The gender division of labor, indoor air pollution and adult and child health.

Mark M. Pitt, Mark R. Rosenzweig, Md. Nazmul Hassan[*]

February 2005

---

[*] The authors are affiliated with Brown University, Harvard University, and Dhaka University, respectively. Prepared for presentation to the Population Association of America Meetings to be held March 31 - April 2, 2005 in Philadelphia.

The gender division of labor, indoor air pollution and adult and child health.

Mark M. Pitt, Mark R. Rosenzweig, Md. Nazmul Hassan

Abstract

In many rural areas of low-income countries, biomass fuel is the principal source of household energy, meaning that indoor air pollution (IAP) is a serious health problem. If exposure to IAP is greatest in areas where combustion occurs, primarily the kitchen, IAP will mostly affect the women who cook and the children whom they supervise. Using a 2000-2003 survey of 1638 rural households in Bangladesh, where biomass fuel provides more than 90 percent of household energy, we investigate the extent to which the division of household responsibilities, household structure, and dimensions and location of kitchen facilities causally affect the health of women and children, taking into account optimizing behavior within households. We exploit as identification restrictions both allocative norms and biological relationships. The results suggest that proximity to stoves adversely affects the respiratory health of women and the young children they supervise, that households appear to be aware of and attempt to mitigate the health effects of cooking with biomass fuels in their time allocation decisions, including effects on young children, such that women with lower endowed health have greater exposure to smoke and women with very young children have less exposure to pollutants. We also find, however, that due to measurement error, conventional estimates of the impact of smoke inhalation are underestimated substantially. Finally, our results suggest that improving ventilation by increasing the permeability of roofs or walls has no significant effect on health, consistent with prior studies examining point-source pollutants and health data.

I. Introduction

In assessing the determinants of poor health and mortality in developing countries, an important factor that has recently gained prominence is the magnitude of the health loss associated with exposure to indoor air pollution (IAP) in poor rural households. Approximately one half of the world's population relies on biomass and coal as their primary source of household energy. Biomass fuel, such as wood, crop refuse, and dung, accounts for one half of household energy in many developing countries, and for as much as 95% in some lower income ones, such as rural Bangladesh (Biswas and Lucas, 1997). Indoor air pollution is thus considered a serious health problem in low-income settings. Exposure to IAP from the combustion of solid fuels has been associated, with varying degrees of evidence, as a cause of several diseases including acute respiratory infections (ARI), chronic obstructive pulmonary disease (COPD), asthma, diseases of the eye such as cataract and blindness, and low birth weight and associated neonatal conditions (as a result of maternal exposure during pregnancy). ARI accounts for 6 percent of worldwide disease and mortality, mostly in the developing countries. Global mortality from IAP is conservatively estimated at 1.5 million to 2.0 million deaths in 2000.

ARI is also the most common cause of illness and mortality in children in the developing world, according to WHO's World Health Report. Acute lower respiratory infection, the most serious type of ARI, accounts for 20 percent of the annual deaths of children under five, with nearly all of these deaths occurring in the developing countries. Not only is IAP- induced ARI a leading cause of deaths in developing countries, but exposure during childhood can have long-term consequences. Lungs typically grow to full capacity during the teen years. The deficits in the lung function of children caused by air pollution are unlikely to be made up as children age even if their exposure levels decline dramatically, and the greatest effects of these pollution-related childhood deficits may occur later in life (Gauderman 2004).

The evidence relating health to IAP, however, has a number of deficiencies. We distinguish two literatures. The *exposure assessment* literature associates pollutant measures taken at one or more places in the household by air monitoring equipment with attributes of the house such as ventilation, fuel type, and distance from cooking fire. The monitoring data available to exposure assessment studies has, until recently, come from air samplers that measure 24-hour average particulate concentrations. Recently, real-time monitors that record airborne respiratory particles less than 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$) at 2-minute intervals for 24-hours have become available which allow investigators to associate pollutant levels with time of day as well as with attributes of the house. Two very recent World Bank working papers by Dasgupta *et al.* (2004a, 2004b) in Bangladesh are excellent examples of this literature. Using both 24-hour average and real-time (for a small sub-sample) particulate monitors, they present regression results for the effects of wall and roof permeability (thatching is the major source of permeability), fuel use, and location of the kitchen and its openness to the other rooms in the house, on household IAP. Their results highlight the importance of ventilation factors in the determination of PM_{10} concentrations. They find that the construction of walls and roofs have large and statistically significant effects on 24-hour average IAP concentration, as does whether the kitchen is located outdoors.

