. The next 37% and 21% of children have parents who have graduated from elementary and middle school, respectively. These cumulative 76% (=18+37+21) of young children have 44% of the total cases. This result runs counter to the expectation that children with less educated parents will have a higher rate of incidence.
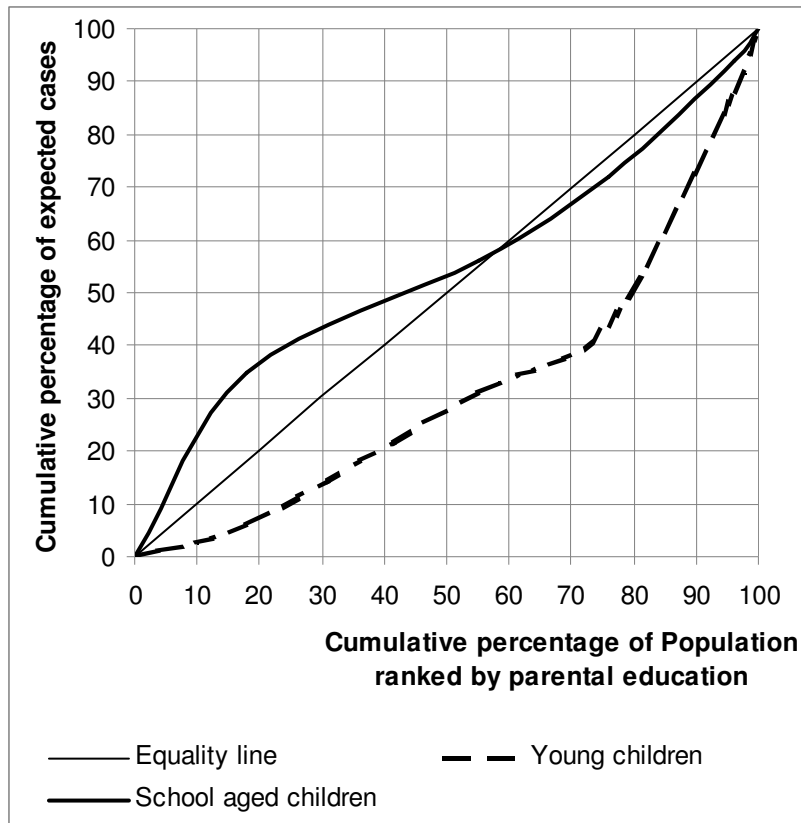
Figure 3.5 Lorenz curves: current typhoid fever cases of
young children and school-aged children without the program

In contrast to the Lorenz curve of young children, the curve of expected cases for school-aged children shows a significant relationship between parents' educational attainment and cases associated with typhoid fever. Children with less educated parents (up to 60% of the population) tend to have a higher incidence rate, which is located over the equality line. Children with more educated parents (the remaining 40%) tend to have a lower incidence rate, located below the equality line.

Figure 3.6 compares typhoid fever cases with and without the immunization programs. Without the program, 45% of typhoid fever cases occur among the 45% of children whose fathers have not graduated from middle school.
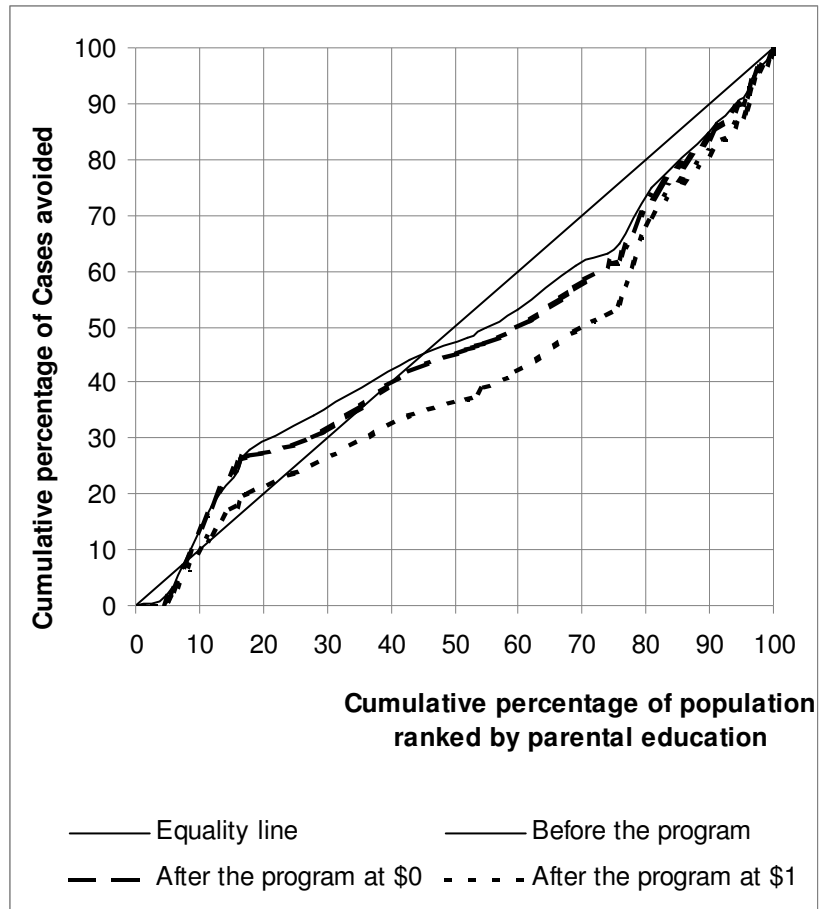
Figure 3.6 Lorenz curves: typhoid fever cases
of all children with/without the program

This group would have almost the same cumulative percentage of cases avoided if the vaccine were delivered for free. Generally speaking, the area between the Lorenz curve and the equality line (area *A* in Figure 3.1) is bigger with the program than it is without the program. The greater the area *A* the greater the inequality. Even the free immunization program would increase inequality, therefore, because less educated parents would be less likely to have their children vaccinated in order to avoid typhoid fever.

Furthermore, the user fee would increase the area between the Lorenz curve and the equality line. If a user fee were charged, the gap in the area (area *A*) with and without the program increases mainly among the population located between 15% and 75% on the educational attainment axis (Figure 3.6). It means that less educated parents (elementary or middle school graduation) are more likely to be sensitive to the user fee. Therefore, a user fee

increases inequality even more by reducing the vaccine take-up rates among children with less educated parents.

7.2. *Efficiency*

Impact of immunization programs

As Table 3.5 shows, a school-based immunization program targeting students only is more effective (80%) than one that targets all children (69%). If a user fee of USD1.1 and USD1.0 for the single and simultaneous administration, respectively, were charged, the vaccination rate would decrease to 49%, on average.

Table 3.5. Program impacts of typhoid immunization programs for children

Parameters	Without user fee		With user fee	
	Students (5-14 yrs)	All Children (2-14 yrs)	Students (5-14 yrs)	All Children (2-14 yrs)
Percentage vaccinated	80%	69%	49%	49%
Number of vaccinations	53K	75K	33K	54K
Number of cases avoided †	(763→) 397	(1174 →) 555	241	394
Number of deaths avoided †	(7 →) 4	(11 →) 6	2	4
YLL avoided ‡	(210 →) 109	(325 →) 153	66	109
YLD avoided ‡	(9 →) 5	(14 →) 7	3	5
DALY avoided ‡	(219 →) 114	**(339→) 160**	69	114
Public COI avoided ‡	($19K →) $10K	($28K →) $13K	$6K	$10K
Private COI avoided ‡	($41K →) $21K	($66 →) $31K	$13K	$22K
Total COI avoided ‡	($58K →) $30K	($94K →) $44K	$18K	$32K

Note: † denotes an estimate over three years. ‡ denotes a discounted estimate over three years. Numbers in parentheses show the estimates without the program.

