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Chad Meyerhoefer
Agency for Healthcare Research and Quality (AHRQ)

David E. Sahn
Cornell University

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Chad D. Meyerhoefer
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1. Introduction

Good maternal health is of fundamental importance to a country's well-being and ability to prosper, and there are few times when maternal health is more at risk than in the period surrounding childbirth. Protecting the health of mothers during reproduction safeguards their future contributions to society and ensures the health and productivity of future generations. If either the health of mothers or their newborn offspring is compromised, there will be serious negative consequences for their families, communities, and the entire process of economic and social development. This is why the United Nations has set as one of its eight Millennium Development Goals (MDGs), the reduction of the maternal mortality ratio (MMR) by two-thirds in the developing world by the year 2015.

The MMR is simply the total number of maternal deaths occurring for a given number of births (typically 100,000), or equivalently, the total number of births times the obstetric risk of death per individual birth. It measures a women's risk of death after becoming pregnant and carrying the child to term.[1] By most accounts, it is unlikely that Sub-Saharan Africa will be able to reach this goal without a significant commitment of financial and intellectual resources. According to joint estimations by the WHO, UNICEF, and UNFPA for the year 2000, the MMR of maternal deaths per 100,000 live births was 920 in Sub-Saharan Africa, compared to 20 among all developed regions and the worldwide average of 400. Despite the fact that Asia accounted for a slightly larger number of total maternal deaths than Africa, no other region in the world came close to the high mortality risk per birth found in Sub-Saharan Africa. When region's risk of mortality per pregnancy is combined with the prevailing fertility rate in the calculation of an individual's lifetime risk of maternal death, the disparity is even more pronounced. Over a women's lifetime the risk of maternal death in Sub-Saharan Africa is 1 in 16, compared to 1 in 2,800 in the developed world, and 1 in 46 in the region with the next highest risk, South-Central Asia (WHO/UNICEF/UNFPA, 2004).

While data on acute maternal morbidity is less readily available, it is far more prevalent that mortality. For example, a recent study of Kalafong and Pretoria Academic hospitals, catering for the delivery of indigent women in the Pretoria health region in South Africa, found that for every maternal death, there were five times as many 'near-

[1] The number of deaths per 100,000 pregnancies would be a more comprehensive and precise metric since it includes mortality from unsafe abortions, but incidence of pregnancy is difficult to track.

misses' described as a patient with an acute organ system dysfunction, which if not treated appropriately, could result in death (Mantel et al., 1998).[2]

Sub-Saharan Africa also has the lowest GDP per capita of any region in the world. There is not doubt that poverty in the region contributes to significant disparities that exist in maternal morbidity and mortality (MMM) between Sub-Saharan Africa and the developed countries. Indeed, there are many ways in which poverty might lead to high MMM, which we will explore in detail below. For example, extreme poverty is often associated with poor nutrition and diseases such as anemia, which are significant risk factors during pregnancy. Poorer member of society may also have limited access to necessary antenatal medical care as well as appropriate medical resources during and after delivery. They may live in sub-standard dwellings without access to fresh water and be at greater risk of contracting malaria or parasitic infections that compromise a woman's immunity during pregnancy. Furthermore, a variety of demographic factors, such as young age at first birth and high overall fertility can increase the reproductive risks to mothers and their offspring.

A corollary of poverty, low levels of education, also adversely affects the health of both mother and child, through a range of pathways. For example, education is paramount in determining the quality of care for children, as well as the ability to access and understand the benefits of health information. This includes messages imparted through schools, but also through other channels such as the print media. Even time preferences and the nature of the individual's discount rate may affect health, as well as subsequent economic outcomes, in important ways. If discount rates are lower among the wealthy and educated, they will take greater steps to insure their longevity and demonstrate health preserving behaviors.

As with other factors influenced by poverty, poor maternal health outcomes can limit the future productivity of households and lead to further impoverishment. This creates a poverty trap whereby mothers are more likely to die or become ill during or after pregnancy because they are poor, and more likely to be poor in the future as a result of negative health shocks during this period. Clearly, illness or death resulting from childbirth will limit a women's future productivity in the labor market, but perhaps a more serous negative consequence of MMM is reduced productivity in domestic and caretaking activities. The inability of mothers to care for their newborns greatly increases the risk of infant mortality or other adverse health events which can have long lasting consequences (Strong, 1998). Other household members are also inevitably affected by

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[2] The most common reasons for a near-miss were: Emergency hysterectomy in 42 women (29%); severe hypotension in 40 (27%); and pulmonary edema in 24 (16%). The most common initiating obstetric conditions were hypertension in 38 women (26%); hemorrhage in 38 (26%); and abortion or puerperal sepsis in 29 (20%). The primary obstetric factors amongst the maternal deaths were: Hypertension (33%); sepsis (27%); and maternal medical diseases (17%) in 10, 8 and 5 women respectively. Sub-standard care was identified in 82 cases. Breakdown in the health care administration was identified in 33, and patient-oriented missed opportunities in 34 occasions.

MMM. For example, the need for pre-existing children to take over the mother's domestic and caretaking responsibilities can lower educational attainment and reduce future earning potential. This problem is particularly relevant to young girls, who are the likely substitutes for women in caretaking roles. The same girls who are therefore likely to withdraw from school are both likely to have high levels of fertility and be primarily engaged in low skilled and low wage self-employment and home production. In any case, the relationship between MMM and poverty is both multi-faceted and complex, necessitating a through investigation using a unified theoretical framework.

Before we proceed in establishing such a framework, we note that the clinical definition of maternal morbidity and mortality (MMM) is often defined in terms of a relatively narrow time frame surround child birth. For example, according to the 10th revision of the International Classification of Diseases (ICD-10), maternal death is defined as *the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes* (WHO, 1992). The concept of maternal morbidity is, therefore, defined analogously by substituting *illness* for *death*. Because the 42 day limit is somewhat arbitrary the ICD-10 also includes a second category for *late maternal death*, which is defined as *the death of a woman from direct or indirect obstetric causes more than 42 days but less than one year after termination of pregnancy* (WHO, 1992). While these definitions are of considerable use for endeavors such as the collection of vital statistics, we find them too restrictive for our efforts. Rather, in this paper we address more broadly the concern over maternal morbidity and mortality of women during their reproductive years and as a consequence of their reproductive experience, even if the health assaults occur outside the narrow definitions of the WHO. Likewise, our concern with the health and well-being of women in their reproductive years includes both indirect (e.g., malaria, anemia, hypertension, malnutrition) and direct causes of morbidity and mortality such as severe bleeding and sepsis.[3] While the distinction between indirect and direct causes of maternal morbidity and mortality may be of some importance in terms of their causation, it is important to note that the far majority of all these conditions could be prevented with proper medical care, information, and reproductive services that alter the women's circumstances and behavior, a point that we will stress in the remainder of this paper.

[3] According to the WHO (1997), bleeding (hemorrhage) lead to 24 percent of maternal deaths, and infections, such as sepsis, caused 15 percent of deaths. The remaining direct causes of maternal mortality were unsafe abortions (13 %), eclampsia (12 %), obstructed labor (8%), and other direct causes (8%), including ectopic pregnancy, embolism, and anesthesia-related death. Indirect causes accounted 20 percent of deaths. A more recent analysis by Khan et al. (2006) based on a sub-set of countries in Africa, suggests hemorrhage is responsible for 33.9 percent of deaths, followed by indirect causes (16.7%), sepsis/infections (9.7%), hypertensive disorders (9.1%), and HIV/AIDS (6.2%).

2. Theoretical Framework

In determining the causal pathways through which poverty impacts MMM and vice versa it is useful to formalize the process of individual health production using a general economic framework. This will serve as a basis for how poverty status interacts with the health of mothers and their newborn offspring. The basic framework presented below relies heavily on the standard neoclassical approach to utility maximization at the household level. While this approach is fundamentally based on individual preferences and decisions, the significant pooling of resources and joint nature of decision-making among members of the same household has traditionally lead to the measurement of most economic variables at the household-level. Assuming the household can be treated as a single decision making unit also greatly simplifies the presentation of the underlying theoretical model. For this reason, as well as to maintain consistency with the data, the unitary household model is still in wide use in both the theoretical and empirical development economics literature.

Of course, the model is only strictly appropriate if all household members share the same preference structure or the household head is able to impose his/her will on the other members in a perfectly dictatorial fashion. These assumptions are surely violated in some situations, but they remain reasonable approximations to reality in others. Rather than presenting a multitude of different models, we lead with the unitary model, followed by a brief discussion of intra-household bargaining models which allow us to consider the fact that preferences are likely to differ among household members. In addition, we point out cases throughout the analysis where the latter approach is most relevant.

While there are many similar versions of the unitary model, we use that of Behrman and Deolalikar (1988) as the basis for our formulation. Theirs is a household-farm production model along the lines of those discussed by Singh, Squire and Strauss (1986), in which the household engages in agricultural production as well as the production of health, nutrition, productivity, and children. First, assume that household preferences can be represented by the following utility function:

$$U = U(H_i, C_i, S, T_i^L, E_i^c, B^S; \xi) \quad i = 1,..., I \tag{1}$$

where H_i is the health of household member *i*, *C* is the household's consumption bundle, *S* is shelter (housing characteristics) and living environment, T_i^L is household member *i*'s leisure time, E_i^c is the educational attainment of child *i*, B^S is the number of surviving children in the household, ξ is a vector of taste norms, and *I* denotes the total number of household members. Note that some of the arguments of *U* are vectors. For example, consumption, C_i, includes each household member's consumption of food, nonfood goods, services, and consumption flows from the household's stock of durable assets.

As part of the utility maximization process, the household is involved in the production of various inputs to utility. The production process we are most concerned

with corresponds to the individual health of mothers and their family members. Following Grossman's (1972) model of health as a stock variable, we assume that maternal health is both produced and maintained by investments made in the current period, which when combined with the previous period's health stock generates current health status:

$$H_{it} = H(H_{it-1}, N_{it}, C_{it}, T_{it}^{H}, E_{it}, M_{it}, S_t). \quad (2)$$

While we will generally suppress all time subscripts, we use them here to demonstrate the dynamic nature of health accumulation. In addition to the previous period's health stock, the mother's current health is a function of nutrient availability, N_{it}, consumption goods, shelter and living environment, time devoted to the maintenance of health, T_{it}^{H}, her education, and consumption of medical services, M_{it}. Through backward recursion, current health is, therefore, a function of all previous values of these inputs as well as the genetically determined initial endowment of health and other physical attributes, η_i.

Closely related to the production of health is the production of nutrients, a key input into the health production function:

$$N_i = N(C_i, E_M, T_M^{P}, S). \quad (3)$$

In (3) T_M^{P} denotes the mother's time spent in home production including the preparation of food. While nutrient production is primarily a function of food consumption, the mother's skill or education level, time spent processing and preparing food, and food storage and sanitation facilities captured by *S* all impact her ability to extract nutrients from raw food inputs. The mother (food prepares') skills and time also enter into nutrient production functions of other household members.

Both health and nutrition are also related to fertility and the mother's ability to successfully carry a child to term. However, the fertility decision is a joint one between the reproductive couple, and is influenced by the father's nutrition and health status as well as the education levels of both the mother and father, their genetic endowments, and their access to contraception and family planning services, C^{C}. Therefore, the production function for births can be written as

$$B_{M,F} = B(H_M, H_F, N_M, N_F, \eta_M, \eta_F, E_M, E_F, C^{C}; \xi). \quad (4)$$

Not all of the children who are born will survive past one year of age (the typical threshold used to measure infant mortality). If we let H_c^{*} denote the critical level of health status required for the survival of child *c*, then the number of surviving children in the household is

$$B^{S} = B_{M,F} - M(H_c - H_c^{*}) \quad c = 1,...,I_c \quad (5)$$

where $M(\cdot) = 1$ if $H_c - H_c^* \leq 0$ and 0 otherwise.