In the rural sample of Bangladeshi households, where LPG/LNG, piped natural gas, and kerosene are not used as cooking fuels, they find that different sources of biomass fuel contributes very little to explaining differences in measured average IAP, concluding that fuel choice is secondary to ventilation factors in explaining variation in IAP among Bangladeshi households. They suggest that an implication of their research for policy is that poor families need not wait for cleaner stoves or fuels to reduce IAP, but that instead inexpensive changes in ventilation will result in significantly cleaner air. By inference, households are either unaware of or unwilling to make the modifications to attain these health gains. However, the conclusions about the health impact of policy interventions are indirect -- they investigate the determinants of particulate densities, not the determinants of respiratory or general health. In the second Dasgupta *et al.* (2004b, p. 14) paper, for example, the suggestion that "during peak cooking periods, simply moving the children outside when weather permits could yield significant health improvements" is based upon the generally understood association between particulate exposure and health, rather than data on health collected as part of their study.

In contrast, the *exposure response* literature directly relates data on the health outcomes of individuals to the measures of particulate exposure. In this literature, the importance of collecting **person-specific** information on exposure rather than information specific to various places in the house is stressed. Relating individual health to average particulate concentrations in the home is very much like trying to understand variations in individual health using total household food consumption data -- the intra-household allocation of time spent breathing polluted air, like the intra-household allocation of food, is unlikely to be equal. The work of Majid Ezzati and colleagues exemplifies this literature. In Ezzati, Saleh, and Kammen (2000) and Ezzati and Kammen (2001), personal monitors with real-time monitoring were employed, along with simultaneous recording of the locations and activities of household members, in order to construct personal exposure profiles for households in rural Kenya. Over a two-year period, community nurses trained in the clinical diagnosis of ARI regularly visited all the study households. The nurses examined all household members who reported any disease symptoms and recorded symptoms, diagnoses, and visits to any other health facility. The field measurements recorded peak concentrations of greater than 50,000 $\mu g/m^3$ (micrograms of particulate matter per cubic meter of air) in the immediate vicinity of the cooking fire with concentrations falling significantly with increasing distance from the fire. In a review of the limited studies examining the pollution "microenvironment," Ezzati and Kammen (2002, p. 1059) stress that:

> ...even in a single room, pollution concentrations exhibit a pronounced spatial gradient rather than instantaneous mixing. This finding implies that the exposure micro-environments for indoor smoke are considerably smaller than those reported in Saksena et al. (1992), possibly as small as 0.5 m.
>
> Coupled with the large variability of emission from biofuels over short periods, with the instantaneous peaks coinciding with household members who cook being consistently closest to the fire, this indicates that the complete time-activity budgets of individuals, in relation to emission concentrations, are important determinants of exposure.

In their Kenyan sample, Ezzati and Kammen (2001) find that one-half of the daily exposure of the highest exposure individuals - those individuals who cook - occurs in high-intensity episodes when they are very close to the stove when stove emissions are at their highest. High-intensity episodes contributed only 0% - 11% of the total exposure of household members who do not take part in cooking. In their statistical analysis, Ezzati and Kammen (2001) find that the relationship between ARI and exposure measured by average daily PM_{10} exposure and time spent indoors, without adjustment for the activities of individuals, mis-estimates the effect of exposure on the probability of a ARI diagnosis for women. Controlling for the time spent cooking, in one specification, and for high-intensity exposure in another, eliminated gender as a significant determinant of ARI, suggesting that gender was simply picking up the effect of the omitted cooking time and peak-exposure variables. The implication of these Kenyan studies is that, based upon average exposures, the policy interventions suggested by the World Bank team in Bangladesh (Dasgupta *et al.*) – to increase roof and wall ventilation in houses – may not be efficacious because these recommendations are uninformed by the importance of the micro-environment and who in the household "stirs the pot."

Even with good measures of individual exposure in a micro-environment, however, there is a potentially serious problem with the Kenyan study and most other studies in the exposure response literature - the analyses assume that exposure to smoke is exogenous. In general, the literature on IAP appears to assume that individuals in settings in which there are no alternatives to biomass fuels are unaware of the health consequences of their use, so the differential exposure to smoke among individuals is essentially random and observed behavior is sub-optimal even given constraints. This assumption is also reflected in policy recommendations manifested in suggestions that individuals in such environments should re-allocate their time, or that of their children, or should re-design their living quarters. Moreover, if there is heterogeneity in health and such heterogeneity influences the division of tasks within the household, whether due to optimizing behavior or other reasons, causal inferences cannot be drawn from studies that do not pay sufficient attention to the nature of allocative decisions in the household. Indeed, Bruce *et al.* (2000) provides a recent survey of a large number of papers estimating the health effects of indoor air pollution in developing countries and concludes that the observational nature of most studies and the inadequate control for heterogeneity results in biased estimates of risk.