If no typhoid vaccine is administered to students attending primary or junior high schools in Tanjung Priok and Koja, 763 cases and 7 deaths associated with typhoid fever are expected over three years. These illnesses impose the economic burden of USD18,521 on the public sector

and USD40,746 on families over three years. Assuming no herd protection[46] and no user fee, 397 cases and 4 deaths would be averted with the typhoid vaccine program for students only over the three years of the vaccine's efficacy. Also, 47% of the economic burden would be avoided.

However, the immunization program targeting students only misses 24% of children at the higher risk of typhoid fever. They are young children (2-4.9 years) and school-aged children who do not attend school. If the program expanded to all children aged 2-14 years in the target area, a total of 555 cases and 6 deaths would be averted. Without the immunization program for all children, typhoid fever cases would result in a loss of 325 life years due to premature mortality and 14 life years in disability over three years. The introduction of typhoid vaccines at zero price in two sub-districts of North Jakarta could avoid a loss of 179 (=339-160) disability-adjusted life years due to typhoid fever. That is, 53% of DALY would be saved. By the same token, 53% of the total economic burden (in other words, total COI) would also be avoided (USD50K out of USD94K).

If a user fee were charged, all the parameters—the number of cases avoided, DALY avoided, and any cost of illness avoided—would be 61% and 71% less for students and all children, respectively, than if a user fee were not charged. The programs with a user fee are therefore clearly less effective than the programs without a user fee.

Program cost

Table 3.6 presents program costs for three different vaccine financing schemes and two different vaccine delivery modes.

The total cost of implementing the vaccination program is approximately USD66,000 for students and USD93,000 for all children (Panel A), assuming a single administration. Without donors' funding or a user fee, the government would be required to spend USD1.24 per vaccinated child. If the typhoid vaccines were simultaneously delivered through the TT booster program, the introduction of typhoid vaccines would cost the government 8% less than the single administration. There is, therefore, no great cost advantage to simultaneous administration.

If the Vaccine Fund or another international institution helps purchase doses of typhoid vaccines, the total costs of the vaccination program are approximately half those of the

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[46] Many studies find significant protection among those who do not receive at least one dose of a given vaccine (for Hib, see Broughton, 2007; for cholera, see Longini et al., 2007; Jeuland et al., 2007; and Cook, 2007; for meningitis, see McIntosh et al., 2005), but there is no study of indirect build-up of herd immunity from typhoid immunization.

governmental funding scheme (Panel B). The average cost per immunized child is USD0.6, since only the delivery cost would be covered by the government. Donors would be required to spend approximately USD34,000 for students and USD46,000 for all children to purchase the vaccines. Though there are the savings to the public COI, the government still has to pay USD24,000 for young children and USD33,000 for all children. If the typhoid vaccines are simultaneously delivered along with the TT booster vaccines, the government has to pay less, i.e., USD18,000 and USD28,000 for students and all children, respectively. In general, the financial burden under the cost-sharing scheme seems affordable for the government.

If a user fee is charged (Panel C), the number of children vaccinated decreases. Then the total program cost decreases, too, between USD38,000 and USD67,000, compared to the total program cost for a program fully funded by the government. The net program cost (=Total program cost−Public COI−Revenue) is zero or slightly positive for any delivery mode.

Table 3.6. Efficiency measures of typhoid immunization programs by vaccine delivery mode, financing scheme, and target group (2007USD)

Parameters	Single admin.		Simultaneous admin.	
	Students	All children	Students	All children
Panel A: Governmental funding				
Program costs				
Total program cost	66K	93K	61K	88K
Average cost/immunized person	1.24	1.24	1.14	1.17
Net Benefits				
Net public benefits (public COI avoided - total program costs)	(57K)	(80K)	(51K)	(75K)
Net societal benefits (WTP benefits + public COI avoided - total program costs)	726K	940K	728K	942K
Cost-Effectiveness				
Net program cost per case avoided	144	145	130	135
Net program cost per DALY avoided	223	222	201	206
Panel B: Donors' funding				
Program costs				
Total program cost of the government	33K	47K	28K	41K
Average cost/immunized person	0.62	0.62	0.52	0.55
Net benefit measures				
Net public benefits	(24K)	(33K)	(18K)	(28K)
Net societal benefits	761K	989K	761K	989K
Cost effectiveness				
Net program cost per case avoided	59	60	46	50
Net program cost per DALY avoided	92	92	71	77
Panel C: User fee				
Program costs				
Total program cost	41K	67K	38K	63K
Net program cost	(5)	(33)	(1K)	(9)
User fee	1.06	1.06	1.0	1.0
Average cost/immunized person	1.24	1.24	1.14	1.18
Net Benefits				
Net public benefits	(35K)	(57K)	(32K)	(54K)
Net societal benefits	459K	663K	459K	663K
Cost-Effectiveness				
Net program cost per case avoided	0	0	(5)	0
Net program cost per DALY avoided	(6)	(25)	(8)	0

Note: Amounts in parentheses denote negative values

Net benefit measures

From a public budgetary perspective, once the total program cost is subtracted from the public COI avoided, none of the programs offers positive net benefits. This is because currently 75 percent of the cost of illness associated with typhoid fever is borne by the families of affected children. However, the net public benefit measure does not account for all the costs of illness avoided by the immunization programs. If pain and mortality risk, as well as the private economic burdens associated with typhoid fever, are taken into account, WTP + public COI net benefits for all programs would pass a social cost-benefit test. Programs with donor funding offer the highest net benefit (Panel A in Table 3.6), while programs with a user fee offer the lowest societal net benefit (Panel C). Simultaneous administration offers slightly more net benefits than single administration. With regard to target group, the immunization program targeting all children offers more positive net benefits than the program targeting students only.

Cost-effectiveness ratio

The cost-effectiveness ratio ranges from USD201 to USD223 per DALY averted (see the last row of Panel A in Table 3.6) without external funding or a user fee. With donor funding, the cost-effectiveness ratio ranges from USD71 to USD92 (Panel B). If there is a user fee at cost recovery points, the net program cost is almost zero and so the net program cost per DALY averted is zero (Panel C). All of the typhoid immunization programs would be judged as "highly cost-effective" for any funding scheme, any target group, and any vaccine delivery modality, since the cost-effectiveness ratio of typhoid immunization program is much less than the standard cut-off value (USD1,812 for Indonesia in 2007)[47].