It is also possible that the mother may die or become ill during pregnancy, delivery, or the postnatal period. The mother's mortality function is likewise

$$M_M = M(H_M - H_M^*). \tag{6}$$

The morbidity function indicating sickness is defined analogously, except that the threshold level of health status corresponding to sickness is higher than that corresponding to death.

In the developed country context where markets are more complete and nutrient availability is less constrained, the above framework would likely be considered sufficient to model health production, nutrition, and fertility with the household's other consumption decisions. However, this separability between consumption and production, or factor markets, may not apply in certain African contexts for two main reasons: 1) many rural households in Africa engage in both own-account agriculture and the cultivation of cash crops, so their food consumption and production decisions are jointly determined; and 2) nutrient availability is more variable and often reaches levels at which health and labor market productivity are adversely affected. In these circumstances, labor market productivity and agricultural production will ideally be modeled jointly with household consumption decisions.

The hypothesis that nutrition and health have some impact on labor market productivity has become widely accepted among development economists, though the level and nature of this relationship is still subject to debate. Two facts are clear: there is a high incidence of malnutrition and infectious disease in many developing countries; and there is a high reliance on physical strength and stamina in most income earning activities, including non-wage work such as own-account agriculture. It is widely acknowledged, both on the basis of theoretical and empirical work, that average productivity per worker is reduced by lower average health status.

To amplify, the "efficiency wage hypothesis" (Stiglitz, 1976; Bliss and Stern, 1978) has made clear the theoretical foundations for the relationship between health and productivity, and thus employment, labor supply and wages.[4] In a review of research related to this efficient wage hypothesis, Strauss and Thomas (1998) conclude that while poor health does not appear to result in widespread involuntary unemployment, moderate to severe health problems do reduce productivity and labor supply. They also conclude that the balance of evidence points to a positive effect of nutrient intakes on wages.

[4] Underlying this hypothesis is the supposition that many people are engaged in wage or piece rate labor that is dependent on physical strength, and therefore, good health, making it likely that health status directly impacts worker productivity.

In order to capture health and nutrition impacts on productivity, the wage is modeled as an endogenous variable dependent on consumption decisions impacting health and nutrition. Thus,

$$P_i^L = P^L(H_i, N_i, E_i, LM, \eta_i) \tag{7}$$

where P_i^L is the individual's wage (or shadow valuation of time) and *LM* represents local labor market conditions. In situations where labor markets are high functioning and chronic malnutrition is rare, as in some urban areas, the wage could be treated as exogenously determined by prevailing labor markets. However, this is not often the case for rural farm households, either because they are subject to fluctuations in nutrient intake or labor markets are poorly functioning.

It is also necessary to account for the household's production decisions related to agriculture, or possibly the informal service or manufacturing sectors. Output from the household's farm (or firm) is a function of a variety of household characteristics and productive inputs, such that

$$Y = Y(H_i, N_i, E_i, T_i^F, \eta_i, K, A, L, S) \quad i = 1,..., I \tag{8}$$

where T_i^F represents the time devoted to farm/firm production (by both adults and children), *K* is capital stock and land, which is either owned by the household (K^H) or rented (K^*), *A* is a vector of intermediate inputs to the production process, and *L* is hired labor. In contrast to hired labor, the household's labor input is substituted out of (8) as a function of health status, nutrient intake, education level, endowments, and time input. While it is assumed that the household can go to the external labor market to hire workers of a given quality, the quality of family labor is determined jointly with consumption decisions and health production. In many case, it may be reasonable to assume that family members' labor is perfectly substitutable for hired labor. However, if a household member experiences a significant drop in health status, a given hour of their labor will no longer contribute as much to output as an hour of hired labor.

When maximizing utility and farm/firm profits, the household faces both a time constraint and a budget constraint. The time constraint states simply that time devoted to all activities cannot exceed T_i, the total allowable time during the day:[5]

$$T_i = T_i^H + T_i^E + T_i^P + T_i^L + T_i^W + T_i^F \tag{9}$$

[5] Often total allowable time is defined as 24 hours minus that devoted to sleeping and eating (6-10 hours). However, in the case where one of the time categories is time spent in health maintenance activities (T_i^H above), much if not all of the time spent eating and sleeping falls under this category, so that total time is exactly 24 hours.

Thus, total time is devoted to health maintenance activities, education, home production, leisure, the external wage labor market, or farm production, respectively.

The budget constraint is simply an expression of the total resources available to the household and a description of how they can be spent. One important component of total resources is farm profits, which is expressed as:

$$\Pi = P^Y Y - P^A A - P^{L^*} L^* - \sum_i P_i^L T_i^F - dK^H - rK^* \tag{10}$$

where P^j represent various output or input prices, *d* is the depreciation rate on owned capital, and *r* is the rental rate on hire capital. The other component of total resources is the value of each household member's time, $\sum_i P_i^L T_i$. Incorporating both total human resources and financial resources into one "full income" constraint yields the following exhaustive representation of household resources and expenditures[6]:

$$\Pi + \sum_i P_i^W T_i^W + R + \sum_i P_i^L T_i \le PC + P^C C^C + P^S S + P^M M + \sum_i^{I_c} P_i^E E_i + \sum_i P_i^L T_i^L \tag{11}$$

where *R* denotes lump sum transfers, and leisure consumption is defined by the identity: $T_i^L = T_i - T_i^H - T_i^E - T_i^P - T_i^W - T_i^F$.

In the most general case where commodity and labor markets are incomplete to the point where commodity prices and market wage rates are endogenous to the household's decisions, maximization of the above system of equations subject to the budget constraint represents a complex process with many simultaneously determined factors. We have formulated the model under the common, and typically defensible, assumption that the household is a price taker in both the goods and hired labor markets. However, we have allowed for the possibility that each household member's wage rate is endogenous to consumption decisions and health production. In the case where all wages are predetermined, the household's goods consumption and farm production activities can be solved in a recursive fashion (Singh, Squire and Strauss, 1986). First, the household's farm profit function is maximized over labor, intermediate, and other production inputs. The optimized value of inputs is then substituted back into the farm profit function and household utility maximization proceeds with respect to the full income budget constraint with recursively determined farm profits.

Therefore, recursive estimation results in a set of commodity demands that are a function of full income and underlying farm profits. As a result, a change in the price of a commodity that is both consumed and produced will have a "profit effect" in addition to the typical substitution and income effects. Under these circumstances an increase in

[6] In the above formulation we have not included savings since the model can be treated as a single period model conditional on prior investments in health. We might also assume that any potential savings are invested in farm capital, K^H .

price could result in an increase in consumption rather than the textbook decrease in consumption consistent with the law of demand under complete and fully efficient markets. However, if consumption decisions do result in productivity effects on the household labor input, recursivity is broken by the fact that the marginal revenue product of family labor (T_i^F) is a function of an endogenously determined wage rate (P_i^L). Although many of the results from the simplified recursive model will still hold, simultaneity in production and consumption must be taken into account to reveal the implications of the more general model.

In the simplified case where $P_i^L = P^*$ is exogenously determined, recursive farm profit and utility maximization results in commodity demand that take the following familiar form:

$$C_i = C(P, P^*, P^C, P^E, P^S, Y^*, \eta, \xi) \tag{12}$$

where Y^* is full income reflecting profit maximization. The demands for *S*, C^C, E_i^c and M_i, and the labor supply or leisure demand functions corresponding to $T_i^H, T_i^E, T_i^P, T_i^W, T_i^F$, and T_i^L are all defined analogously. These demand functions are then substituted into H_i, N_i, and B_i to generate "derived demands" for health, nutrition, and births. In contrast, when household productivity is endogenously determined, P_i^L and P^* appear separately in (12) and the former is treated as an endogenous variable. Nonetheless, one can substitute out all of the endogenous variables in each demand equation to obtain a reduced form set of demand equations. Because of the simultaneity of production and consumption each endogenous variable will be a function of all the exogenous variables in the system, including prices, the rental and depreciation rates for capital, initial endowments, pre-determined (parental) education, owned capital, lump sum transfers, and taste norms.

While the common preference, or unitary model, can be used to describe household behavior in a large number of situations, intrahousehold bargaining models are sometimes more appropriate to the underlying behavioral process. An intuitive review of household bargaining models is provided by Strauss and Thomas (1995) based on the ground-breaking work of Chiappori (1988, 1992). The underlying premise of these models is that preferences among different household members are not uniform, implying that each member will seek to allocate resources over which they have control to the goods they most prefer. Since resource allocations must be negotiated with other household members, control over a greater proportion of resources increases a member's bargaining power relative to others. While one household member will typically bring more resources to the household than others and emerge as dominant, all members have a fallback position in the event of non-cooperation. If the household were to dissolve, each member would be able to keep a certain percentage of the household's total resources for

themselves. The utility they would derive from such non-cooperative behavior is know as the "threat point". Therefore, if the bargaining outcome between members results in a total allocation of utility that is below the sum of all individual member's threat points, non-cooperation will ensue (Ulph, 1988; Lundberg and Pollak, 1993). Any gains above this level of utility resulting from a cooperative solution will be shared among household members in accordance with the relative bargaining strength of each.

There are several different forms of intrahousehold bargaining models depending on the level of complexity of assumed interactions. The Nash cooperative bargaining model is the most common (McElroy, 1990, McElroy and Horney, 1990). The identification of these models usually necessitates having information on resources controlled by each family member. In the common case of the husband-wife model, it is often difficult to obtain such information for wives who do not work in the wage labor market. One approach that has been attempted in the past is to use household assets originating from the wife's dowry or from women's earning in agricultural activities that are culturally gender differentiated (Hoddinott and Haddad, 1995). Other attempts to deal with the endogeneity of men and women's incomes include using various forms of non-earned income, such as gender-specific transfers or assets (Sahn and Gerstle, 2004; Thomas 1990, 1993). If suitable individual-specific resource information is available, bargaining models can be used to determine household demand levels that reflect the divergent preferences and relative bargaining power of different household members. These demand levels may be very different from those predicted using the unitary model if the husband and wife's preferences are sufficiently divergent, and the wife has control over a nontrivial share of total resources.

3. Poverty and Maternal Health

The strong correlation between poverty and maternal health indicators at the country and regional levels suggests that living in poverty greatly increases the risk of illness for pregnant women and those with newborn offspring. This association is also observed within developing countries across different poverty levels. For example, Graham et al. (2004) examine the relationship between poverty and maternal death in ten developing countries (six in Africa) and find that the proportion of women dying of maternal causes increased consistently with poverty quintile.

Using the theoretical framework in Section 2, we will discuss the most important pathways through which poverty impacts MMM. If poverty does impact maternal health, we know that it must be through the arguments of the health production function in equation 2. These are current and past consumption of medical services, other commodities, housing, nutrient intake, the time devoted to health maintenance activities, and educational attainment. While some of the literature looks at the impact of poverty, or income, on health status in a reduced form sense, we will begin by describing aspects of the literature that shed light on how poverty influences each input to maternal health. In some cases very little empirical research is available on these pathways, but strong

connections can still be inferred from the theory and empirical research on health outcomes in general.

The Demand for Medical Care

One of the most direct inputs into the production of health is the consumption of medical care. The medical services considered most relevant to the prevention and treatment of MMM are recommended antenatal care, medical assistance during delivery and follow-up postnatal care from a qualified medical provider. A number of studies, reviewed by Carroli, Rooney, and Villar (2001), have documented the importance of antenatal care in preventing poor maternal health and infant outcomes in developing countries. Similarly, Koblinsky (2003) finds that assistance by a skilled birth attendant or medical professional during delivery is associated with a significant decline in maternal mortality. Therefore, access to maternal health services stands to play and important role in the production of maternal health.