In this paper we use new survey data on the health and time allocation of individuals in rural households in Bangladesh to investigate how and to what extent the division of household responsibilities, household structure, and the physical structure of the house affect both child and adult health, given the prevalence of the use of biomass as cooking fuel in Bangladesh, and given household optimizing behavior. IAP levels in Bangladesh are very high. Dasgupta *et al.* (2004a) find that concentrations of 300 $\mu g/m^3$ or higher are common in Bangladeshi households. In comparison, the California Air Resources Board has set an indoor air quality standard of 50 $\mu g/m^3$.[1] There is, moreover, great variation within the day, with the peak reading for the "dirtiest" household of 4,864 $\mu g/m^3$, and, as in many studies of IAP, Dasgupta *et al.* find that IAP levels are highest in kitchens and at cooking times, and that the variation in exposure was greater within houses over time than between houses. The decision of who cooks within a household and for how long therefore is critical in a setting in which fuel choice is limited to biomass.

The data set we use, the 2002-2003 Nutrition Survey of Bangladesh, provides detailed information on the time allocation of all family members across a 24-hour period, on health symptoms, location of kitchen facilities, and features of house construction. In a setting where alternative energy sources are not available, we show how these data can be used to assess to what extent, if at all, exposure to cooking-related smoke causally affects health when there is health heterogeneity, to assess the efficacy of improved ventilation associated with construction materials, and to identify to what extent household decisions about who cooks reflect an awareness of the health consequences of IAP.

In section II of the paper, we set out a simple model of household time allocation incorporating health heterogeneity to highlight the determinants of who cooks when households are fully informed about, and attempt to minimize, the "disease burden" of IAP but cannot substitute away from biomass fuels. The model delivers the results that there will be specialization in cooking, that less healthy individuals will cook, and that child care

---

[1] A very recent study (and accompanying editorial) published in the *New England Journal of Medicine* (Gauderman *et al.*, 2004) finds striking effects of air pollution on lung development and function measured annually for eight years among California children 10-18 years of age. The most polluted community among the 12 study communities had a seven-year mean PM_{10} of approximately 65 $\mu g/m^3$ and the remainder were between 15 and 42 $\mu g/m^3$, compared to the 300 $\mu g/m^3$ common in Bangladesh. The estimated proportion of children with low forced expiratory volume (FEV_1) was predicted to be 4.9 times higher at the highest level of community particulate exposure ($PM_{2.5}$) than at the lowest level. Such striking effects when concentrations are far lower than in Bangladesh suggests the potential health effects of reducing IAP in Bangladesh. In this study too, exposure (associated with location) is assumed to be random.

responsibilities will affect individual cooking assignments in the household, reflecting both the burden of child care and the consequences for children's exposure to IAP. Such optimizing behavior and full information lead to upward-biased estimates of the ill-health effects of exposure to IAP when exposure is measured without error. Section III contains a description of the data and descriptive statistics on the allocation of time of household members, and respiratory and intestinal symptoms by age and gender. These show a high correlation between respiratory symptoms and cooking tasks, which are almost exclusively assigned to women, that is not observed for intestinal symptoms.

In section IV we set out our econometric strategies to identify the own health effects of exposure to IAP associated with cooking time and report the estimates of how cooking time and thus stove proximity affect the incidence of respiratory and intestinal symptoms. The estimates indicate that cooking time affects respiratory but not intestinal symptoms, that these effects are not mitigated by more permeable house construction or kitchen location, and that estimates that do not take into account both measurement error and heterogeneity result in a significant downward bias of IAP effects on ill health. In section VI we examine intergenerational exposure effects, estimating how the mother's cooking time affects her child's health, again taking into account individual health heterogeneity. We find that the effects on children are age-dependent, with respiratory problems of children younger than five more severely affected than respiratory problems for children 5-9 for a given increase in maternal cooking time. In section VII we examine the determinants of cooking time, exploiting panel data on direct measurements of person-specific health endowments. The estimates are consistent with both the social hierarchy of status among women in Bangladesh and the full-information optimizing model in which households minimize "disease burden" - mothers endowed with less health spend more time cooking, mothers who have child care responsibilities spend more time cooking, but among such mothers with the youngest infants (below five) cooking time is reduced.

II. Theory

We set out a simple heuristic model to show how households seeking to minimize the burden of an unhealthy but necessary activity will allocate the unhealthy task among its members. Consider a separable household utility function of the form

(1) $$U = U_m(H_m, X_m) + U_f(H_f, X_f)$$

where $H_m = (h_{m1}h_{m2},...,h_{mJ})$ is the set of health statuses of the J males in the household, $H_f = (h_{f1},h_{f2},...,h_{fK})$ is the set of health statuses of the K females in the household, and $X_m = (x_{m1}x_{m2},...,x_{mJ})$ and $X_f = (x_{f1},x_{f2},...,x_{fK})$ are sets containing the allocations of composite consumption goods. For simplicity, we abstract from leisure and assume that a single unit of time is allocated between a productive activity that is deleterious to health ("cooking") (t_c) and productive employment (t_a, "agriculture") that is not. Only women devote time to the cooking activity, and so we will only focus on the household's allocation of women's time.[2] To simplify exposition, assume that K=2, and that the total quantity of cooking time t_c that women in the household must provide is fixed. Consequently, time spent cooking must be allocated such that $t_{c1} + t_{c2} = t_c$. Health for women is produced with technology

(2) $$h_{fi} = h_f(t_{ci}, x_{fi}) + \mu_{fi}, i = 1, K$$

(3) $$\frac{\partial h_f}{\partial t_c} < 0, \frac{\partial h_f}{\partial x_f} > 0$$

where μ_{fi} is the exogenous component of health (health endowment).