7.3.   *A trade-off between efficiency and equality*

Efficiency and equity are two standard criteria in policy analysis. If there are potential tradeoffs between efficiency and equity, prioritizing interventions solely on the basis of one criterion is unlikely to optimize the welfare of society because of people's concerns for both (James, et al., 2005). When deciding between two or more immunization programs, a society would be better off by choosing the one that promises the lowest cost or the maximum net

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[47] 2007 national GDP per capita in Indonesia is obtained from the IMF's World Economic Outlook. GDP is not adjusted for purchasing power parity.

benefit (efficiency), while also distributing the well-being gains — here, immunization coverage — across children from different socioeconomic strata (equity).[48]

Figures 3.7 to 3.9 present trade-offs between equality and efficiency in different vaccination schemes. The *y*-axis in Figure 3.7 represents the Gini index of cases avoided in each immunization scenario, while the *x*-axis represents three efficiency measures. They are net program costs per DALY avoided (Figure 3.7), net public benefits (Figure 3.8), and net societal benefits (Figure 3.9). A lower Gini index (*y*-axis) presents less inequality and the right hand side of the *x*-axis presents more efficiency. Thus, the lower right-hand corner is best in the sense of maximizing efficiency and minimizing inequality. The upper right-hand corner and the lower left-hand corner are worse in the sense of maximizing efficiency and inequality and minimizing efficiency and inequality, respectively.

Abbreviations for the various immunization scenarios are as follows:

G Single administration without donor funding at price of $0

g Simultaneous administration without donor funding at price of $0

U Single administration without donor funding at price of $1

u Simultaneous administration without donor funding at price of $1

D Single administration with donor funding

d Simultaneous administration with donor funding

Figure 3.7 shows that the programs with a user fee (U and u) for any targeting group, whether students only or all children, offer the most efficiency in terms of net program cost per DALY avoided, as well as the most inequality in terms of cases avoided (a smaller net program cost/DALY means more efficiency, while a larger Gini coefficient means more inequality across parental educational levels).

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[48] Williams and Cookson (2000) provide a good summary of two criteria of equity, i.e., horizontal and vertical equity. Horizontal equity means reduced inequalities in vaccine coverage rate between children, which is consistent with egalitarianism. The other, vertical equity, is consistent with Rawls' theory of justice in terms of favoring the most disadvantaged.
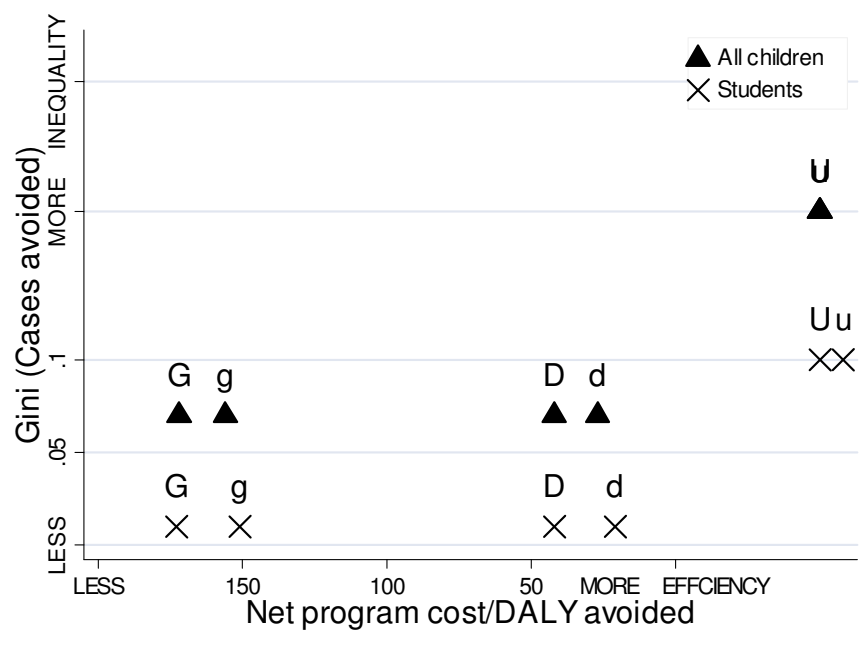
Figure 3.7 Efficiency-equality trade-offs of typhoid immunization programs:
Gini coefficient against net program cost per DALY avoided

The programs funded by the government are the least efficient in terms of the cost-effectiveness ratio. Thus, the programs with both a user fee and government funding heavily favor one side in the efficiency/equality trade-off at the expense of the other. As for programs with donor funding, they do not improve equality, compared to the government-funded programs, but their efficiencies are improved. If the criterion is to avoid programs providing only efficiency or only equality, the programs with donor funding for either all children or for students only show better balance across both dimensions. With regard to simultaneous versus single administration, simultaneous administration (d, g, and u) offers more efficiency than single administration (D, G, and U), while holding equality steady. Typhoid immunization programs targeting students alone provide more equality to society than the programs targeting all children, but not greater efficiency in terms of cost-effectiveness ratios.

Figure 3.8 presents the Gini coefficient of cases avoided through an immunization program against net public benefit.

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Figure 3.8 Efficiency-equality trade-offs of typhoid immunization programs:
Gini coefficient against net public benefits

If one seeks a trade-off between efficiency and equality from a public budgetary perspective, the programs with a user fee for all children and the programs with government funding for all children look less attractive. If a program charges a user fee, it maximizes inequality, while achieving efficiency at a medium level compared to other programs. If a government fully funds immunization against typhoid fever for all children, it minimizes efficiency, while achieving equality at a medium level. Thus, neither is a good option on the trade-off equality/efficiency front. The four programs with donor funding for any age group are more attractive because they minimize loss in net public benefits and maximize equality. The programs with a user fee for students look attractive, too.

Figure 3.9 shows the trade-off between equality and net societal benefit. For the sake of simplicity, the points for simultaneous vaccine delivery are dropped in Figure 3.9 since they are same as the points for single vaccine delivery.
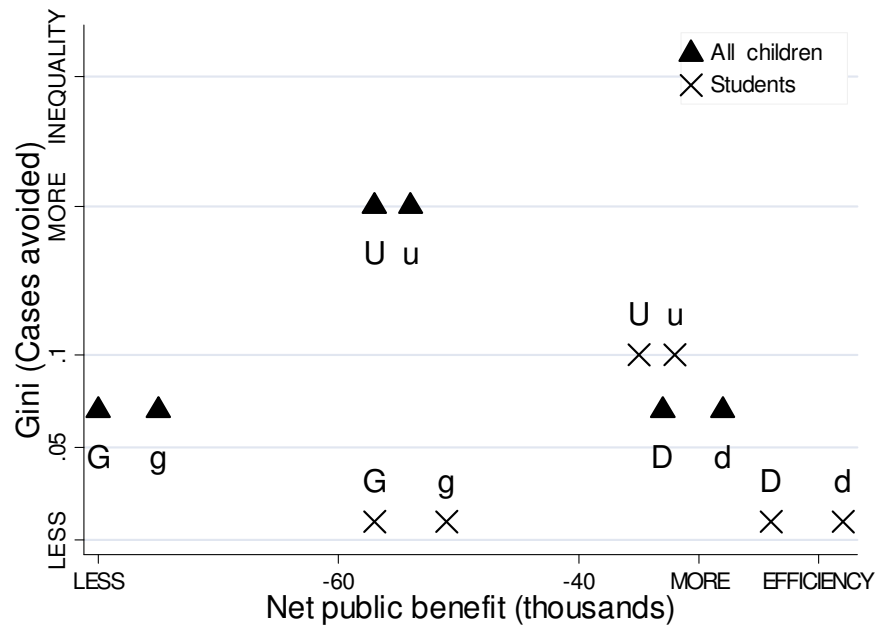
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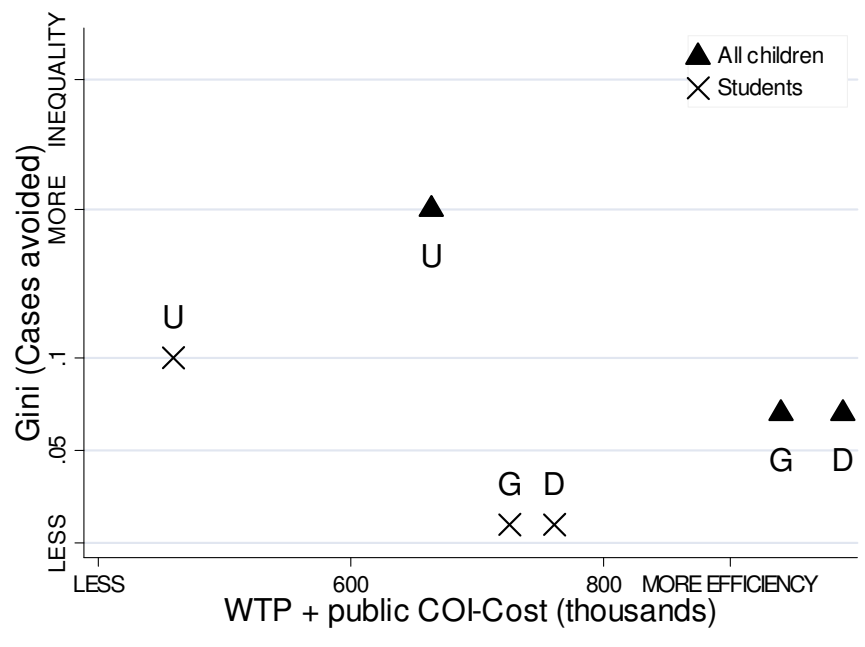
Figure 3.9 Efficiency-equality trade-offs of typhoid immunization programs:
Gini coefficient against net societal benefits