Since health is a stock variable, past investments in health are also important determinants of current health outcomes. A mother's access to and consumption of health services leading up to pregnancy is necessary for the identification and treatment of conditions that can greatly increase the risks associated with childbirth. For example, the treatment of sexually transmitted diseases, urinary tract infections, or malaria prior to pregnancy can greatly improve a woman's chances of a having a healthy pregnancy and delivery. In addition, Tsu (1994) contends that antenatal care is crucial to the detection of elevated delivery risks and the referral of women to medically assisted delivery environments, suggesting the cascading effect of medical care utilization occurs right up the point of delivery. Therefore, general results from the literature of the relationship between medical care demand and poverty are just as important as those specific to reproductive health services.

Two major strains the in the literature explore explicitly the link between health care utilization and poverty. The first, which is largely descriptive in nature, is the work on fiscal incidence. Studies of fiscal incidence tell us how expenditures on reproductive and related health services are distributed among households, and thus, the extent to which they reach the poor. The second falls in the domain of "behavioral analysis"; this involves the exploration of how individuals or households alter their behavior in response to a policy change. Such analysis is typically conducted using empirically identified demand functions. These allow one to investigate the effects of prices and the quality of health services on access to care, and determine consumers' willingness to pay for publicly subsidized health care.

Fiscal Incidence

Fiscal incidence describes who benefits from public expenditures, such as reproductive health services (Selden and Wasylenko, 1992; Van de Walle, 2003), and therefore, indicates the impact of these services on an individual's welfare, or the welfare of different groups of individuals. More specifically, benefit incidence analysis enables us to determine the overall progressivity of public spending on reproductive health services, for example. Furthermore, this assessment of progressivity can be done both in terms of whether a given service is more progressively distributed relative to the often skewed income or expenditure distribution, or relative to the higher standard of benefits falling disproportionately upon the poor in absolute terms. It is generally focused on the economic, rather than statutory incidence of spending, since the former is largely a description of who is meant to benefit by law, and the latter of whom actual receives the benefits. Furthermore, in the assessment of who generally "benefits" in terms of utilization or access to health services, measurements are typically made using the income equivalents of the services to allow aggregation across services.

Conducting a study of expenditure incidence first requires a valuation of the private benefits that accrue to an individual as a result of a particular type of government expenditure, such as on reproductive health services. While ideally we would use demand functions to estimate the value of these services, this is complex and we therefore generally employ a first-order approximation of the government's cost of providing the service. For some health expenditures, deriving a monetary estimate is straightforward. For example, a visit to the family planning clinic can be valued using the market cost of the birth control device, and the unit cost of providing the service as determined by budget data, including the cost of personnel, facilities, and so forth. If the service is associated with a payment by the consumer, the monetary value is simply the subsidy rate multiplied by the cost of delivering the service. Where this process gets complex is in determining the (private) value of a service provided, especially when the government is the sole provider of the service, and services are rationed. Likewise, it is difficult to value externalities associated with health service provision.

Once the value of services is determined, the second step is to determine whose welfare increases as a result of receiving the services provided. To do this, we initially must rank individuals in the population by per capita or some similar adult equivalent measure of total expenditures, which provides us a picture of the welfare distribution prior to receiving the service or subsidy.

The final step is then to determine whether the distribution of income is the same, worse, or better after the value of the service or subsidy is distributed across the same ranking of the population. In making this comparison, it is possible to employ an index, such as a gini coefficient, to reduce the information from a continuous welfare distribution to a single value. Thus, we compare aggregate welfare with and without valuing the public expenditure as part of an individual's welfare. Given the arbitrary nature of the choice of indices, however, the use of tests of stochastic dominance in comparing concentration curves is generally preferred (Yitzhaki and Slemrod, 1991). A

concentration curve is similar to a Lorenz curve in that it graphs the cumulative share of the sample, from poorest to richest, on the horizontal axis, against the cumulative share of benefits from a given service or subsidy on the vertical axis. Public services whose benefits are more concentrated among the poor will have higher (more convex) concentration curves, and vice versa. We can also compare the concentration curves to other benchmarks: a Lorenz curve for per capita expenditures and the 45 degree line.

There is a large literature, both theoretical and empirical on conducting incidence analysis (Van de Walle, 2003). The work by Sahn and Younger (2000) is notable among this literature because it provides a cross-country examination of a range of services, including public and private health services that are both primary and hospital based. The general picture emerging across many different studies is that public health services tend to be more progressive, in contrast to private health services and tertiary care. When such analyses disaggregate public service provision to a lower level they tend to find no statistical difference in terms of the progressivity of services accessed by men and women. However, what is virtually absent in the literature is incidence analysis that focuses on women's use of reproductive health services, such as family planning, or pre- and post-natal care.

While incidence analysis is often considered an attractive research area, the limitation of this approach is that it is static, capturing the situation given the policies and conditions that are prevailing at the time that data are collected. It is impossible, however, to use such information to simulate the impact of how households or individuals will respond to policy changes. Thus, while quite common among researchers, development practitioners and program planners, it is perilous to formulate policy recommendations without an appropriate counter-factual analysis.

Demand Analysis

Econometric studies of demand behavior allow us to determine how individuals respond to alternative policies and to fluctuating market conditions, through the use of standard comparative statistics results. More specifically, we can assess the impact of policy changes on service utilization, conditional upon a wide range of individual, household, community and clinic characteristics at various points in the income distribution. Furthermore, this type of exercise allows us to value public services as well as assess their costs. Valuations can be made specific to sub-groups defined by income, race, ethnicity, location, and so forth, making it easier to determine how best to encourage vulnerable members of the population to access desirable public services.

The demand functions for medical care specified in the form of equation 12, suggest that prices and (recursively determined) full income are the primary economic determinants of utilization.[7] Therefore, estimates from structural medical care demand

[7] If recursivity cannot be assumed, then the other exogenous variables will have a direct impact as well, but we will focus primarily on predetermined full income. Note that this still allows us to consider price effects in the form of wages, which influence labor supply and other time allocation decisions.

models of price and income effects should allow one to determine the impact of poverty, or low income levels, on the demand for medical care and production of health. Other socio-economic determinants may also be important in the sense that they are correlated with both poverty status and the demand for medical care. While the literature on non-economic factors is somewhat less conclusive, we will review some of the findings for Africa to aid variable selection in demand functions.

A number of researchers have investigated medical care utilization among the poor in developing countries, primarily in the context of how access to care is influenced by user fees and distance to health care providers. User fees, or fixed charges per visit/procedure, became an important issue for developing country health delivery systems beginning in the mid-1980s when a number of countries with fully subsidized medical services began to impose them in order to help finance the public provision of medical care. Because user fees are generally not means tested they are regressive in the sense that they represent a larger share of a poor household's income than a wealthier household's income. This would be the case even if the price responsiveness of medical care was invariant across all members of the population. However, the regressive nature of user fees is compounded by the fact that several researchers have found that higher prices for medical care reduce utilization by the poor proportionally more than by wealthier individuals.

For example, Gertler, Locay, and Sanderson (1987) find that medical care demand becomes less price elastic as income rises in Peru. Meyerhoefer, Sahn, and Younger (2007) conducted user fee simulations in Vietnam and similarly found that their removal would substantially increase access to publicly provided medical care and both hospitals and clinics. Again, due to the declining relationship of medical care price elasticities with income, this improvement in access would be most beneficial to those below the poverty line.

Similar results have been reported for Africa. Deininger and Mpuga (2005) found that the removal of user fees in Uganda lead to improved access to care by the poor and a reduction in the probability of sickness, presumably through better access to preventative health services. Similar evidence from other African countries, such as Ghana (Waddington and Enyimayew, 1990), Kenya (Mwabu et al., 1995), Swaziland (Yoder, 1989) and Zambia (Kahenya and Lake, 1994), indicate that there are significant declines in the use of public clinics subsequent to the imposition of user fees.

Although none of these studies is focused specifically on the demand for maternal health services, it is reasonable to assume that the same relationship between price and demand that holds for medical care in the aggregate applies these services as well. Therefore, increases in the price of maternal care presumably limits access by the poor more than the wealthy, making the poor particularly vulnerable to the imposition of user fees for reproductive health services.

One might argue, however, that user fees are not the true rationing mechanism for medical care in developing countries. Even in places were user fees are zero, access to

health services is often limited by the substantial distances many households must travel to reach public medical facilities. This is especially true in rural areas, where a large proportion of the population lives below the poverty line. Dor et al. (1987) have likewise demonstrated using date form rural Cote d'Ivoire that the familiar curvature in price elasticities holds for travel distances as well. In particular, poorer individuals are significantly more travel time elastic than wealthier individuals, so even non-monetary access costs are a bigger limiting factor for the poor. This result is confirmed by Sahn, Younger and Genicot using data from Tanzania (2003), when travel distances are translated into forgone labor earnings.

The only study of which we are aware that estimates the demand specifically for maternal health services in Africa is by Overbosch et al. (2004). Using data from Ghana, they measure the impact of socioeconomic variables, the cost of care, and distance to medical providers on the demand for antenatal care. While they do not provide elasticity estimates by poverty status, they do find that lowering the price of care to zero increases the likelihood that a woman visits a trained physician the recommended number of times (four) prior to delivery. This effect, however, is small relative to the removal of travel costs to doctors' offices, which increases the share of mothers that purchase or receive at least four doctor visits by 5.1 percentage points. The provision of basic education to all increases the proportion of mothers that receive sufficient antenatal care, by a doctor, midwife, or nurse, by 10.9 percentage points. Consistent with previous studies, their relatively large effects for distance and education level suggest that the poor, who live in rural areas relatively further from most providers and are less educated, on average, are significantly less likely to receive recommended levels of antenatal care than others.

While most policies aimed at increasing access to health care to the poor operate through lower prices, or increased provision of services in rural areas (to reduce travel costs), income also has a direct and distinct impact on the demand for medical care. It is widely recognized at this point (and all the above studies confirm) that medical care is a normal good, and so has a positive relationship with income. While the magnitude of the income effect varies from one study to another, the implication of nearly all studies is that economic growth improves access to medical care, and consequently, maternal health services. This result is not very surprising, but it does suggest the demand for care is such that individuals prefer more of it even at relatively high levels of income.

While the issue of quality in the provision of medical services is notoriously difficult to address owing to the lack of data on treatment implementation, some of the above studies indirectly address quality by investigating the demand for care across a range of providers. Physicians are assumed to provide higher quality care than midwifes or nurses. Likewise, hospitals and private facilities generally offer more comprehensive and better treatment than public clinics. By looking at utilization patterns among the different providers across poverty status, one can infer whether there is differential access to high quality services. For example, Meyerhoefer, Sahn, and Younger (2007) find that utilization of lower quality providers (public clinics and self-care) is much higher among the poor than higher quality public hospitals. They do find, however, that utilization at

private facilities is fairly constant across poverty levels, which suggests the poor do have equal access to this one presumably higher quality treatment option.

Overbosch et al. report that utilization of antenatal care is highest for midwives in Ghana, but that simulations to improve access to care, reduce travel distances, and remove user fees lead to greater demand for higher quality doctor visits (for the entire sample), suggesting those who have the financial means to overcome access and cost barriers enjoy better access to higher quality care. Results from Sahn, Younger and Genicot (2003) suggest the demand for health services in Tanzania would increase if people had the option to see a better doctor/nurse, get access to pharmaceuticals, and attend a health center, clinic or dispensary that is cleaner, has a toilet and water, and a roof. While improvements in the quality of doctors/nurses in public clinics and dispensaries appear to increase the demand for treatment in private clinics, many doctors and nurses working in public clinics often have private practices.

In addition to the economic determinants of medical care utilization, poverty status is often associated with certain socio-demographic factors that are correlated with demand. For example, a number of studies have found that parity effects are strongly correlated with use of antenatal care. In particular, women of low parity, particularly those having their first child, are more likely to utilize antenatal care than those of high parity (Pebley et al., 1996; Raghupathy, 1996; Magadi, Madise and Rodrigues, 2000; Short and Zhang, 2004). While some of the authors hypothesize that women with previous birthing experience may have a lower perceived need for care, it is also the case that poorer women tend to have higher fertility rates.