The productivity (earnings) of time spent in agriculture is sensitive to health

(4) $$w_{fi} = w_f(h_{fi}), i = 1,2$$

(5) $$\frac{\partial w_f}{\partial h_f} > 0$$

but the productivity of time spent cooking, t_{ci}, is the same for all values of h_{fi}. Households

---

[2] We do not seek to explain the gender division of labor. In the spirit of the model, however, if on average men are more productive in agriculture than are women, then we would observe more cooking by women than by men on average in health-burden minimizing households. If all women have children, this always leads to reduced productivity and time spent in agricultural tasks (see below), and if there are high returns to specialization over time, one can obtain the result that almost no men would cook.

maximize the utility function (1) subject to (2), (4), the time constraints, and the budget constraint

$$\textbf{(6)} \qquad v + \sum w_{fi} t_{ai} - p \sum x_{fi} = 0$$

where v is the sum of non-earnings income and male earnings net of their consumption ($\sum w_{mi} t_{ai}$ - $p \sum x_{mi}$), and p is the price of consumption good x.

Consider a model nested in this utility maximization problem, in which women's contribution to household income, the left-hand side of (6), is maximized subject to the time constraints. Because health only affects income through agricultural work, then even if all women are identical ($\mu_{f1}=\mu_{f2}$) and $t_c \leq 1$ (household cooking time is less than the time available to any one women), one woman will do all of the cooking and the other woman will specialize in agriculture.[3] The rationale is clear – any time spent in cooking by a woman reduces her health and productivity in agriculture without affecting her productivity in cooking. If one woman is innately less healthy than another ($\mu_{f1}<\mu_{f2}$), even to the smallest degree, she will do all the cooking, while the other will specialize in agriculture.

In the utility-maximization case, a compensatory household may not exhibit complete specialization by task, reflecting the disutility of health reductions caused by cooking. Nonetheless, even with identical women ($\mu_{f1}=\mu_{f2}$), the differential effects of health on the productivity of time by task, will, in general, result in one woman spending more time cooking than the other, meaning an unequal sharing of the health burden. And if $\mu_{f1}<\mu_{f2}$, the less healthy woman will be the one to devote more time to cooking. Thus, the observed association between time exposed to an unhealthy environment and ill-health will be an upward-biased measure of the effect of exogenously increasing exposure.

The productivity function (4) can be generalized to

$$\textbf{(7)} \qquad w_{fi} = w_f(h_{fi}, \mu_{fi}, \lambda_{fi}), i = 1,2$$

---

[3] If $1 < t_c \leq 2$, one woman would only cook and the other woman would split her time between cooking and working in agriculture.

(8) $$\frac{\partial w_f}{\partial \lambda_f} < 0$$

where λ_{fi} is any characteristic of a woman that affects productivity in agriculture but does not alter utility directly. As before, the productivity of time spent cooking is assumed to be unaffected by both h_{fi} and λ_{fi}. One important example of λ_{fi} is the need to care for one's own infant or young child, which may diminish the productivity of a woman's time in agriculture but have little effect on cooking efficiency.[4] For example, it may be much harder for a woman to tend to her child while weeding or transplanting rice compared with cooking rice. If a woman who cares for an infant or young child (λ_{fi}=1) has lower productivity in agriculture she, all else being the same, will tend to spend more time cooking than another woman in the household without a young child (λ_{fi}=0).[5] If an important reason that cooking and child care are joint products is the proximity of mother and child, as for very young infants, then there are potential exposure effects for the child when the mother is exposed to the unhealthy environment. In a more elaborate model in which the health of children are also a component of household utility, given that the youngest children do not contribute to household income or production, mothers with very young children may temporarily spend less time in the unhealthy activity.