If a society seeks to improve both health equality and efficiency in immunization programs from a societal perspective, the program with a user fee for both students and all children are not attractive. Compared to the other programs, the user fee program for all children accomplishes the least equality in terms of cases avoided through the program, while the one for students accomplishes the least net societal benefit. These options look the worst on the net societal benefit and equality dimension. Moreover, the user fee program for students is the least efficient because it reaches the fewest children. The program funded by both the government and donors represents more efficiency in terms of net societal benefits, as well as more equality, compared to the program with a user fee. On the equality/net societal benefit trade-off front, donor funding seems a better option than government funding.

In sum, if one focuses on net program cost per DALY avoided as a measure of efficiency, user fee programs maximize the efficiency while minimizing the equality. From both the public budgetary and the societal perspective, a user fee decreases the equality the most without increasing efficiency the most because of its lower coverage rate. As we have seen from Table 3.4, the vaccination rate of programs with a user fee is 49%, while the vaccination rate of

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programs without a user fee is 69-80%. This finding is consistent with other studies (Evans, Barer, and Stoddart, 1993; Nolan, 1993; Van Doorslaer, Wagstaff, and Rutten, 1993; OECD, 1994; Creese, 1997; and Kutzin, 1998). Therefore, if one prefers cost-effective programs while achieving equality across all three tradeoffs (Figures 3.7, 3.8, and 3.9), the programs with donor funding are the best, while the programs with a user fee are the worst option.

7.4.   Sensitivity analysis

In order to test the robustness of the results, I varied the assumptions over the parameters and conducted the Monte Carlo probabilistic sensitivity analysis. In the Monte Carlo analysis, each assumption of each parameter is assigned a range of values with a frequency distribution instead of a point value, as shown in Table 3.7. Values for each assumption are randomly drawn from its uniform distribution and each model is run 10,000 times.

Table 3.7. Monte Carlo analysis results of total/net program cost and donor funding (2007USD)

Parameters	Single administration		Simultaneous administration	
	Students (5-14 yrs)	All Children (2-14 yrs)	Students (5-14 yrs)	All Children (2-14 yrs)
Panel A: Governmental funding				
Total program cost	32K-110K	45K-149K	21K-103K	34K-148K
Net program cost per DALY avoided	34 - 624	35 - 601	20 - 576	24 - 521
Net public benefits	(22K)-(100K)	(34K)-(133K)	(11K)-(96k)	(19K)-(138K)
Net societal benefits	498K - 980K	647K - 1,240K	500K - 974K	666K - 1,179K
Gini coefficients	0.05-0.11	0.05-0.09	0.05-0.11	0.05-0.09
Panel B: Donors' funding				
Total program cost	25K-48K	35K-65K	19K-39K	29K-56K
Donor funding	23K-39K	27K-68K	23K-38K	32K-52K
Net program cost per DALY avoided	24- 251	24 - 241	13- 196	16 - 210
Net public benefits	(39K)-(16K)	(53K) - (22K)	(30K)-(8K)	(44K) - (15K)
Net societal benefits	525K - 973K	731K - 1,205K	523K - 989K	716K - 1,220K
Gini coefficients	0.05-0.11	0.05-0.09	0.05-0.11	0.05-0.09
Panel C: User fee				
Total program cost	33K-109K	48K-150K	24K-104K	37K-143K
Net program cost	(35K)-43K	(50K)-60K	(44K)-40K	(55K)-56K
Net program cost per DALY avoided	(176)- 301	(189) - 291	(241)- 213	(210) - 247
Net public benefits	(99K)-(24K)	(136K) - (33K)	(95K)-(15K)	(131K) - (231K)
Net societal benefits	500K - 987K	667K - 1,205K	475K - 1001K	665K - 1,220K
Gini coefficients	0.01-0.05	0.15-0.21	0.01-0.05	0.15-0.21

Note: Amounts in parentheses denote negative values

Program cost

The first row of each panel in Table 3.7 shows the range of the total program cost while accounting for uncertainty. Without donor funding or a user fee, the government may be required to spend at least USD32,000 for the typhoid immunization program if the typhoid vaccines are delivered to the students separately from TT boosters. Under the worst scenario, it may cost as

much as USD110,000. However, if the vaccines are administered together with the TT vaccines, the program might cost the government less (USD21,000-USD103,000).

With external funding, the cost to donors to purchase the single shot of typhoid vaccines for students may range from USD23,000 to USD39,000. In addition, the government must be prepared to spend a maximum of USD65,000 for the students.

Because there is vaccine demand failure for school-aged children who do not attend school as shown in Figure 3.4, home delivery or a more intensive campaign should be considered as strategies for reaching this population. (Appendix C specifies the characteristics of this group, using the probit model).

As Table 3.8 shows, these strategies incur higher vaccine delivery costs. In order to take into account uncertainty of vaccine delivery costs, I run a sensitivity analysis according to vaccine delivery costs at USD1, 2, and 3. This range corresponds to the home delivery costs of Hep B vaccines (see Table A.6 in Appendix A).