A more direct proxy for lower socio-economic status, education level, has also been shown to be correlated with use of maternal health services. For example, Obermeyer and Potter (1991), Bhatai and Cleland (1995), Raghupathy (1996), and Short and Zhang (2004) all find that higher levels of parental education are associated with greater use of services.[8] Short and Zhang further find that lower socio-economic status, as captured women's occupational characteristics, is associated with the use formal delivery assistance. Finally, Magadi, Madise and Rodrigues (2000) include information on whether pregnancies where mistimed or unwanted and find a significant negative impact of these categorizations on antenatal care use in Kenya. In estimating this effect they control for age of the mother and likewise find teen mothers to be less likely to seek care. Given that the poor are presumably most susceptible to mistimed and unwanted pregnancies, particularly at a young age, these factors can be viewed as further evidence of the negative impact of poverty and low socio-economic status on access to and utilization of maternal health services.

While the focus of the previous discussion is on health care utilization, as we discuss elsewhere, the next link in the chain in terms of how access to care affects health status is even more difficult to quantify and has been the subject of even less research.

[8] Raghupathy actually investigates the impact of education on three different types of maternal health services. While she does find higher utilization is correlated with higher levels of education for prenatal care and delivery assistance, she does not find this to be the case for tetanus toxide inoculations.

The impact of the price of health care on health care outcomes was explored, for example, by Dow (1997) in the US and Indonesia using data from randomized experiments conducted in the two countries. He finds that objective health measures, particularly activities of daily living, worsen as prices increase. Clearly, the data and methodological challenges of running experiments, let alone relying on non-experimental data to address the causal effect of health care prices on demand for services and health outcomes is a major challenge, but one with potentially very high benefits.

Efficacy of public expenditures

While the analysis of behavior is clearly important for gaining an understanding of the efficacy of public expenditures, and the extent to which reproductive health services, for example, reach vulnerable women, there are other important aspects of public services provision that reach beyond their impact on individual behaviors. In particular, questions remain about the economic and administrative efficiency of the services provided. For example, we need to know how efficient public spending is in translating expenditures into the goods and services that they intend to provide.

Regarding the former issue of efficiency, there has been a considerable amount of attention focused on this question, especially in the form of tracking surveys that examine the flow of resources from their source to the point of service. Budget allocations may not be the best indicator of the supply of public services in developing countries with poor accountability and weak institutions. Governments may spend on the wrong goods and people; money may fail to reach frontline services; if money does reach the frontline, incentives to provide the service may be weak, and lastly, even if services are provided efficiently, households may not take advantage of them. In combination, these considerations will determine the efficiency of the services delivered. Of course, there is the additional issue of whether, and to what extent the goods and services provided actually translate into better reproductive health outcomes among the intended recipients, a question that is far more complex and dealt with elsewhere when we talk about behavior and assessing outcomes.

Regarding the issue of whether the money reaches the frontline service, there remains limited research focused on this question. The general form of such efforts – public expenditure tracking surveys (PETS) — examine the flow of resources from the source to the point of service.[9] These types of surveys are particularly valuable for quantifying leakages of funds, capture of resources by politicians and bureaucrats, and problems related to the availability and actions of staff and materials goods, (such as pharmaceuticals).

Even more limited is the research on the extent to which the services are provided conditional upon money reaching the clinic or school. For example, absenteeism may be widespread due to low pay and lack of incentives and oversight of local service

[9] For a clear and concise presentation of the methods and approach discussed in this section, see Dehn, Reinikka and Svenson (2003) and Devarajan and Reinikka (2002).

providers, such as doctors and nurses. This question is generally addressed using tools such as quantitative service delivery surveys (QSDS). These types of surveys collect information on both the *agent* who is responsible for service delivery, and the *principal*, such as the ministry of finance that allocates the resources to the local level. In both types of research, the emphasis is on measuring provider incentives and behavior through the appropriate survey instruments.

In conducting both PETS and QSDS, great care is required given that the characteristics of public service providers and the nature of tasks make it difficult to evaluate performance. Multiplicity of tasks done by the service providers, unobservable actions and outcomes, lack of input and output data, and difficulty in the measurement of output are major constraints in measuring the effectiveness of public service delivery. Tracking surveys explicitly recognize that the officials in charge of service delivery also have strong incentives to misreport (or not report) key data. Therefore, data collection strategies are designed to rely on different sources for the purposes of cross-validation. The facility or frontline service provider is typically the main unit of observation. Data are also collected from facility records, as well as from local, regional and national provider organizations (Dehn, Reinikka and Svenson, 2003).

Tracking surveys are distinct from other existing survey approaches, such as facility modules in household surveys or empirical studies to estimate demand functions, as discussed above. As we note, demand analysis focuses on the response of the household to existing conditions. But those models afford little attention to the question of why quality and access are the way they are. Similarly, in most facility-based surveys, information collected relies on the knowledge of one or more informed individuals. Information supplied by informants is therefore dependent on the perception and expectations of a few individuals. The data is thus subjective in nature and sensitive to respondents' expectations. By contrast, the Public Expenditure Tracking Survey (PETS) or Quantitative Service Delivery Survey (QSDS), approach emphasizes and quantitatively measures provider incentives and behavior. Non-sampling error (caused by poor survey implementation) is more of a concern using the PETS-QSDS approach than sampling error, as the data are often in a highly disaggregated form and hence labor-intensive to collect.

There are a number of African examples of tracking surveys that provide great insight into the efficiency of service provision. This research provides some good insight, both in terms of findings and methods. The fact that previous work has not included the provision of reproductive health services highlights a potential area for future research. Noteworthy among the tracking surveys conducted was the first of its kind, conducted in 1996 in Uganda. The focus was on the education sector, and the study found that on an average, only 13 percent of the annual capitation (per student) grant from the central government reached the schools in 1991–95, on average. By 1995, the proportion had only increased to 20 percent (Reinikka and Svensson, 2002a, b). About 20 percent of teacher salaries were paid to ghost teachers—teachers who never appeared in the classroom (Ablo and Reinikka, 1998; Reinikka, 2001).

In response to this finding, the government instituted an information dissemination campaign on the provision of public funds for schools, which greater reduced the losses in the system from the estimated 80 percent in 1995 to 20 percent in 2001 (Reinikka and Svensson, 2003).

Other studies from Africa, including those from Tanzania and Ghana (Reinikka and Svensson, 2002a, b), have also included looking at health care expenditures. In the case of the former, local (district) councils diverted a large part of funds disbursed by the central government to other use and private gain. Leakage was estimated at 57 percent in education and 41 percent in health care. And in the case of Ghana, only about 20 percent of the non-wage public health expenditure reached the frontline facilities. While these studies were looking more broadly at the health sector, there is clearly scope for similar research that focuses on reproductive health services more specifically.

Fertility, the Demand for Children, and Maternal Health

The relationship between MMM and fertility is a complex one that operates through a multitude of pathways linking health, nutrition, labor supply decisions, and household preferences for children. Much of the literature on poverty and fertility has investigated macroeconomic relationships between economic growth and fertility rates. Studies using long time series of historical data, such as Dyson and Murphy (1985) and Kremer (1993) suggest an inverted U-shaped relationship between economic development and fertility, whereby fertility rates increase at low levels of income, but decrease as aggregate income increases. The turning point in this relationship is often referred to as the "demographic transition", which is preceded by falling mortality and corresponds to increasing levels of investment in the quality of each child rather than production of a larger quantity of children. Tabata (2003) has demonstrated, for example, that incorporating preferences for the "quality versus quantity" of children into an economic model of growth and fertility results in the familiar U-shaped relationship where fertility rates decline as investments in education and other forms of human capital increase. Likewise, there is considerable support in the literature for the so-called "replacement hypothesis," in which lower child mortality is seen as effectively contributing to reduced fertility. Indeed, several papers have explicitly examined this question, such as the work of Ben-Porath (1984), who finds that higher expected mortality increases the number of birth and shortens birth intervals. Likewise, Olsen (1980) finds that replacement is a significant factor and that higher child mortality contributes to greater fertility.

While broad-based theoretical and empirical studies suggest that both child mortality and fertility rates decline with economic growth in the aggregate, researchers have identified some differences across subsets of poor countries. For example, studies from the 1960's and 70s in a number of South/Southeast Asian countries found a negative relationship between poverty and fertility (Aassve et al., 2005). In a recent study of 25 countries in Sub-Saharan Africa, however, Schoumaker (2004) found that fertility generally declined with poverty levels. These inconsistencies in the macroeconomic

evidence are likely a reflection of heterogeneity in the poverty-fertility behavioral relationship at the micro level, and it this level where we would argue that research opportunities, and potential policy relevance are greatest.

The conventional explanation of high fertility among poor agrarian households is that large families are needed to provide inexpensive labor for agricultural production, and that children serve as a form of old-age insurance for their parents. Despite the initial perception that poor households are less likely to be able to support additional children than wealthier ones, economic theory predicts fertility decisions are made by comparing the marginal productivity of each additional child with the cost of supporting it. As long as productivity exceeds cost, parents will continue to reproduce.

However, parents' forecasts of their children's future productivity are certainly less than perfect, and health shocks can play a significant role in a child's ability to contribute the future productive activities. Furthermore, the decision to have children is made jointly with production decisions and, in accordance with equation 4, is influenced by a multitude of difficult to observe factors such as parental health endowments, contemporaneous maternal health status, and knowledge of contraceptive and family planning services. Failure to account for unobservables and the joint nature of the fertility/agricultural production process will lead to biased estimates of the fertility production function and confound estimates of the impact of poverty on fertility. To date, few if any current studies account for these factors, and thus our limited knowledge in this area is based on simple correlations or biased estimates of true underlying relationships.

One area where there has been a fair amount of research is on the impact of maternal health and family planning services and contraceptive use on the production function for births. Not surprisingly, increased use of contraceptives and family planning services is negatively associated with fertility rates. In fact, some have gone so far as the credit these programs with being major factors in the fertility transition of some developing countries (Cleland et al., 1994). There is also an interaction between contraceptive use and access to maternal health care in the birth production function. Using a latent variable structural equation model (SEM) to control for the simultaneity, Ahmed and Mosley (2002) find that the use of maternal-child health care and contraceptives are significantly associated, independent of other determinants. They interpret this as a reflection of the household's desire to jointly increase the quality of medical care for mothers and their infants and limit family size. The positive correlation suggests the two types of utilization are reinforcing so that improving access to health care during the reproductive process actually helps to limit future fertility. This is consistent with previous findings by Warren et al. (1987), Monteith et al. (1987), and Potter, Mojarro, and Nunez (1987).

While the investigation of fertility dynamics is important in its own right, we are most interested in how changes in fertility, particularly those that arise from changes in poverty status and the provision of family planning related reproductive health services, affect MMM. A review of the literature suggests a clear perception that higher rates of

fertility have a negative impact on maternal health. For example, Kaufman (2005) concludes that despite declining access to government sponsored health care over the past twenty years, China's rigid population policy has lead to an overall improvement in women's health by reducing pregnancies and the risk of child bearing. These perceptions and persuasive macro-level correlations notwithstanding, the literature on the impact of high fertility on MMM is both sparse and inconclusive. Much of this literature is focused on the identification of a condition known as "maternal depletion", or the situation that occurs when a mother's health is compromised by the stress and strain of repeated child bearing.

Earlier studies found varying relationships between parity, or the number of delivered children, and health outcomes. For example, Trussel and Pebley (1984) using the Malaysian Family Life Survey, found that if the 5^{th} or higher order births were eliminated, maternal mortality would fall by 4 percent. A study from India has similarly found that 24 percent of the declining maternal mortality rate that occurred between 1972-76 and 1982-86 was attributable to the declining birth rate (Bhat, Navaneetham and Rajan, 1995).