In the Bangladesh context, relative productivities (λ_{fi}) and health endowments (μ_{fi}) may not be the only factors that allocate women to tasks, but also the identity of women in terms of their relationships to the household head. In particular, Cain *et al.* (1979), in describing decision-

---

[4] Any cognitive or physical ability, such as schooling or ability, that has a return in the labor market but not in cooking, and which may not be observed in the data, are components of λ_{fi}

[5] In a household with two women having equal values of λ_{fi}, the relative allocation of time spent cooking will still depend on the health endowment μ_f. If the productivities λ_{fi} are positively correlated with health endowments μ_{fi} (high-ability women tend to have more exogenous health), and if the efficiencies of specialization influence a household's allocation of women to tasks, then the correlation between unobserved health heterogeneity and cooking time will be larger. If the need to care for children is the source of differential efficiencies, and if high health endowment women have more births, then efficiency λ_{fi} may be negatively correlated with health endowments μ_{fi}.

making in Bangladeshi households, report that mothers-in-law dominate daughters-in-law, mothers dominate daughters, and elder brothers' wives dominate younger brothers' wives. A young wife submissively follows the lead of her husband's mother, and is rarely involved in decision-making (Chowdhury 1995). The autonomy of women from the oversight of their mothers-in-law increases with the birth of her children and her age. The death of the father-in-law undermines the authority of the mother-in-law but does not destroy it. Young daughters-in-law cannot leave the *bari* (family compound) without permission, and adherence to *purdah* (seclusion of women) is more strict for a young wife. After several years and births, a daughter-in-law gains some autonomy of action and movement relative to her mother-in-law and other women in the household, including other daughters-in-law. When she has her own daughter-in-law within the household, her freedom is enhanced and she is ordinarily free to leave the *bari*, leaving the completion, but not the management, of household chores, including cooking, to her daughter-in-law.

Fafchamps and Quisumbing (2001) suggest that such a system of changing social status among the women in a household may be a socially acceptable mechanism that avoids costly bargaining and friction by simplifying the time allocation process in ways that preserve many, but not all, of the benefits of specialization and comparative advantage. They suggest that if social norms were the only determinant of time allocation within the household, the efficiency cost would potentially be very large. The existence of such norms, however, provides a source of variation in household tasks that is independent of individual productivity and health that we exploit in the econometric results reported below.

III. Data

The data for our analysis comes from the 2000-2003 Nutrition Survey of Bangladesh. The survey sample has two components. It includes (1) a random sample of all households in 14 villages that was carried out in 2000, and (2) a panel survey, consisting of the households of all surviving individuals included in the 1981-82 Nutrition Survey of Bangladesh (Ahmed and Hassan, 1983) (originally sampled from the same 14 villages) regardless of their residence during the interval 2000-2003, some of whom were also included in the 14 village random sample frame of year 2000. Taken together, this data set provides multi-level (individual, household and village) survey information on health status, activities, and resources for over

4000 men and women. A key feature of the panel component of the survey is that, by including individuals who departed from the original 14 villages chosen in the 1981-82 survey, it is characterized by very low household and individual attrition rates despite the approximately 20-year interval between rounds.

The questionnaires elicited information on (i) activities, including those for pay and not for pay, as well as the earnings from paid activities, (ii) home dimensions and construction materials, and (iii) household expenditures. Information on housing includes the location of the kitchen (outside or not) as well as roof and wall material. Because roof and wall permeability mediate the dispersion of point-source smoke and were identified as important objects of policy in the research of the World Bank team, they are important variables for our analysis of the effects of IAP in Bangladesh.

The time-activity information is a detailed and exhaustive list of all market and non-market activities, such as pounding grain, cooking, cleaning, and time spent with children, in a 24-hour period. Activities were coded into more than 150 categories, of which seven were "household chores" separate from child care. A key feature of this module is that activities are anchored around the five prayer times observed during the day, salient features in the lives of the Muslim respondents. The accuracy of the amounts and timing of activities is thus aided by these multiple set points that are endemic to the study population.

The time-allocation information is important because, as shown in prior studies, it is proximity to the point source of pollution - the stove - that has important effects on respiratory health. With detailed information on time spent in the kitchen when cooking for all household members combined with information on wall and roof construction and/or point-source pollution, we can, as discussed below, identify the effects of IAP on children's and adult health and test for the influence of housing characteristics.

The data suggest that respiratory problems are both prevalent and correlated with time spent cooking. The survey contained a checklist of 23 health symptoms for all household members. These are provided by each household respondent over age 10, and for children less than or equal to 10 by the relevant mother. Of the 23 symptoms, three symptoms are respiratory-related (coughs, difficulty breathing, with or without fever). Figure 1 provides the proportion of individuals with one or more respiratory symptom by age and gender. As can be seen, over 37%

of boys and 32% of girls younger than five exhibited some respiratory symptoms. This difference is statistically significant (N=900). The incidence of respiratory problems evidently declines with age and starting at age 15 or so, the gender difference reverses as women exhibit more respiratory symptoms than do men, the difference being statistically significant in the age group 25-50 (N=2488). In that age group, over 17% of women report respiratory problems, compared with12% of men.