Table 3.8. Sensitivity analysis for all children by applying various vaccine delivery costs for school-aged children who do not attend school (2007USD)

	Single administration			Simultaneous administration		
Vaccine delivery cost	$1	$2	$3	$1	$2	$3
Panel A: Governmental funding						
Total program cost	96K	101K	107K	91K	96K	102K
Net public benefits	(83K)	(88K)	(93K)	(78K)	(83K)	88K
Net societal benefits	937K	932K	927K	940K	934K	929K
Net program cost per case avoided	150	159	169	140	149	159
Net program cost/DALY avoided	229	244	259	214	229	243
Panel B: Donors' funding						
Total program cost	50K	55K	60K	45K	50K	55K
Net public benefits	(36K)	(42K)	(47K)	(31K)	(36K)	42K
Net societal benefits	986K	981K	976K	986K	981K	976K
Net program cost per case avoided	66	75	85	56	65	75
Net program cost/DALY avoided	100	115	129	86	100	115

Panel A of Table 3.8 shows that when applying the higher delivery costs to the school-aged children who do not attend school, the program costs for a government-funded program increase from USD93,000 (at $0.6 of base delivery cost from Table 3.6) to USD107,000 (at $3 of delivery cost from Table 3.8) for single administration and from USD88,000 (at $0.45 of base delivery cost) to USD102,000 (at $2.7 of delivery cost) for simultaneous administration. The government would be expected to spend USD14,000 for either single or simultaneous administration in order to reach these disadvantaged children.

Panel B of Table 3.8 shows that in the case of cost-sharing funding, the government would be required to spend USD13,000 more than the baseline scenario (60K at $3 of cost from Table 3.8–47K at base delivery cost from Table 3.6).

As delivery costs increase once a program includes the disadvantaged children, net benefit measures decrease and cost-effectiveness ratios increase. However, the cost-effectiveness ratios of a program that reaches school-aged children who do not enroll in school are still highly favorable.

Cost-effectiveness ratio

We can see from Table 3.7 that the ranges of the cost-effectiveness ratios from the Monte Carlo analysis are not too wide and still fall below the standard cut-off value even in the worst-case scenario, i.e., USD624 per DALY avoided (for a single administration program funded by the government for students). Therefore, the introduction of typhoid vaccines through schools is justified in North Jakarta using the cut-off value (USD1,812), regardless of funding source, vaccine delivery modes, and target groups.

Net benefit measures

Despite the impact of different factors on net benefit estimates, the sensitivity analysis of net benefit measures in Table 3.7 delivers a clear message: the net public benefit is almost always negative in the 10,000 simulations regardless of funding source, target group, and administration option, while the net societal benefit is always positive.

The sensitivity analysis also highlights that, thanks to less variation in vaccine delivery costs, the ranges of the results are not very wide, which means less uncertainty, an important consideration for any policy decision maker.

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Table 3.9 shows the impact of each parameter, listed in Table 3.1 and 3.2, on net benefit estimates of the typhoid program.[49] For both net benefit measures, public and societal, the most important factors in the probabilistic sensitivity analysis are vaccine take-up rates of students and enrollment rate, as well as vaccine costs, public COI, and WTP.

Table 3.9. Effect of parameters on net benefits in the Monte Carlo analysis, ranked in order of significance to variation in results

Net Benefit	Most important	Second	Third	Fourth
Net public benefits (=public COI–total cost)	Vaccine cost	Take-up rate (students)	Public COI	Enrollment rate (junior high)
Net societal benefits (=WTP + public COI–total cost)	WTP (5-14 yrs)	Vaccine cost	Take-up rate (students)	Enrollment rate (primary)

As discussed earlier, the vaccine demands for school-aged children who do not attend school are significantly different from the demands for children in school. Therefore, in child immunization policy analysis it is important to account for whether children are in school or out of school. However, this aspect is often disregarded in child immunization policy analysis.

7.5.   *Comparisons of cost-effectiveness ratios with other health interventions*

Do these highly cost-effective typhoid immunization programs compete with other important health interventions? In order to answer the question, I use the result of the sensitivity analysis from this study in terms of cost effectiveness ratio.

Figure 3.10 compares cost-effectiveness estimates for the typhoid immunization program with those for other health interventions. They are the Haemophilus influenzae type b (Hib) vaccination in Indonesia (Broughton, 2007), the cholera immunization program in the same sub-districts as this study (Jeuland et al., 2007), and other low-cost interventions in developing countries (Laxminarayan et al., 2006a, 2006b).

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[49] The tornado chart tool of Crystal Ball provides this measure.
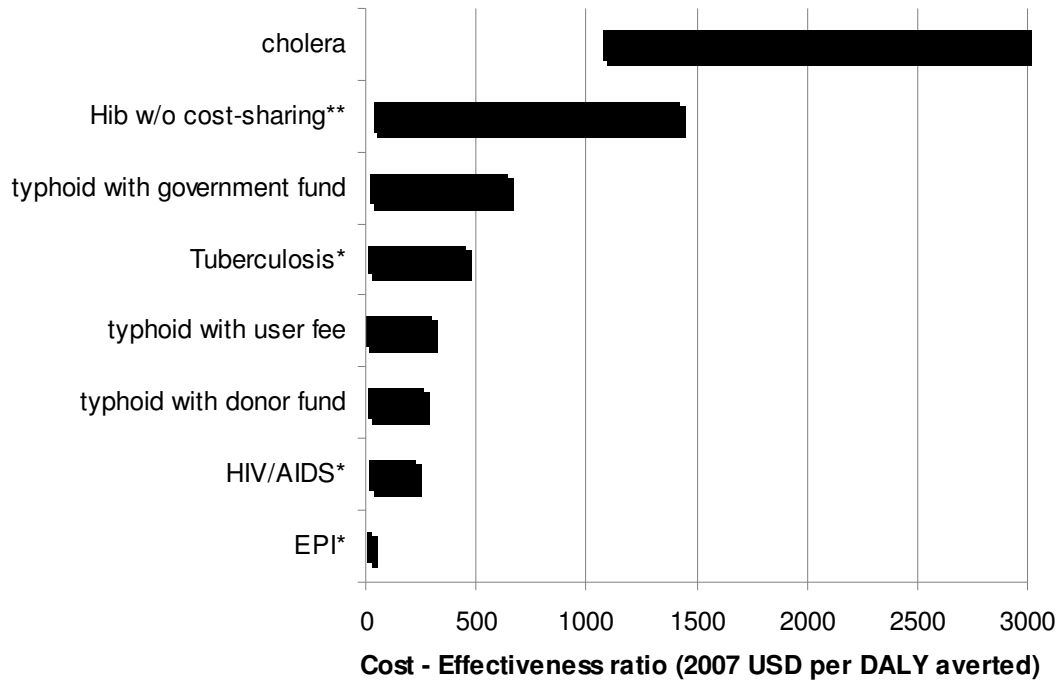
Figure 3.10 Comparison of cost-effectiveness ratios by health intervention program (2007USD)

Note: The symbols * and ** indicate the results from Laxminarayan et al. (2006b) in low- and middle-income countries and from Broughton (2007) in Indonesia, respectively.
For the purpose of presentation, the cost-effectiveness ratio of cholera vaccine is trimmed at 3,000. Its original range is reported as 1,076-8,963.

The cost-effectiveness measures in Figure 3.10 require careful interpretation. Laxminarayan et al. (2006a, 2006b) warn that their final estimates are from published work or standardized resource costs adapted from the WHO's CHOICE project. Also, the cost-effectiveness ratio of the Hib vaccination is for all of Indonesia, not just North Jakarta. Though the cholera immunization program of Figure 3.10 targets the same area as this study, it is based on different assumptions from the ones guiding this analysis. Therefore, it is important to use the order of the estimates in Figure 3.10, rather than each estimate's specific range, as an indicative guide for policy making.