A similar strain of the literature focuses more specifically on the role of family planning services in averting maternal deaths. Winikoff and Sullivan (1987) use data sets from Bangladesh, Nigeria, Sweden and the US to argue that a strategy focused on general fertility reduction, including abortion services and family planning for high risk groups might reduce maternal mortality by 50 percent in developing countries. They also, however, stress the importance of better obstetric facilities and care for pregnant women. Another study from Bangladesh and Egypt makes the case for focusing greater attention on promoting family planning, rather than improving obstetric facilities as a means of reducing maternal mortality (Fortney 1987).

These and other similar studies, however, are limited by the fact that they did not treat parity as and endogenous choice variable. A good example of addressing this weakness in the literature is the paper by Higgins and Alderman (1992). In order to account for the correlation of parity with unobserved preferences for maternal and child health as well as health endowments of the mother, they make use of instrumental variable techniques. Using BMI as a measure of nutritional status they found a positive effect of parity on nutritional status in OLS regressions, but a significant negative effect after instrumenting. They also found after including parity in the models that the magnitude of coefficients on the education variables shrank by 60 percent, suggesting much of the apparent ameliorative effect of education on women's nutrition operates through reduced fertility.

Merchant (1994) has hypothesized that the reason for inconsistent evidence of maternal depletion in earlier research is related to poor measurement of the mother's nutritional status throughout the various stages of the reproductive cycle, and equally poor measures of reproductive stress. With regard to the latter, researchers often use parity as a measure of reproductive burden, but this masks important factors such as time between pregnancies and time allocations to physically demanding versus more sedentary

activities during recuperative periods. Likewise, the use of BMI as a measure of nutrient availability during a women's reproductive cycle does not accurately reflect nutritional status, nor does it account for the fact that a women's weight may vary due to a variety of factors, ranging from water balance to their own pre-natal experience, that condition their propensity to accumulate body fat. In support of Merchant's hypothesis, research by Conde-Agudelo and Belizan (2000) in Latin America and the Caribbean on the impact of interpregnancy interval on MMM found that after adjusting for confounding factors, short intervals significantly increased the risk of maternal death and the following morbidities: Third trimester bleeding, premature rupture of membranes, puerperal endometritis, and anemia.[10] Although it is likely that poverty status is negatively associated with the length of interpregnancy intervals, more research needs to be conducted to determine whether this is indeed the case in Sub-Saharan Africa.

Assuming that maternal depletion is in fact a persistent phenomena, the next question is, why do couples reproduce with such frequency that it compromises maternal health? One answer may be found in terms of the lack of access to information and related reproductive health services, contributing to the discordance between desired and actual fertility. However, the answer to this question may be more complex, and follow from behaviors that are not fully consistent with the standard collective model of household decision making and rationality. Observed maternal health outcomes suggest that adult preferences within the household are not uniform, and that the relatively weak bargaining power of women in poor households leads to fertility decisions not in their best interest. This is particularly true of younger brides who are at greatest risk for pregnancy related complications, but under the most pressure to reproduce (Nour, 2006). Ultimately, conflicting preferences for additional children between couples has the potential to severely compromise the health of both mother and child. For example, Magadi et al. (2000) found that use of antenatal care was infrequent for unwanted or mistimed pregnancies, and the WHO (1997) reports that unsafe abortions account for 17 percent of maternal deaths worldwide.

In order to explore these issues further research using intrahousehold bargaining models is necessary to tease out power structures within the household that influence maternal health outcomes. The existence of maternal depletion also suggests there are market failures in the provision of objective information on contraception and family planning services. Contraception may be an effective means of reducing the short birth intervals that lead to maternal depletion as well as empowering women to take more control of their reproductive destiny. However, public policy aimed at increasing contraceptive use will certainly benefit from economic research on the most cost-effective means of provision of information and services to the poor.

[10] They also find that very long intervals of greater that 59 months put women at risk for pre-eclampsia and eclampsia.

Nutrient Intake, Infectious Disease and the Living Environment

It is widely recognized that proper nutrition is fundamental to the production of good health. Not only do nutrients make proper growth and biological development possible, they allow the body to function properly and ward off disease throughout the lifecycle. Adequate nutrient intake is also essential for desirable pregnancy outcomes, as well as a successful lactation.

The role of nutrients during early child development is especially critical, since deficiencies during this time will lead to smaller body size and greater susceptibility to disease in adulthood. Women with past histories of poor nutrient intake causing short stature are more likely to face complications in pregnancy, such as obstructed labor, and to produce low birth weight babies (Pojda and Kelly, 2000). Therefore, the consequences of poor nutrition are both long term and intergenerational.

Malnutrition during pregnancy is also a significant risk factor for MMM and poor infant health. For example, poor nutrition during conception and lactation, low gestational weight gain, and inadequate micronutrient consumption during pregnancy are significantly associated with low birth weight and infant mortality, as well as maternal complications such as anemia and hemorrhage (FANTA, 2006).

Equation 3 provides a functional representation of nutrient production. It corresponds to an underlying process in which women (the typical prepares of food) extract nutrients from purchased and home grown food using their knowledge, available nonfood inputs, and the characteristics of their dwelling, such as food storage and preparation areas. Poverty status can impact the production of nutrients through all of the inputs in the nutrient production function. Specifically, poor women have lower educational attainment, sub-standard food preparation and storage facilities, and a limited ability to purchase or grow food for consumption. Therefore, some of the effects of poverty on nutrient production occur through lower purchasing power, while others are mediated through lower asset and human capital accumulation. As an example of the latter, Wolfe and Behrman (1987) find that the children of women with more schooling have higher nutrient intakes, even after controlling for unobserved common childhood background. In order to empirically identify these affects of poverty on nutrition one can, in accordance with equation 12, estimate individual demands for food and other inputs to nutrient production as a function of prices, incomes, and exogenous endowments and tastes. To determine the overall impact of poverty on nutrient intakes, these individual demands can be substituted into equation 3 to generate the derived demand for nutrients.

Much of the research on the relationship between poverty and nutrition has taken place in the context of reduced form derived demands, involving the estimation of income or expenditure elasticities of calories and nutrient intake. Reviews of the empirical literature on these elasticities can be found in Behrman and Deolalikar (1988) and Strauss and Thomas (1995). Empirical estimates tend to vary widely (ranging from

0.01 to 1.18 for total calories), in part due to differences in methodology and the failure to account for endogeneity and measurement error. Elasticity estimates based on the indirect computation of calorie elasticities from food demand systems tend to be higher than those computed directly from commodity specific consumption data. In addition, elasticities based on current income tend to be lower than those based on expenditures, possibly as a result of greater measurement error in the former. Both measures are susceptible to endogeneity due to the reciprocal impact of nutrient intake on productivity and wages. Studies also suggest the calorie-income relationship is highly non-linear, which complicated the interpretation of earlier estimates based on more restrictive linear specifications. Non-parametric estimates of the calorie/nutrient-income relationship suggest that nutrient and calorie intake is moderately responsive to increases in income among the poor, but as income levels rise this responsiveness decreases and nutrient intakes plateau, with further increases in income having no effect on intakes.

While there is a large literature on the nutrient-income relationship at the household level, there is a paucity of research on this relationship at the individual level, and particularly among women during their reproductive cycle. The distribution of food and nutrients within households is clearly an area where some researchers have suggested the common preference model of household decision making is inappropriate, or at least of limited value. The concern is threefold. First, children may be discriminated against in terms of the allocation of food and nutrients. Second, young girls are especially vulnerable if there is a gender bias within the household that adversely affects girls, and thus, their future productivity and reproductive experience. And third, women of reproductive age may be discriminated against in favor of their male partners.

The literature provides a substantial amount of evidence on unequal intrahousehold food distribution in the context of allocations to children. There are several papers that show a greater proportion of income under the control of women is spent on children (e.g., Hoddinott and Haddad, 1995; Sahn and Gerstle, 2003; Lundberg et al., 1997). Likewise, there is a considerable amount of evidence that gender preferences exist for male versus female children among men, but that this is not the case for women (e.g., Thomas, 1990; Sahn and Stifel, 2000, 2002). While these findings have clear and important implications, the latitude and options for public policy to address within-household decision making processes might be quite limited (Alderman, Haddad and Hoddinot, 1997).

Because women have more control over food preparation than men, it stands to reason that they may be able to mitigate distributional disparities in food between themselves and the other adult household members. For example, Pitt, Rosenzweig, and Hassan (1990) find that the variance in calorie consumption between men and women in Bangladesh seems to reflect perceptions of male participation in activities where productivity is sensitive to health status.[11] They also find that households are averse to

[11] The implication is that increases in the diversity of labor force opportunities for women would narrow differences in calorie intake relative to men, but increase intake inequalities among women, as those with higher endowments who are more likely to take more physically demanding jobs are reinforced with additional calories.

inequality in the distribution of calories, suggesting that models of household behavior should incorporate preferences for distributional equality. Thus, differences in intrahousehold food allocation between adults are found to exist, but they do not necessarily reflect a gender bias against women in this case.

Among poor agricultural households, the ability to achieve recommended levels of nutrient intake is not constant, but varies throughout the year with the season and agricultural production process. Along these lines, Behrman, Foster, and Rosenzweig (1997) have shown that calorie intake is moderately responsive to increases in wages during the planting stage, but when food becomes plentiful during the harvest stage, increases in income have little impact on calorie consumption.[12] Likewise, Poskitt (1995) finds, in a case study from the Gambia, that women expend the most energy during the planting stage and subsequent rainy season when food is the least plentiful. The implication is that women who become pregnant or are lactating during these periods will have much more difficulty maintaining adequate levels of nutrients or reaching appropriate gestational weights. In Malawi, for example, there was a 2 kg difference between the weights of lactating women during the pre-harvest and post-harvest periods (Ross and Habicht, 1995).

Therefore, we may expect that poor mothers in Sub-Saharan Africa are having trouble meeting nutrient intake requirements, even when they are not pregnant, and particularly during the planting and subsequent rainy seasons. Moreover, the added nutritional requirements associated with pregnancy and lactation exacerbates pre-existing conditions and lead to new indications of diet related disease. Micronutrient deficiencies in vitamin A, zinc, folate, calcium, iodine, and iron have all been linked to MMM throughout the developing world (UNSCN, 2004). These deficiencies often lead to diseases, such as anemia, that are risk factors for MMM in and of themselves, and make women more susceptible to other pregnancy related complications.[13] Based on a meta-analysis of eight countries in Africa, anemia was found to cause 3.7 percent of maternal deaths. Furthermore, having anemia makes women less likely to survive bleeding (hemorrhage) during or after pregnancy, which is the leading cause of maternal death in Africa, accounting for 33.9 percent of all deaths (Khan et al., 2006).

The significant burden of anemia among the poor in Sub-Saharan Africa is in a large part due to the high prevalence of infectious diseases such as malaria, hookworm, and HIV/AIDS. Indeed, between 200,000 and 500,000 pregnant women in Sub-Saharan Africa develop severe anemia as a result of malaria (Steketee et al., 2001). Malaria is also associated with increased risk of stillbirths and spontaneous abortions, and in highly endemic areas is more likely to infect women in the first pregnancy, who are at greater risk for other complications (Miaffo et al., 2004; Garner and Gulmezoglu, 2001). There are several places where the incidence of infectious diseases interfaces with our economic

[12] They also find that small productivity effects of calorie consumption during the planting stage are realized during the harvest, suggesting that mechanisms allowing poor households to increase calorie consumption during planting will serve two purposes; that of reducing malnutrition and increasing farm profits.

[13] Approximately 50 percent of all anemia is due to iron deficiency (FANTA, 2006).

model of MMM. Clearly, the treatment of these diseases is highly dependent on access to high quality medical care and preventative services, which as demonstrated above, is adversely affected by high poverty status. Nonetheless, these diseases differ in the sense that their contraction is very` much due a women's living environment.[14]

One constraint faced by the poor is the limited ability to purchase suitable housing in a sanitary environment. Often, the poor cannot afford to sufficiently screen their dwellings and are forced to live in marginal areas near pools of collected water, both of which make them more susceptible to mosquito transmitted malaria infections. Their living environment often does not include access to clean water, or suitable land to separate livestock from their general living area, which increases their exposure to parasitic infections, such as hookworm (another leading cause of anemia).[15] In either case, the financial constraints placed on poor families result in a less desirable living environment, putting them at greater risk of contracting communicable diseases having adverse consequences for maternal health.