The time allocation data were collected from household members according to the same rules as for health symptoms. Figure 2 provides the average minutes per day spent in kitchen chores (cooking and food preparation) for the same age groups as reported in Figure 1 for respiratory symptoms. The data show that the youngest children, unsurprisingly, spend little time in this activity, but that women starting at age 10 do almost all of the cooking and spend on average considerable time in this activity, with women aged 25 through 50 spending almost 4.5 hours per day in the kitchen. The gender differences and age-gradient in cooking time allocation (Figure 2) corresponds to respiratory symptoms (Figure 1) for the women above age 15 in a way consistent with the hypothesis that cooking time and thus exposure to smoke adversely affects health - the incidence of respiratory ailments among women grows as their average time spent cooking increases, and the gender gap in respiratory symptoms also grows with the gender gap in cooking time. That children less than five have a higher incidence of respiratory problems than do their somewhat older siblings is consistent with young children staying close to their mothers. Their exposure to smoke is thus similar to that of the women over age 15, but they are evidently more vulnerable to smoke exposure.

Table 1 provides summary statistics and definitions of all of the variables used in the analysis.

IV. Does cooking time cause respiratory illness symptoms among adults?

A. Estimation strategy. It is possible to interpret the relationships between Figures 1 and 2 as merely indicating that poor households, who have poor health, have a greater number of younger children and women who spend more time cooking. To quantify more precisely the relationship between exposure to smoke associated with time spent in the kitchen, and take into account health heterogeneity, we exploit the data more fully. The equation we estimate is given by

$$(9) \qquad h_{ij} = \alpha_t t_{ij} + \boldsymbol{\alpha}_{\mathbf{A}}\mathbf{A}_{\mathbf{ij}} + \mathbf{Z}_j\boldsymbol{\alpha}_z + \mathbf{X}_j\boldsymbol{\alpha}_X + \mu_{hj} + \mu_{hij} + e_{hij},$$

where h_{ij} is the incidence of any respiratory symptom for person i in household j; t_{ij} is the time spent cooking; A_{ij} is a set of person-specific attributes (age, sex, education); $\mathbf{Z}_j$ is a vector of household-level smoke-related factors that reflect ventilation (permeability of walls and roof, and whether cooking is carried out outdoors); $\mathbf{X}_j$ is a vector of other household-level characteristics that may affect health, such as income; and α_t, $\boldsymbol{\alpha}_A$, $\boldsymbol{\alpha}_z$ and $\boldsymbol{\alpha}_X$ are the corresponding vectors of coefficients. Equation (9) also contains terms capturing health heterogeneity, divided into a household health component μ_{hj}, an individual-specific health component μ_{hij}, and an iid error term e_{hij}.

The coefficient of interest is α_t, which expresses the relationship between an individual's time spent proximate to a stove and their respiratory health. The problem for estimation is that cooking time may be correlated with unmeasured household and individual-specific health variables. To eliminate household unobservables, we use a household fixed-effects procedure, which differences across women in the same household

$$(10) \qquad \Delta^j h_{ij} = \alpha_t \Delta^j t_{ij} + \boldsymbol{\alpha}_{\mathbf{A}}\boldsymbol{\Delta}^{\mathbf{j}}\mathbf{A}_{\mathbf{ij}} + \Delta^j \mu_{hij} + \Delta^j e_{hij},$$

where Δ^j is the across-person difference operator.

Estimates of α_t from (10) will not be consistent if (1) the within-household distribution of women's chores is related to the differences in individual health endowments, or (2) there is measurement error in the time exposed to smoke (t_{ij}) variable. The theoretical model presented in Section 2 suggests that there may be efficiency gains to the household in assigning less healthy women to cooking tasks, either because health differentially affects the productivity of time spent at tasks to which women are assigned, or because there is another non-health component of individual productivity that allocates women to tasks, and that component is correlated with health such that less healthy women spend more time cooking. In either case, α_t will be biased upward.

The measurement error issue arises if the time spent cooking varies from day-to-day and our measure, time-spent cooking in a particular 24-hour period, differs from average time spent cooking sampled over a greater period of time, or if there is recall error. If measurement error is of the classical variety -- uncorrelated with the determinants of health -- then the estimated parameter of interest α_t will tend to be biased downwards (attenuation bias). As is well-known, fixed-effects procedures exacerbate attenuation bias if there is measurement error in the regressor. The net effect of the two sources of bias is of opposite direction and unknown *a priori*.

To deal with the problems of heterogeneity bias and measurement error, we implement an instrumental variables procedure to estimate (10). We need variables that affect the allocation of cooking time across women in the same household but do not, given a women's time allocation, otherwise affect her health. As noted in section 2, households in rural Bangladesh contain sexually segregated spheres of influence in which gender-specific hierarchies, based in large part on relationship to the head of household, operate to allocate women to tasks based both on the gains from specialization and on rank in the household hierarchy. Differences across women in their relationships to the household head are unlikely to directly affect differences in respiratory health or to be correlated with individual health endowments or productivity net of age. Thus, the identity of a household member as a daughter-in-law or the wife of the head and their interactions are used as instruments to identify the effect of time spent cooking on health. Note that because (10) nets out the household fixed effect, the estimation procedure is robust to household structure being correlated with the household-level health unobservables (endogenous household structure).