Figure 3.10 shows that the school-based typhoid immunization program with external funds is highly cost-effective, on a par with the HIV/AIDS prevention program. Immunization programs against typhoid fever are more cost-effective than those against cholera, Hib, and tuberculosis. The difference between the typhoid and cholera immunization programs requires

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some explanation. Both target the same area and the same age group, but the typhoid program is more cost effective than the cholera program. This is mainly because the cost of the typhoid vaccine (USD0.6) is assumed as half the cost of the cholera vaccine (USD1). If we assume the same vaccine cost per dose for both the typhoid and the cholera program, the typhoid program would still be more cost effective because cholera immunization requires two doses of vaccines. The total cost of the cholera vaccine would be twice as much as the total cost of the typhoid vaccine, making the cholera program significantly less efficient.

8.   *Discussion and Conclusion*

        While the main purpose of this study is to demonstrate the impact of child immunization programs against typhoid fever in terms of both efficiency and equality, it has produced three additional findings that are key to any consideration of typhoid immunization programs. First, the vaccine delivery cost through schools to children is only two thirds of the cost through mass vaccine delivery. Second, targeting students only is more effective than targeting all children, mainly because of the higher vaccination rate of a school-based program. Third, if one focuses only on efficiency, all of the immunization strategies, whatever their funding source, delivery mode, or target group, would be considered "highly cost-effective."

        With these findings in mind, I conclude that a program with a user fee, while clearly cost-effective, would be regressive for lower-income families in North Jakarta. In order to examine whether children with lower socioeconomic status are either more likely to suffer from typhoid fever or less likely to get vaccinated against typhoid fever, I determine that status by using parents' educational attainment from all of the available data sets (epidemiology data, cost-of-illness data, and contingent valuation data) in the Koja and Tanjung Priok districts of North Jakarta.

        There is no clear evidence that children with less educated parents have higher incidence rates of typhoid fever. However, less educated parents are more likely to suffer from the catastrophic economic burden of having their children become sick or hospitalized with typhoid fever. In other words, the *economic* consequences of typhoid fever are regressive.

        Children with less educated parents are less likely to be vaccinated against typhoid fever, even when the vaccines are provided for free. Furthermore, the demand for free vaccines is the lowest for school-aged children who do not attend school. There may be a dead zone that

government information campaigns on immunization do not reach. Households with school-aged children who do not enroll may not fully know about the benefits of immunization. In order to reach these disadvantaged children, the government would be expected to spend at maximum USD14,000 more than the baseline scenario without intensive campaign strategies, regardless of which financial scheme is adopted.

If a user fee is charged at the cost recovery point (USD1), expected vaccine coverage rates become clearly regressive. Children in North Jakarta suffer from chronic typhoid fever illnesses because of inadequate water supplies. Drinking water in Jakarta is scarce, and only relatively high-income families can afford piped water connections. Poor families must rely on vendor water, which costs 10 to 25 times as much as piped water. The absence of this public good imposes regressive water expenditures on the poor. Now, as an alternative to providing safe drinking water, the government is considering the introduction of immunization programs against a water-transmitted disease, typhoid fever. If, in turn, these programs favor children from highly educated parents at the expense of children with less educated parents, as a program with a user fee would, then the vicious circle never ends.

A program with a user fee for all children, then, is the worst option if the government wants to both maximize efficiency and minimize inequality, because such a program decreases equality the most while not increasing efficiency the most. This finding corresponds with several studies that indicate that fees have rarely generated large amounts of revenue and are unlikely to improve (and might even have worsen) efficiency.[50]

The programs with donor funding for any age group turn out to be the most attractive, followed by programs with government funding. One reason donor funding is the most attractive financing scheme for immunization in Indonesia is that with a limited health care budget, the government would not be able to introduce typhoid fever vaccines without cutting the budgets of other health interventions.

With donor funding for the purchase of the vaccines, the net program cost for any immunization strategy seems affordable for the Indonesian government. Since a cost-sharing method is less expensive to the government than a use fee system, the government prefers donor funding for vaccine procurement cost to a user fee. The cost-effectiveness measures indicate that

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[50] For further details see Fabricant, Kamara, and Mills, 1999; Arhin-Tenkorang, 2000; and James, Morris, Keith, and Taylor, 2005.

typhoid immunization with external funding is highly cost-effective (USD13-USD251 per DALY averted). The societal net benefit measures also pass a societal cost-benefit test, though the net public benefits using public COI do not.

However, a cost-sharing scheme between the government and donors is usually limited to five years. Therefore, the government must make financial plans to sustain the immunization program once grants are ended (GAVI Alliance, 2006). In cases where the government is not able to make such plans, a partial subsidy program whereby user fees do not cover the costs of vaccination and the government pays the difference could be considered. Though I did not analyze this type of cost-sharing policy, we can expect that the vaccination rate of the partially subsidized program would be higher than the rate of a full user-fee program. The net program cost per DALY avoided for a partial subsidy program would be a little higher than the one in which a user fee is fully charged to parents, but it would still fall in a highly cost effective range. This type of partially subsidized program would minimize the inequality more than a full user-fee program, while the government would bear the same financial burden as with the cost-sharing program with donors.

In sum, the results of this study suggest that to strike a fair balance between efficiency and equality, policy makers would be best advised to adopt a school-based typhoid fever immunization program, partially funded by donors (and with plans for sustaining it in the future), in which the typhoid vaccine was simultaneously delivered with the TT booster vaccines.

If the typhoid programs for children from the two sub-districts of North Jakarta were expanded to the rest of North Jakarta, trade-off results in both the efficiency and the equality dimension might be similar. To reach this conclusion one has to examine such parameters as the distribution of population, incidence rate, costs, and benefits. The percentage of young children and school-aged children in the two sub-districts and the rest of North Jakarta are comparable, according to the 2004 population census in N. Jakarta. With regard to vaccine costs, Lauria and Stewart (2007) argue that in urban areas there may be economies of scale, though there is little evidence and there are conflicting opinions on whether economies of scale exist. Since North Jakarta is a part of the capital city of Indonesia, the vaccine delivery cost could decrease based on the economy of scale. The last parameters are net benefits and incidence rate. Though it is likely that there are differences in socioeconomic characteristics and incidence rate between the

two sub-districts and the rest of North Jakarta, we can assume that any cost-of-illness estimate, willingness-to-pay estimate, and incidence rate are the same in both areas. Finally, taking into consideration all the differences in the parameters, I find that there may be improvements in efficiency mainly because of the reduced vaccine delivery cost, as well as slight improvements in equality because of a slightly larger percentage of school-aged children in the rest of North Jakarta than in the smaller area. However, since all of the metrics increase at the same rate across all of the programs, the trade-off results on the efficiency-equality dimensions cannot definitively be said to change with the size of the vaccination program. The trade-off findings in the two sub-districts, therefore, may hold for the rest of North Jakarta, too.

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Appendix A. Cost of vaccine delivery through single adminstration in Indonesia

This section discusses and derives the delivery cost of typhoid vaccines based on several studies estimating the costs of delivering vaccines specifically in Indonesia. First, total vaccine costs per fully immunized child and total vaccine costs per dose are calculated. Second, procurement costs of vaccines per dose are estimated based on certain assumptions and limited available vaccine price data. Finally, vaccine delivery costs are calculated by subtracting procurement costs from total vaccine costs per dose, since total vaccine costs per dose are the sum of procurement costs and delivery costs.