Time Allocation Decisions

How women spend their time and how much time they have for rest and health maintenance activities is an important, if not frequently overlooked determinant of health status. As women progress in their pregnancies they require more time away from their traditional household production tasks and labor market activities. To the extent that poor women are unable to reduce the amount of time spent working they are less likely to achieve the proper gestational weight or seek appropriate levels of antenatal care. There are a number of characteristics of poor households that suggest pregnant women are constrained in the amount of time they allocate to leisure (rest and health maintenance). First of all, the household may depend on their external labor market earnings or time supplied to agricultural production in order to purchase basic subsistence commodities. Second, poor households tend to have high fertility, so that the amount of time a women needs to devote to home production and caretaking is high, and will generally increase with every birth. These burdens of child care are especially acute when birth intervals are short and thus, the average age of children in the household is low. Finally, there often exists a tradeoff between leisure consumption and proper nutrient intake. To the extant that women have specialized skills or culturally determined roles in meal preparation, for which there are not good substitutes within the household, a poor women's ability to reduce time spent preparing meals may be limited, and doing so could potentially harm the nutritional status of both herself and her children.

There is very little empirical economic research on time allocations as they relate to health, and none that we are aware of specifically for MMM. A number of researchers

[14] Some infectious diseases are in fact more related to education levels, and access to family planning and other health services than to the living environment. Chief among these are sexually transmitted diseases such as HIV/AIDS.

[15] The most common method of hookworm contraction in developing countries is walking shoe-less through soil contaminated with animal feces.

have shown in the context of household agricultural production and commodity demand models that the assumption of weak separability between the demand for leisure (or labor supply) and other goods does not hold. Furthermore, jointly modeling labor supply and food consumption decisions has a measurable impact on demand elasticities (Blundell and Walker, 1982; Swafford and Whitney, 1987; Browning and Meghir, 1991; Alderman and Sahn, 1993). In a study of time allocation for a small number of Rwandese households Bhargava (1997) finds that men and women with low energy intakes spend more time resting and sleeping in order to maintain body mass. Estimates from his empirical model also suggest that women substitute between household and agriculture, with children increasing their contributions to the former when they become old enough. One would assume that the same tradeoffs that apply to food consumption, leisure and the supply of labor to agricultural production also apply to the production of health and nutrition.

There are very few studies that investigate the impact of labor supply decisions on health seeking behavior in a developing country context. One study, by Meyerhoefer, Sahn, and Younger (2007), models labor supply decisions jointly with the demand for health care. They construct a measure of leisure that includes time spent on health maintenance activities, but excludes all other types of home production and labor supply. By estimating a joint model of commodity, leisure and health care demand, they find that health care and leisure are complements, and that changes in individuals' value of time (shadow wage) have a differential effect on the demand for health care providers in accordance with their travel distance to households; increases in time valuations decrease provider demand proportionally more for distant providers. The complementarity of health care and leisure also suggests that individuals increase their leisure consumption when sick in order to travel to providers and implement prescriptions for rest and recovery. In the context of maternal health services, this implies that as women's time in home production and labor supply activities becomes relatively more valuable, they are less likely to seek appropriate levels of antenatal care or spend time recovering from a recent pregnancy. This is compounded by the fact that many poor women live in isolated rural areas far away from hospitals with modern obstetric technologies. Therefore, both high travel costs associated with care at high quality providers and cross price effects of user fees for medical care on leisure demand work to limit health seeking behavior by the poor.

The investigation of time allocations in the context of maternal health clearly needs more specific investigation. Critical issues include the ability of other household members to substitute their labor for that of pregnant or lactating women in household and agricultural productions activities, and how such substitutability varies with production season.[16] This is clearly linked to issues of family size and age composition of the pregnant woman's household. Having multiple young children may put an additional strain on women if no one can substitute for caretaking tasks, but as children grow older they may be able to substitute for women's time in domestic tasks during pregnancy and following delivery.

[16] For example, research by Poskitt (1995) in the Gambia suggests that pregnant women have difficulty maintaining appropriate weight levels during the planting/wet season.

Impact of Maternal Health on Poverty

Beyond considering the impact of poverty on maternal morbidity and mortality, and related issues such as demand for children, health care and food, there is another important dimension of the maternal health/poverty nexus: the relationship between maternal health outcomes and the subsequent well-being of the household as mediated through household income and home production activities. As we note in discussion of the neo-classical model in Section II, health status, or accumulated health stock, is an input into several equations that measure the productivity of household members and determines their ability to generate household income and engage in home production activities, particularly the care for children.

Morbidity/Mortality and Labor Productivity

Many women in Africa are important economic providers for their households, both during and after pregnancy. While the share of women engaged in the formal wage sector remains small (Sahn, Dorosh and Younger, 1997), women are still actively engaged in the labor market as own-account and self-employed workers in agriculture and small scale enterprises. In all these cases, adverse health events reduce both the number of hours they can supply to the labor market and the productivity of their work. There is the additional concern that reductions in the mother's labor supply and earnings as a result of adverse health shocks may mean that child labor will be substituted, lowering children's educational attainment and future productivity and resulting in general allocation inefficiency.

The empirical evidence on the impact of health shocks that cause MMM on earnings is sparse, and clearly an area ripe for further inquiry. Indeed, there is a convincing literature that the health of women (and men) has important effects on productivity, both within and outside of agriculture. The paper by Strauss and Thomas (1998) remains the seminal review article in this area. They review the correlations between health and labor market outcomes, and address the methodological challenges or generating non-experimental evidence on the causal impact between health, labor supply and productivity.

Most of the literature on the relationship between health, labor supply and earnings focuses on nutritional status, and likewise, the preponderance of the studies are non-experimental in nature. This literature includes the impact on both agricultural wages rates and own-farm output, as well as earnings outside of agriculture, both in the wage and non-wage sector. For example, the work by Haddad and Bouis (1991) indicates that there is a positive relationship between nutrition and the wages of agricultural workers, as well as production of own-account producers. Interestingly, however, they conclude that the nutrition effects, particularly as manifested in better adult height, are primarily a reflection of early childhood (presumably including pre-natal) factors, rather than recent-term nutrient intake. Thus, they implicitly highlight the role of the reproductive health of mothers, and inter-generation transmission of human capital.

A serious of other papers has examined the impact of nutrition on farms output and wages, such as Strauss's (1986) work in Sierra Leone and Deolalikar's (1988) in India. These papers all rely on non-experimental evidence. And likewise, there are similar studies that examine the impact of calories and nutrition on urban wage and non-wage workers, such as the work of Strauss and Thomas in Brazil (1997) and Glick and Sahn in Conakry, Guinea (1998). All of this work contrasts with the nutrition and biomedical literature where there are several examples of efforts to examine the labor market effects of nutritional supplementation using randomized controls. For example, Wolgemuth et al. (1982) report on a study that shows that road workers in Kenya witness small productivity gains as a result of energy supplementation; Basta et al. (1979) report on the impact of supplementing rubber tree tappers and weeders workers in Indonesia with iron; and Imminck et al. (1981) and Viteri et al. (1981) examine the impact of calorie supplementation on sugarcane workers in Guatemala.

While the results of the latter literature are mixed, it too is not focused on women during their reproductive period, nor does it explicitly link shocks and adverse events to poor health, and subsequent deleterious labor market outcomes. This neglect in the literature is important for a number of reasons. Perhaps most prominent is that there is a failure to understand and appreciate the potentially substantial benefits in terms of higher productivity and economic growth that accrue from public investment in the health sector, and particularly in the needs of women during the reproductive period. It is also worth noting that these returns are likely to be greatest among the poor, who are particularly vulnerable to the negative consequences of poor health on their ability to work and provide for their families basic economic needs.

Beyond the impact of health on labor market activities, there is a related concern that SAMM adversely effects home production and caring for children. Indeed, there is every reason to expect that the same type of deleterious effect of poor maternal health and mortality on work performance outside the household will occur with respect to traditional household roles and responsibilities. That is, mothers who experience SAMM are also less productive at home and less able to take care of their newborn or pre-existing children. For example, the inability to breast feed may have negative consequences for child nutrition. They may also be less likely to provide the appropriate care in terms of various forms of nurturing, food preparation, ensuring a safe and sanitary living environment, or even taking the child for appropriate post-natal care. As intimated earlier, loss of productivity in this sphere is particularly worrisome in as far as it goes beyond the contemporaneous loss of income and earnings, but may adversely impact outcomes later in life and reduce the future productivity of children, thus creating an inter-generational poverty trap.

Research in this area is far more limited that the labor market literature, although, clearly, the two are inextricably linked. This point is made, for example, in the paper by Bhargava (1997) that finds that the low incomes and high prices that reduce nutrient intake contributed to additional time resting and sleeping, both at the expense of household and agricultural work. However, what is particularly interesting is that it appears that among women, there is a substitution in favor of them working in

agriculture, while work in the home is relegated to other members. This could imply a compromise in terms of the caring for children, especially if this pattern occurs during the period of lactation and weaning.

4. Empirical Modeling

Identifying the structural relationships between poverty and maternal morbidity and mortality generally requires the use of complex econometric and statistical methods. The same is true of studies measuring the effectiveness of public health interventions or poverty reduction strategies. This is because most of the data used for such purposes is observational in nature, and not produced under the protocol of a randomized controlled experiment. Even in the case of the latter, statistical techniques must be employed to quantify the effect of a given treatment. Because economic or policy modeling using observational data is both more common and more challenging from an econometric standpoint, we will focus on these techniques. However, we will also discuss methods commonly applied to "natural experiments" (instances when a natural control group arises after the implementation of a policy change or intervention). Since many of the techniques discussed below are covered in far greater detail in standard econometrics texts, we do not provide references in many cases. Examples of widely used references include Wooldridge (2002) and Greene (2003).

Structural Equation Modeling and Reduced Forms

Often researchers will be interested in modeling several of the structural relationships in section 2 in order to forecast the impact of an economic or policy change on a particular outcome. For example, one might be interested in how higher wages brought about by a wage subsidy program impact the demand for post-natal care. This may be an important policy question in cases where mothers return to wage labor shortly after bearing children. The framework presented in section 2 suggests the demand for medical care is a function of wages, but that wages depend on an individual's health status, and may therefore, be contemporaneously correlated to the consumption of medical services. Empirically, the relationship between the demand for post-natal care and mother's wage can be expressed as:

$$M_i = \boldsymbol{\beta}_1' \mathbf{X_i} + \boldsymbol{\gamma}_1' \mathbf{Z_{1i}} + \delta_1 P_i^L + \varepsilon_{1i} \tag{13}$$

$$P_i^L = \boldsymbol{\beta}_2' \mathbf{X_i} + \boldsymbol{\gamma}_2' \mathbf{Z_{2i}} + \delta_2 M_i + \varepsilon_{2i} \tag{14}$$

where $\mathbf{X}$ denotes a vector of variables that affect both the demand for post-natal care and determine wage rates, $\mathbf{Z_1}$ is a vector of variables affect the demand for medical care, but are uncorrelated with wages, and the variables in $\mathbf{Z_2}$ affect wages, but not medical care.

As long as $\mathbf{Z_1}$ and $\mathbf{Z_2}$ both contain at least one column, then the system of equations in (13) and (14) is a fully identified simultaneous system of equations, where $\mathbf{Z_1}$ and $\mathbf{Z_2}$ contain the identifying instruments. The problem in most empirical work is that either such instruments are unavailable, or that the simultaneous relationship between medical care and wages is ignored, and each equation is estimated separately using ordinary least squares (OLS). In the case of the latter, the estimated $\boldsymbol{\beta}$ parameters will be biased and inconsistent. To see this note that if the wage rate is not included on the right-hand-side in equation (13), it will become part of the error term. Since P^L and $\mathbf{X}$ are correlated in accordance with equation (14), orthogonality between the error term and regressors does not hold and the parameter estimates are biased.