B. <u>Estimates of direct exposure effects</u>. Table 2 provides estimates of the effects of cooking time on the incidence of respiratory symptoms for all adults in the sample of households, and for adult women only. Columns (1) and (4) present random-effects estimates that do not take into account either heterogeneity or measurement error. The estimate of α_t in column (1) suggests that respiratory symptoms are significantly related to cooking time but an individual's gender has no effect on such symptoms except through cooking time. This is the same finding reported in Ezzati and Kammen (2001) for their Kenyan sample using a similar estimation procedure as used to obtain the results in column (1). The size of the regression coefficient for cooking time α_t for the full sample is unaffected by dropping adult men from the sample in column (4). None of the ventilation measures that Dasgupta *et al.* suggest are related to smoke exposure – permeability of the roof, permeability of the walls, and the indoor/outdoor location of the kitchen – are statistically different from zero. Columns (2) and (4) present household fixed-effects estimates that control for all observed and unobserved sources of household-level heterogeneity, including the household health component μ_j, and all ventilation, kitchen location and size, and fuel use factors. These estimates do not address the possibility that the allocation to tasks within the household may be related to unobserved individual health endowments (μ_{hij}) through the efficient sorting of women to tasks, or the problem of measurement error in time allocation reports.

Instrumental variable estimates of the within-household and within-women models are presented in columns (3) and (6) of Table 2. The instruments are dummy variables indicating whether the person is a wife of the head or a daughter-in-law, the interaction of wife and daughter-in-law with the number of daughters-in-law, and the interaction of daughter-in-law with the presence of any wife of the head in the household. The set of hierarchical identifying variables are jointly statistically significant in explaining cooking time in the first stage equation for both the full sample of adults and the women only sample.[6] The FE-IV estimates of the effect of time spent cooking of the incidence of respiratory symptoms, α_t, more than triples for the full sample of adults, and nearly triples for sample of women as compared to the corresponding fixed effects estimates. A Hausman test rejects the null hypothesis that $(\alpha_1^{FE\text{-}IV} - \alpha_1^{FE})=0$ for the full sample at the 2 percent level (t=2.27) and for the women sample at the 8 percent level of significance (t=1.75). In both cases, the estimated effect of time spent cooking on respiratory illness is large and statistically significant. The point estimates indicate that a four hour per day increase in the time spent cooking - notably the difference between the average hours spent by women and by men - is associated with a 10.8 percentage point increase in the probability of reporting a respiratory symptom. In elasticity terms, a doubling of cooking time increases the probability of respiratory problems by 36 percent.

The model of a household with health heterogeneity described in Section 2 would suggest that the FE estimates would overestimate the true effect of cooking time if less healthy women were assigned to cooking. The underestimation of α_t in the fixed-effect models of columns (2) and (4) results suggests that measurement error is the predominant source of bias, or

---

[6] The test-statistics are F(5, 3212)=153.5 and F(5, 828)=29.6. The sign patterns of the women’s status variable generally conform to those indicated in the anthropological literature, and are discussed below.

that it is women with better respiratory health who are sorted into cooking. We present direct evidence on the sorting of women by health status below.

C. Do ventilation and kitchen location matter? The work of the World Bank team in Dasgupta *et al.* in Bangladesh suggest that ventilation is a major determinant of particulate density. They find that kitchen location and the permeability of the roof and walls are the most important determinant of particulate density at various points distant from the cooking fire as measured with particulate concentration monitors. The problem is that their data provide no measures of health or of the actual inhalation of airborne particles. Without knowing where household members are situated in space at the time the cooking fire is ablaze, and how the smoke inhaled affects respiratory health, the mapping from particulate concentration to individual health is tenuous. In Table 2, columns (1) and (4), we found no evidence that either the permeability of roof and walls or the location of the kitchen inside or outside of the residential dwelling influence the incidence of respiratory symptoms in a random effects specification. Those estimates make no attempt to control for household-level heterogeneity that may bias inference, however.

We now directly test whether the permeability of roof and walls and the location of the kitchen inside or outside of the residential dwelling reduce the deleterious effect of time spent cooking on respiratory symptoms by interacting the housing material and kitchen location variables with the exposure measure, using our FE-IV method. The results, reported in Table 3, provide no support for the hypothesis that ventilation matters for either the all-adult or the only-women samples. These results are in accord of those of Ezzatti and colleagues, who found that only those persons very close to the fire, within 0.5 meters, are importantly affected by the smoke of kitchen fires. Thus, while the World Bank may stress that simply improving roof and wall ventilation in the homes of the poor is an inexpensive and efficacious policy intervention that unenlightened Bangladeshi's are unaware of, such a conclusion is not supported by our estimates.