First step: estimating total vaccine cost per fully immunized child

The basic data comes from Mardiati et al. (2004). It reports a unit cost of seven antigens per immunized person in Jawa Tengah and Bangka Belitung provinces from 2001 through 2003. The seven antigens consist of BCG, DPT, polio, measles, Hepatitis B, TT, and TT booster. The EPI vaccine costs per fully immunized child (FIC) are calculated by multiplying a unit cost by the number of shots recommended. This step is taken in order to ensure that the data is within the normal range. The total costs per FIC vary according to the definition of EPI vaccines, i.e., whether they are the traditional "EPI6" vaccines or include new and/or underused vaccines. Table A.1 summarizes the total vaccine costs per FIC in Indonesia.

Table A.1 Total vaccine costs per fully immunized child (2007USD)

Study	Vaccines	Mean	S.D.	Median	Min.	Max.
Mardiati et al. (2004)	EPI6	5.6	2.5	4.4	3.5	11.0
	EPI6, Hep B	12.0	4.2	12.2	6.3	21.5
	EPI6, Hep B, TT	14.3	4.5	12.9	7.6	23.1
	EPI6, Hep B, TT, BIAS	16.4	4.8	14.7	9.6	25.2
REACH (1987)	EPI6	20.0	NA	NA	6.9	35.5
WHO (1981)	BCG, DPT, TT	7.1	1.3	7.0	5.5	9.3
Barnum et al. (1980)	BCG, DPT	8.3	0.5	8.3	7.9	8.7
Creese et al. (1982)	BCG, DPT	6.0	1.6	6.5	4.3	7.4

Mardiati et al. (2004) use the richest data on vaccine cost in Indonesia. From 2001 through 2003, the vaccine costs per FIC for administering the traditional EPI6 vaccines were on

average USD5.6 in four districts (Bangka, Belitung, Banjarnegara, and Pekalongan). If Hep B vaccines are included, the cost goes up to USD12.

There were early costing studies conducted in the 1980s by the WHO and the USAID-funded REACH project (Resources for Child Health). The results show that the average cost per FIC in 2007 dollars was approximately USD20 (Brenzel et al., 2006; GAVI, 2004; and Lydon, 2007), with a range from USD7 to USD36.[51] The country-specific studies commissioned by the WHO in the early 1980s (Barnum et al., 1980; WHO, 1981; and Creese et al., 1982) also found that the average cost per FIC was USD7-8 for BCG and DPT, and TT vaccines in Indonesia. Finally, the total costs per FIC in Indonesia fall into the lower boundary of the results from the REACH project, which focused on the traditional EPI vaccines.

Second step: estimating unit vaccine cost per dose

The goal of this section is to subtract the procurement costs from the total costs in order to derive the delivery costs of typhoid vaccines per dose. As the first step, the unit cost of each vaccine, i.e., the total cost divided by the number of vaccines, is estimated using Mardiati et al. (2004). The first panel of Table A.2 shows the unit cost of the traditional "EPI6" vaccines by district. Though there is variation across the districts, the average unit cost per dose is USD0.9 (median USD0.6). If a hepatitis B vaccine is included, the total cost per dose goes up to on average USD1.4 (median USD0.8). Finally, when TT and TT booster vaccines are added, the total cost per dose goes down slightly to USD1.1, on average.

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[51] The author's calculation using Lydon (2007).

Table A.2. Unit cost of vaccines per dose (2007USD)

District	Median	S.D.	Mean	Min.	Max.	No. of observations
EPI6						
Bangka	0.5	0.3	0.6	0.3	1.2	12
Banjarnegara	0.6	0.4	0.6	0.2	1.3	12
Belitung	1.1	1.2	1.4	0.4	4.0	12
Pekalongan	0.6	0.6	0.8	0.2	1.9	12
Sub-summary	0.6	0.8	0.9	0.2	4.0	48
EPI6, Hep B						
Bangka	0.5	0.3	0.7	0.3	1.2	15
Banjarnegara	0.8	1.0	1.0	0.2	2.8	15
Belitung	1.1	1.1	1.4	0.4	4.0	15
Pekalongan	0.7	1.4	1.4	0.2	4.9	15
Sub-summary	0.8	1.4	1.4	0.2	4.9	15
EPI6, Hep B, TT, and BIAS						
Bangka	0.7	0.4	0.8	0.3	1.5	21
Banjarnegara	0.4	0.9	0.8	0.2	2.8	21
Belitung	1.1	1.0	1.4	0.3	4.0	21
Pekalongan	0.7	1.2	1.2	0.2	4.9	21
Total summary	0.8	0.9	1.1	0.2	4.9	84

Source: Mardiati et al. (2004)

Third step: estimating vaccine procurement cost per dose

In order to estimate vaccine prices from the unit costs, two assumptions are made. First, for the traditional EPI6 vaccines, it is assumed, based on Lydon (2007), that vaccine procurement costs represent 20-30% of the average vaccine costs.

Compared to the traditional EPI vaccines, the price of non-traditional EPI vaccines such as the hepatitis B vaccine is high. Table A.3 summarizes the procurement cost of the Hep B vaccine by vial format in Indonesia from several studies.

Table A.3. Price of Hep B vaccine and disposable syringe

Study	Vial format	Price (2007USD)
Vaccine		
GOI (2001)	Multi-dose vial	0.4
Levin et al. (2005)	6-dose vial	0.9
	5-dose vial	1.6
	Uniject	2.3
GOI (2004)	Uniject	1.1-1.2
Anwar (2001)	Uniject	0.8
Syringe		
Levin et al. (2005)	Disposable	0.1-0.3

Based on all of the data available, the procurement cost of Hep B vaccine ranges from USD0.4 to USD2.3. I assume a simple linear relationship between the unit cost and the procurement cost of Hep B vaccines and assign the procurement cost for each observation. Table A.4 shows the assumed procurement cost of Hep B vaccines in details.

Table A.4 Estimates of the Hep B procurement cost (2007USD)

Study District	Admin. year	Unit cost	Estimated procurement cost	
			Lower bound	Upper bound
Mardiati et al. (2004)				
Bangka	2001	1.0	0.4	0.5
	2002	1.2	0.4	0.5
	2003	0.8	0.4	0.5
Belitung	2001	1.5	0.4	0.5
	2002	1.4	0.4	0.5
	2003	0.9	0.4	0.5
Banjarnegara	2001	2.8	0.8	1.6
	2002	2.8	0.8	1.6
	2003	2.7	0.8	1.6
Pekalongan	2001	2.7	0.8	1.6
	2002	3.4	1.6	2.3
	2003	4.9	1.6	2.3

Note: USD1= Indonesian Rupiah (Rp) 9,250 in 2000; USD1= Rp 10,000 in 2001; USD1= Rp 9,350 in 2002; and USD1= Rp 8,550 in 2003.

Next, the procurement costs of all vaccines are summarized in Table A.5 based on the two assumptions above. In Indonesia the EPI vaccines are purchased from Bio Farma and so the domestic prices could be a little different from the international prices. The international prices of EPI vaccines reported by Lauria and Stewart (2007) are similar to the lower bound of the estimated prices under the assumptions discussed above.