If instruments are available to fully identify the simultaneous system, the choice of estimator involves a tradeoff between the potential for propagating model mis-specification errors and greater statistical precision. In the typical case where ε_1 and ε_2 are assumed to be correlated estimation techniques that account for this correlation will be the most efficient. Provided that the errors are also normally distributed, the efficient estimator for the simultaneous system is full information maximum likelihood (FIML). However, departures of the error distribution from normality will result in biased estimates, so it is common to instead use three stage least squares to estimate (3SLS) the system. There are also single-equation estimators that are available which are still consistent, but less efficient that FIML and 3SLS because they do not account for the correlation of the errors in estimation. Again, if the errors are normally distributed the most efficient estimator in this class is limited information maximum likelihood (LIML) and a consistent estimator that does not require a distribution assumption is two stage least squares (2SLS). While the single-equation estimators are less efficient than the systems estimators, they do have the advantage that specification errors in one equation with not be propagated throughout the entire system.

In some cases, one may be able to assume that current wages are not a function of current consumption of medical services. Several reasons why this might be the case include 1) Medical services are rendered for a condition that does not significantly effect productivity; 2) Wages are sticky in the current period; 3) The impact of medical services on productivity occurs primarily over the long run. However, it may still be the case that the wage rate is endogenous in a demand equation for post-natal care due to the omission of one or several important variables that impact medical care and productivity (information on educational attainment, for example). We can represent this situation by setting $\delta_2 = 0$ in equation (14). Indeed this is the common case where one suspects that the key policy variable (P^L) is potentially correlated with important unobservable factors in the error term. Again, in order obtain consistent estimates of the structural parameters using 2SLS, one must have instruments that are significantly correlated with the wage rate, but orthogonal to post-natal care and the error term.[17]

[17] While the applied literature is replete with examples of the exactly identified case where only *K* instruments are used to correct for the endogeneity of *K* endogenous variables, and often over-looked result from Kinal (1980) states that the mth moment of the 2SLS estimator exists iff m < # of instruments - # of endogenous regressors + 1.

An alternative to structural equation modeling and the separate identification of the relationships underlying an economic or behavioral process, is the specification and estimation of a reduced form model. For example, one could substitute (14) into equation (13) and obtain a new expression in which the demand for post-natal care was a function of all the exogenous variables in the model and combinations of the structural parameters. This is a common approach when instruments $\mathbf{Z_1}$ and $\mathbf{Z_2}$ are not available. However, without instruments there is no way to separately identify the reduced form from the structural parameters. Nonetheless, the reduced form parameters can be estimated consistently using OLS, and this may provide all the information needed to conduct policy analysis. If we are only interested in the overall affect of a change in an exogenous regressor on the demand for post-natal care, then reduced form estimates would be the appropriate ones for policy analysis as well as the easiest estimates to obtain. Some researchers prefer to estimate hybrid models in which some relationships are modeled structurally while others are incorporated in a reduced form manner. The choice of which relationships to model structurally is typically made based on the availability of data. A good example of the construction and estimation of a quasi-reduced form model is Glick and Sahn's 1998 paper on maternal labor supply and nutrition in West Africa.

Panel Data and Quasi-Experimental Techniques

There are many situations in which panel data can be used to obtain the unbiased impact of a potentially endogenous variable on the outcome variable of interest. In panel datasets information on respondents is collected during several time periods, thereby providing a means for account for unobserved confounding factors, or *unobserved heterogeneity*. For example, consider a modified version of equation (13) where data has been collected in time periods $t = 1,...,T$

$$M_{it} = \boldsymbol{\beta}_1' \mathbf{X}_{\mathbf{it}} + \delta_1 P_{it}^L + c_i + \varepsilon_{1it} . \tag{14}$$

In this specification c_i represents an unobserved time-invariant factor. If the factor c_i is orthogonal to the wage rate, then OLS still provides a consistent estimate of δ_1 the parameter of interest. However, it is possible to improve upon the statistical precision of the OLS estimates by using a *random effects* panel data estimator, which explicitly accounts for the presence of c_i in the error term.

The more common situation that arises is that the unobserved factor is correlated with the wage rate, so that both OLS and random effects estimates of δ_1 are biased. In the current example, this would be the case if c_i were used to denote an individual's unobserved health endowment. Intuitively, the inclusion of a dummy variable for every individual in the estimating equation would solve the unobserved factor problem by explicitly controlling for all unobserved individual-specific, but time-invariant effects. Computationally, such as approach would likely be infeasible due to the large number of

individuals in the dataset relative to the typically short time dimension of most panel data. Fortunately, there exists a *fixed effects* panel data estimator that is mathematically equivalent to the inclusion of a dummy variable for every individual, but is implemented computationally feasible way (by putting all variables in deviations from their individual specific means). In the case where there are only two time periods in the panel, the fixed effects estimator is equivalent to a model where all the variables have been first-differenced. Since the unobserved factor c_i is the same in both time periods, it will clearly drop out of a differenced model, solving the omitted variables problem.

When using the fixed effects estimator to control for potentially confounding unobservables it is important to keep in mind that this method will not mitigate endogeneity generated by omitted variables that are not fixed over time. More general panel data specifications are available that can be used to capture some dynamic effects, but they are more difficult to implement than standard fixed effects estimators. Based on the previous work of Chamberlain (1980), Jakubson (1991) implemented a *correlated random effects* estimator where the relationship between the outcome variable and the unobserved individual-specific effect was allowed to vary over time (such that c_i is replaced by $\rho_t c_i$ in (14)). As is the case with conventional random effects models, this model requires the assumption that c_i follows a specific (usually normal) distribution. More recently, unobserved factor models have developed that do not require such a distributional assumption. Rather, they use non-parametric techniques to approximate the distribution of c_i. These *discrete factor* models can also be applied to panel data to control for individual heterogeneity (Mroz, 1999).

While panel data can be used to address a wide range of questions and to mitigate unobserved variables biases, it is expensive to collect and is often not available. A popular alternative to panel models are *difference-in-differences* (DID) models, which can also be used to control for unobservables using repeated cross sections of data sampled from the same underlying population. These models are commonly applied to program evaluations or policy analysis when the sample can be divided into logical treatment and control groups.

For example, suppose that an outside agency funds a set number of free pre-natal visits to obstetricians for all pregnant women, but offers this program only in one region of the country, region A. Inevitably, some pregnant women in region A will participate in the program and others will not. Among those individuals eligible for the program, the participants are likely different from the non-participants in important, but observationally unobservable ways. Therefore, a comparison of maternal and child health outcomes for participants and non-participants will reflect, in part, the baseline differences in the participating population in addition to the effect of the free medical care. However, if individuals in an adjacent region, region B, were very similar to those in region A in both observable and unobservable dimensions then these individuals who were not eligible for the program could serve as a control group.

Implementing the DID model requires pooling two cross sections of data from both regions: One collected before the pre-natal care program is put in place, and another collected after it takes effect. The empirical formulation of the DID model is as follows:

$$y_i = \boldsymbol{\beta}'\mathbf{X_i} + \delta_1 d2_i + \delta_2 dA_i + \delta_3 d2 \cdot dA + \varepsilon_i \tag{15}$$

where y_i is the outcome of interest (maternal health), $\mathbf{X_i}$ is a vector of control variables, $d2_i$ is a dummy variable indicating the second (post-intervention) time period, and dA_i is a dummy variable indicating that the pregnant women lived in region A, and was therefore eligible to receive free pre-natal care. Under this formulation, $d2_i$ is used to control for aggregate differences that impact maternal health in the same way for pregnant women in both regions, while dA_i captures otherwise unobserved difference between the two regions, one of which is the treatment group (A) and the other is the control group (B). The coefficient δ_3 on the interaction term measures the effect of the pre-natal care program on maternal health. To see this note that $\hat{\delta}_3$ can be expressed as a function of the conditional mean of the outcome variable as follows:

$$\hat{\delta}_3 = \left(\bar{y}_{A,2} \mid \mathbf{X_{A,2}} - \bar{y}_{A,1} \mid \mathbf{X_{A,1}}\right) - \left(\bar{y}_{B,2} \mid \mathbf{X_{B,2}} - \bar{y}_{B,1} \mid \mathbf{X_{B,1}}\right) \tag{16}$$

The differencing of the conditional mean within region essentially nets out any aggregate factors that changed between the pre- and post-intervention period that might impact maternal health. After these unobservable confounding factors have been differenced away, the difference between the within region differences is attributable to the pre-natal care program.

Clearly, the DID framework requires that the treatment and control groups be as similar as possible in order to generate valid estimates of the program effect. In addition, while aggregate observables are differenced away, the framework does not allow one to control for individual-specific heterogeneity. Rather, it is assumed that idiosyncratic factors are distributed in such a way that they do not result in any systematic difference between the conditional means of the outcome variable in each region.

The DID approach is sometimes referred to as a *quasi-experimental* method because it attempts to replicate the design of a randomized controlled trial using observation data by specifying a treatment and control group and accounting for aggregate time-varying confounding factors. Another method in this category is referred to as a *regression-discontinuity design* (RDD). The RDD estimator can be applied in situations where the right hand side variable of interest is potentially endogenous, but there is some external process, often a rule or regulation, that generates a discontinuity in the level of that variable. This rule can then be used as instrument for the endogenous regressor because it causes variation in the regressor beyond the control of the observational unit. Furthermore, the fact that identification results from a discontinuous or non-monotonic relationship allows one to control for a variety of smooth relationships between other regressors and the dependent variable. The classic example of an RDD is

Angrist and Lavy's (1999) use of Maimonides' rule in the Israeli public school system. Maimonides' rule limits the maximum class in each grade level to 40 pupils. Therefore, a class with a projected enrollment of 41 pupils would be split into two classes with 20 and 21 students, thereby generating a discontinuity in the relationship between grade enrollment and class size. Using an instrumental variables type estimator the authors are able to use this rule to identify the effect of class size on academic performance.

Both the DID and RDD are particularly useful in the exploitation of *natural experiments* for policy analysis. This term refers to instances where some exogenous change in the environment, whether it be the passage of a law or regulation only affecting certain groups or a natural event altering the economic situation of some individuals, leads to clear and valid treatment and control groups. While the exogenous change did not occur as part of a controlled experiment, it is generated in such a way that the individuals falling into the treatment and control groups do not exhibit any systematic differences. Of course, one need not rely on natural experiments if they have sufficient resources to conduct an actual randomized experiment, or randomized controlled trial (RCT). While RCTs have the substantial advantage that nearly all confounding factors can be randomized away (which greatly simplifies data analysis), they suffer from a number of disadvantages. RCTs are expensive, they are targeted toward the investigation of a specific policy question and may have little utility in answering other questions, and they often do not reflect real-world scenarios. Nonetheless, in the biomedical field the RCT is still viewed as the "gold standard" in the analysis of treatment effects.

Selectivity Models

Selectivity models are commonly employed in the literature on program evaluation in order to generalize empirical findings for program participants to the entire population. For example, a government health agency may administer a family planning program which disseminates information on different birth control methods and provides access to birth control devices. Based on data from the program, one could compare the effectiveness of different birth control methods in limiting fertility. However, these results are not necessarily transferable to the general population of sexually active adults because the individuals who decide to participate in the program may be different from those in the general population in ways that influence the comparative effectiveness of the methods. If there were a representative data sample that contained information on those who participated in the program as well as others living in the same area that did not, a selectivity, or *sample selection model*, could be used to determine the comparative effectiveness of the birth control measures while correcting for the selection effect among program participants.