Table A.5 Comparison between international EPI prices and estimated prices (2007USD)

Vaccine	EPI price	Estimated price per dose	
		Lower bound	Upper bound
BCG	0.17	0.16	0.24
DTP	0.12	0.12	0.18
Measles	0.25	0.31	0.46
Polio	0.15	0.07	0.10
Hep B	0.84	0.79	1.17

Fourth step: estimating vaccine delivery cost

Finally, the vaccine delivery costs are estimated by subtracting the estimated procurement costs from the unit costs (see Table A.6). The third column (mean) shows that the average delivery costs range from USD0.2 to USD1.4. This finding is comparable to the vaccine delivery costs for seven GAVI-eligible countries. Their delivery costs, from country-level financial sustainability plans, range between USD0.3 and USD1.0 per dose in 2007 dollars (Sinha et al., 2007). Since the price estimates using 20% of the unit cost are close to the international prices above, the upper bound of the estimated delivery costs is used in the main analysis.

Table A.6. Estimated delivery costs of vaccines per dose (2007USD)

Vaccine	Median	S.D.	Mean	Min.	Max.	No. of observations
Lower bound (=unit-cost vaccine price estimated at 30% of unit cost)						
BCG	0.54	0.22	0.56	0.27	0.95	12
DPT	0.36	0.16	0.42	0.27	0.74	12
Polio	0.20	0.10	0.23	0.12	0.43	12
Measles	0.83	0.64	1.07	0.45	2.82	19
Hep B	0.95	0.55	0.98	0.30	2.57	14
TT	0.58	0.55	0.80	0.23	1.88	12
TT booster	0.43	0.30	0.49	0.18	1.07	12
Upper bound (=unit-cost vaccine price estimated at 20% of unit cost)						
BCG	0.61	0.25	0.63	0.31	1.08	12
DPT	0.42	0.19	0.48	0.31	0.85	12
Polio	0.23	0.11	0.26	0.14	0.49	12
Measles	0.94	0.73	1.22	0.52	3.22	19
Hep B	1.04	0.82	1.35	0.40	3.32	14
TT	0.67	0.63	0.91	0.27	2.15	12
TT booster	0.50	0.34	0.56	0.20	1.22	12

Appendix B. Cost of vaccine delivery through simultaneous administration

In one of the scenarios, the typhoid vaccine would be simultaneously delivered with the TT vaccine through the existing BIAS program. Since the TT booster program is already established for primary school students, the only additional costs of delivering the typhoid vaccine would be the cost of the additional volume of typhoid vaccine and the cost of additional administration time. Personnel costs are often the single largest cost in immunization programs. Table B shows the contribution of personnel cost to the incremental costs from several studies.

Table B. Percent of personnel cost out of the incremental cost

Country	Type of vaccine	Personnel cost	Vaccination staff salary	No. of immunizations	Administration year
Stewart (2005)					
Indonesia	typhoid	81%	29%	4,828	2004
India	typhoid	62%	26%	37,686	2004
Vietnam	typhoid	92%	57%	32,267	2003
Pakistan	typhoid	41%	41%	12,830	2003
Hutton and Tediosi (2006)					
Tanzania	malaria	36%	NA	1,438,000	2003
WHO (1981)					
Indonesia	EPI	53%	NA	11,394	1979-1980
Creese et al. (1982)					
Indonesia	EPI	42%	NA	1602	1979-1980
Philippines	EPI	60%	NA	396	1979-1980
Thailand	EPI	55%	NA	189	1979-1980

In a recent and comprehensive study, Hutton and Tediosi (2006) estimate the incremental costs of adding a hypothetical malaria vaccine to the EPI schedule in Tanzania. They find that 36% of the incremental costs are personnel costs. Two studies conducted in Indonesia and using data from the 1970s (WHO, 1981; and Creese et al., 1982) show personnel costs to be 42-60% of the incremental costs. Except for the DOMI projects (Stewart, 2005), the average contribution of personnel costs falls in the range of a finding from the GAVI Immunization Financing (IF) Database. The IF database collects the existing costing information across countries and

summarizes that personnel costs in general account for 50% to 75% of the incremental costs (Lydon, 2007).

The DOMI projects (Stewart, 2005) provide detailed information for each of the average delivery cost components. Specifically, the salary of the vaccination team is reported as 26% to 57% of the incremental costs. In order to remove the extra research expenses from the project costs, 50% is subtracted based on a careful review of the IF database and the DOMI projects. The salary of the vaccination team is therefore approximately equivalent to USD0.3 out of the delivery cost (USD0.6) for the single administration. If it is assumed that the vaccination time of the simultaneous administration is half that of the single shot, the delivery cost decreases to USD0.45 (=USD0.6-USD0.3×1/2). This is a conservative estimate since it does not reflect other potential savings in the vaccine delivery. In order to account for uncertainty, it ranges from USD0.2 to USD1.2.

Appendix C. Probit analysis of whether school-aged children attend school

The probit model is based on the information provided by the contingent valuation survey on whether a school-aged child attends school. In order to specify the characteristics of this group, the probit model is used. The dependent variable, or indicator variable, is set to one for those who have school-aged children who do not go to school. Otherwise, it is zero. Table C presents two different specifications.

Table C. School attendance of school-aged children using probit model, N=835 (t-statistics in parentheses)

Independent variable	Model 1	Model 2
Income quintile II (monthly household income is USD61-88)	-0.041 (-0.26)	-0.039 (-0.25)
Income quintile III (USD88-138)	-0.083 (-0.52)	-0.079 (-0.5)
Income quintile IV (USD138-): richest	-0.011 (-0.08)	-0.007 (-0.05)
Respondent is 30-39 years old	0.202 (1.46)	0.206 (1.49)
Respondent is 40-49 years	0.783*** (5.1)	0.788*** (5.18)
Respondent is 50-59 years	0.517*** (2.62)	0.507*** (2.58)
No schooling	0.420*** (2.72)	0.356*** (2.49)
Primary school	0.301** (2.06)	0.287* (1.98)
Middle school	0.141 (0.89)	0.131 (0.83)
Respondent is a worker in formal sector†	-0.242* (-1.69)	-0.246* (-1.73)
Number of children	0.456*** (11.25)	0.454*** (11.21)
Travel time to nearest health facility > 15 min.	0.006 (0.05)	
Typhoid is common in neighborhood	0.224* (1.63)	0.213 (1.6)
Respondent knows someone who has had typhoid fever	-0.039 (-0.32)	
Respondent knows about EPI vaccines	0.009 (1.53)	0.008 (1.46)
Religion is Muslim	-0.145 (-0.62)	
Respondent fails effectiveness twice	-0.185 (-1.23)	
Constant	-2.028*** (-6.58)	-2.195*** (-11.18)
Pseudo R^2	0.227	0.225
Log likelihood	-401.35	-402.35

Note: † Formal sector is defined as civil servant, worker in public or private sector, sewage worker, service worker, or laboratory personnel

School-aged children are less likely to attend school if (1) their mothers or fathers are 30-59 years old, as compared to parents younger than 30 years old; (2) their mothers or fathers have lower educational attainment (i.e., respondents did not complete middle school); (3) their mothers or fathers do not have formal jobs such as civil servant, worker in the public or private sector, sewage worker, service worker, or laboratory personnel, but rather are mostly street vendors, housewives, self-employed, unemployed, or retired; and (4) the number of children in their household is large.

There is no clear evidence that the following have an effect on school enrollment: (1) monthly household income; (2) how far the nearest health care facility is located; (3) their mothers of fathers know someone who has had typhoid fever; (4) their mothers of fathers know about the EPI vaccines; (5) their families are Muslim; or (6) their mothers or fathers fail to understand the concept of vaccine effectiveness.