The empirical specification for a sample selection model is based on the following underlying latent structure:

(17) $$\tilde{y}_{1i} = \boldsymbol{\beta}_1' \mathbf{X}_{1i} + \varepsilon_{1i}$$

(18) $$\tilde{y}_{2i} = \boldsymbol{\beta}_2' \mathbf{X}_{2i} + \varepsilon_{2i}$$

where $\varepsilon = (\varepsilon_{1i}, \varepsilon_{2i})' \sim i.i.d.N(0, \Sigma)$, $\Sigma = \{\sigma_{ij}\}$. Equation (17) captures the propensity to participate in the program, while (18) describes the outcome variable for the participating population. Therefore, the observed data maps to the latent model as follows:

(19) $$y_{1i} = 1 \text{ if } \tilde{y}_{1i} > 0; 0 \text{ otherwise}$$

(20) $$y_{2i} = \tilde{y}_{2i} \text{ if } y_{1i} = 1; \text{ not observed otherwise}$$

The first equation in the system is estimated using a Probit specification where the dependent variable denotes program participation and the dependent variables are factors though to be correlated with the likelihood of participation. The second equation is estimated on only those individuals that participated in the program, and the dependent variable is the outcome of interest (the fertility rate in our example). Because of the correlation between the error terms in (17) and (18), separate estimation of the outcome equation on the program participants will not yield unbiased parameter estimates. However, both equations can be estimated efficiently using joint maximum likelihood estimation, but it is important to note that the joint likelihood function for the two equations is not globally concave. Therefore, most software packages that perform joint estimation first condition the likelihood on the correlation coefficient between the two error terms, then perform a grid search on this parameter and iterate to convergence.

In the past when joint maximum likelihood estimation of the sample selection model was computationally expensive, a popular alternative was the use of a consistent *two-step approach*. This approach is still widely used today to obtain starting values for the ML procedure, or in cases where the available software package does not have a pre-programmed sample selection routine. In the first step of the two-step approach, a Probit model is estimated on the full sample and used to construct an inverse Mill's ratio (or selection correction term), having the following form: $\varphi(\hat{\boldsymbol{\beta}}_1'\mathbf{X}_{1i}) \big/ \Phi(\hat{\boldsymbol{\beta}}_1'\mathbf{X}_{1i})$. This inverse Mill's ratio is then added to the second equation, which is estimated using OLS. When interpreting the estimation results from the two-step approach, analysts should be mindful of the fact that the non-concave joint likelihood function has been found to frequently exhibit a local maximum near zero, so findings of "no selection" should be treated with some skepticism. Finally, if the two-step approach is used, the standard errors generated by OLS will not be correct due to their failure to account for the stochastic nature of the inverse Mills ratio. The delta method can be used to correct the standard errors.[18]

A fundamental issue in both joint ML as well as two-step estimation is the separate identification of the first and second stages of the model. In practice, the variables thought to influence the probability of participation are the same ones that affect outcomes among participants. As a result, $\mathbf{X}_1$ and $\mathbf{X}_2$ will share many common elements, with robust identification of the model requiring at least one variable in the former (that is strongly and significantly related to participation) that is not in the latter.

[18] Note, however, that the uncorrected standard errors are the appropriate ones for testing the null hypothesis of "no sample selection".

Unfortunately, it is often difficult to identify theoretically plausible exclusion restrictions for the second stage. Although the model is technically identified even without exclusions, this identification is achieved purely through functions form. In the two-step approach, this type of identification is made possible by the nonlinearity of the inverse Mills ratio. However, the variability of the data in many samples is such that the inverse Mills ratio is not highly nonlinear, and therefore, identification is tenuous at best without a valid exclusion restriction.

Because of the difficulty in finding valid exclusion restrictions to identify the sample selection model, some researchers have made use of an alternative specification call the *two-part model* (Duan et al., 1983; Jones, 2000). This model shares the same basic set-up as described in equations (17) – (20), with one key difference: The error terms in equations (17) and (18) are assumed to be uncorrelated. While this may be an unrealistic assumption not well suited to behavioral modeling, supporters of the two-part model claim that it is valid when the main objective is to predict the second stage outcome variable. Nonetheless, there has been a fair amount of debate about the appropriate use of the two-part model relative to the sample selection model (Hay and Olsen, 1984; Duan et al., 1984). Perhaps the best guidance on choosing between the two comes from a 1987 study by Manning, Duan, and Rogers. Using Monte Carlo techniques, they find that the two-part model out-performs more general sample selection models in the common case where an exclusion restriction to empirically identify the first stage is not available. However, the greater generality of the sample selection model suggests it is preferred in cases where a valid exclusion restriction does indeed exist.

Risks, Shocks and Dynamic Models

One of the most interesting findings of the recent surge in qualitative poverty analysis is the emphasis that poor people place on vulnerability when they define their own poverty or concerns over their health. Time and again, the risk of falling into poverty (measured in many possible dimensions) and falling ill receives as much attention as deprivation itself in conversations with the poor. While people everywhere face risks, these risks are larger for poor, agrarian economies, and in tropical ecologies. Likewise, they are worse in countries, such as throughout Africa, where the poor have fewer means for dealing with the risks and shocks that they face.

In this regard, it is hard to place enough emphasis on the important gender dimension of vulnerability to shocks. Women, particularly of reproductive age, have risk assessments that differ systematically from men's, emphasizing issues of health and violence – often of a sexual nature – far more frequently (Narayan *et.al*. 2000a, b; Smith, Barrett and Box, 2001). There is thus a particular need for policy-oriented research that identifies vulnerability in a gender-sensitive fashion that focuses on the vulnerability of women in their reproductive experience, and subsequent roles as caregivers. Of particular importance are downside risks associated with negative shocks. While research on poverty dynamics shows much movement in and out of poverty over time in Africa, downside health risks, especially associated with childbirth and deleterious health

related events, represent the type of shock that contributes to a poverty trap. In other words, the family's ability to fully recovery from a maternal death or severe maternal morbidity is often limited, inducing a recurring cycle of crisis and deprivation. This often has an inter-generational aspect, as illness of a mother may force the family to pull children, especially girls, out of school. Hence, it is important to understand, for example, the extent to which child labor acts as a coping mechanism against vulnerability, especially given that it imposes severe costs by reducing future productivity and insuring that poverty and deprivation is transmitted across generations. Likewise, research on the role of policies to reduce risk and vulnerability, rather than just reacting to the shock itself, is of critical importance.

A focus on notions of vulnerability and risk associated with reproductive health strongly suggest research approaches that employ methods that allow us to focus on dynamics of behaviors and outcomes in response to uncertainty and risk. Outcomes and choices regarding pregnancy and the broad range of factors that contributes to maternal morbidity and mortality, as well as issues related to choices women make in terms of caring for children, are inherently part of a complex dynamic process. Women who are lucky or are more adept at accessing services and opportunities will help protect themselves against the ravages that are often associated with the risks of childbearing. Other less fortunate households suffer shocks, such as unwanted pregnancy, maternal mortality and morbidity, loss of employment, and so forth, with long-term repercussions that send them spiraling downward into greater poverty. Understanding these processes is key to understanding how policies might help the poor to rise out of poverty, and requires data on households' events and circumstances over time.

The most obvious form of such data are longitudinal and panel surveys, which only very recently have become available for Africa. Examples include the panel surveys from Ethiopia and Zimbabwe. In panel surveys, households are interviewed at different points in time. Analysis of dynamics using such data for developing countries is new, but rapid progress is being made on methodologies and treatment of specific statistical issues such as measurement error and attrition bias. Panel data of sufficient length allow researchers to make a crucial distinction between chronic and transitory poverty, and the role of maternal and reproductive health in this regard. Furthermore, they allow researchers to control for differences in genetically determined health endowments that affect the decisions of individuals, but are unobservable in most survey data.

Indeed, we know that key determinants of long-term changes in poverty status are likely to include accumulation or dis-accumulation of assets; policy-induced changes in returns on those assets; and shocks, particularly those associated with women's reproductive experiences. In principle, these factors are identifiable from household surveys. In addition, initial conditions are likely to be important and can also be measured to varying degrees in surveys. These include levels of human, social, and physical capital; presence of physical and social infrastructure; access to markets; and access to, demand for, and utilization of services.

Mixed Methods

Analysis of the issues discussed above inevitably requires some expansion of boundaries between disciplines, and potentially, research strategies that combine quantitative and qualitative methods. There are various models for achieving these objectives, including concepts such as **"**triangulation," where to paraphrase Robert Chambers (2001), qualitative and quantitative researchers engage in their own effort, and subsequently bring them together to compare results. Triangulation checks for similar findings from the different methods. A different model, the idea of "sequential mixing" (Martin Ravallion 2001) often involves beginning research programs with focus groups, unstructured interview, or ethnographies – that bring out interesting ideas and perspectives on a particular research theme. A quantitative analyst could then devise hypotheses consistent with these ideas to be tested empirically with data from representative samples. Yet a third model is to insert qualitative methods directly into a quantitative study, and vice-versa.

Researchers at the Cornell Food and Nutrition Policy Program (CFNPP) have practiced these approaches successfully in Africa already. We see several further concrete possibilities for simultaneous mixing of research strategies in the context of the AERC project. One concrete example would involve the use of contingent valuation, a method in which the researchers conduct a quantitative-type survey, but with questions more familiar to psychologists than economists. In particular, researchers explore the value of public services, such as family planning services, or institutions to recipients by asking a carefully phrased equivalent of "how much is this worth to you?" A similar effort at contingent valuation was made in the context of a survey in Tanzania designed to examine health status and service delivery in Tanzania. One of the objectives of the survey was to understand the factors that influence the demand for health services, particularly the influence of school and clinic quality. We are interested in exploring the use of such methods in our research, particularly when evaluating public goods. Thus, while we would argue strongly that sound empirical and quantitative analysis is the appropriate focus of AERC's initiatives in exploring the reproductive health/economic growth nexus, consideration should be given to incorporating mixed methods and disciplinary perspectives into the research.

5. Conclusions

As we point out in the introduction, good maternal health is of fundamental importance to Africa's future. Protecting the health of mothers during reproduction safeguards their future contributions to society and ensures the health and productivity of future generations. If either the health of mothers or their newborn offspring is compromised, there will be serious negative consequences for their families, communities, and the entire process of economic and social development at the national level.

There is no doubt that poverty and poor reproductive health are inextricably linked, contributing to each other and jointly determined by a set of failed policies and other social and economic conditions that prevail throughout the region. In addition, disparities in household incomes and community characteristic within countries undoubtedly explain a large share of the within country inequality of reproductive health in Africa.

Indeed, there are many ways in which poverty might lead to high MMM. For example, extreme poverty is often associated with limited access to necessary antenatal medical care as well as appropriate medical resources during and after delivery. Furthermore, the lack of access to family planning and reproductive health services may result in a demographic profile, such as young age of first birth and high overall fertility, which increases the reproductive risks to mothers and their offspring. The poor may not have access to fresh water, and may live in sub-standard dwellings and be at greater risk of contracting malaria or parasitic infections that compromise a woman's immunity during pregnancy.

Clearly, illness or death resulting from childbirth will limit a women's future productivity in the labor market and earning power, thereby contributing to a cycle of poverty and poor maternal health outcomes. The result is a poverty trap whereby mothers are more likely to die or become ill during or after pregnancy because they are poor, and more likely to be poor in the future as a result of negative health shocks during this period. Likewise, mothers who are sick or die are not able to provide adequate care for their children, thus further contributing to this downward cycle of poor reproductive health outcome and poverty.

In this paper we have focused on the complexity and multi-faceted nature of the relationship between MMM and poverty. We have also provided a thorough presentation of a unified theoretical framework, and discussed the types of complex empirical models that can capture the linkages and evaluate the range of public policies designed to improve the reproductive health of women. Our goal has thus been to elucidate the substantive and methodological approaches and challenges, and research opportunities for the AERC network in Africa.

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