D. Are the results spurious? Testing the determinants of cooking time on non-respiratory symptoms. We can further assess whether a positive relationship between time spent cooking and respiratory ailments is due to less healthy women spending more time in the kitchen by exploiting the rich information on health symptoms in the data. If in our data it is found that cooking time "causes" non-respiratory symptoms not known to be affected by exposure to smoke, that would be an indication of a spurious relationship between cooking time and health that might also affect the FE-IV estimates of Tables 2 and 3. Consider a health outcome, d_{ij}, such as intestinal symptoms, for which individual cooking time is unlikely to be related on *a priori* grounds, and write the analogous form of equation (9):

$$\textbf{(11)} \quad d_{ij} = \beta_t t_{ij} + \boldsymbol{\beta}_{\mathbf{A}}\mathbf{A}_{\mathbf{ij}} + \mathbf{Z}_j\boldsymbol{\beta}_z + \mathbf{X}_j\boldsymbol{\beta}_X + \mu_{dj} + \mu_{dij} + e_{dij},$$

where all the independent variables are defined as they were for equation (9), but the household- and individual-level health endowments contributing to health outcome d_{ij} are μ_{dj} and μ_{dij}, respectively, rather than μ_{hi} and μ_{hij}. The μ_{dij} and μ_{hij} individual health endowments may have common components so that $E(\mu_{dij}\ \mu_{hij}) \neq 0$, and similarly for household health endowments μ_{di} and μ_{hi}. If our fixed-effects-instrumental-variable procedure did not correct for the purposive allocation of less healthy women to time cooking, we should expect to see $\beta_t > 0$. The finding of $\beta_t=0$ is consistent with, but not sufficient to establish, the validity of our FE-IV procedure.[7]

Table 4 presents estimates of the determinants of the effects of cooking time on the incidence of intestinal symptoms. In the random effects and fixed effects estimates without instruments using both the full sample of adults and the sample of just adult women, the effect of cooking time on intestinal symptoms is positive and statistically significant at conventional levels. In the FE-IV estimates in both samples, these estimated effects fall in magnitude and the standard errors rise so that the asymptotic t-values are less than 1. These results suggest that health heterogeneity does affect time allocation. We find that time spent cooking affects respiratory symptoms, but there is no evidence that it affects intestinal symptoms in the same sample using the same estimation procedures. The fall in the point estimates from the FE to the

---

[7] This comparison of α_t and β_t is akin to a differences-in-the-difference estimator in which one of the differences is between women in the household, and the other is between diseases, where the treatment (cooking time) is presumed to not alter the intestinal symptoms outcome, and so represents the control. For this to be a valid implementation of differences-in-the-difference, it is necessary that chore assignments are based on a common general health and not on specific health symptoms, such as coughing or intestinal disorders. However, it is still possible that women of the same general health but who exhibit respiratory problems (as opposed to other health problems) are assigned non-kitchen chores, which would bias α_t downward.

FE-IV specifications in Table 4 is consistent with women who are less healthy (intestinally) spending more time cooking, although this could simply reflect sampling variation as the estimates are very imprecise.

V. Intergenerational effects of indoor air pollution

Mothers with infants and young children are likely to devote significant amounts of time to their care and keep them close at hand. If children are kept physically close to their mothers as the mothers cook, they may also be at risk for the respiratory symptoms caused by their proximity to the cooking fire. We can use the same approach used to examine the effects of cooking on adults to investigate the presence of intergenerational health externalities associated with the combination of child care and cooking responsibilities assigned to women. For each child in the household, we know the time allocation of his or her mother. For children between the ages of two and nine years[8], we estimate the following equation

$$h_{ijk} = \gamma_0 + \boldsymbol{\gamma_A A_{ijk}} + \gamma_t t_{ij} + \gamma_D D_{ijk} t_{ij} + \mathbf{Z}_j \boldsymbol{\gamma}_z + \mathbf{X}_j \boldsymbol{\gamma}_X + \mu_{hj} + \mu_{hij} + e_{hijk}, \quad \textbf{(12)}$$

where h_{ijk} is reported respiratory symptom of a child k (age 2-9 years) born to mother i in family j, A_{ijk} is the age, age squared and gender of the child, D_{ijk} is a dummy variable if the child's age is 2 to 4 years of age, and t_{ij} is the time allocated to cooking by the child's mother. The interaction $D_{ijk}t_{ij}$ in equation (12) permits the effects of the mother's exposure to smoke while cooking on the child's respiratory health to differ by child age. Older children can be farther away from their mothers than younger children and yet still be safely cared for, yet are still too young to engage in cooking over a fire alone. The relationship between the mother's cooking time and a young child's health thus will be due to either (a) exposure to smoke associated with being proximate to the mother or (b) a correlation between a mother's endowed healthiness, the child's inherent healthiness and the mother's time allocation. Household fixed effects estimation used in estimating previous models only differences out household-specific heterogeneity μ_{hi}. However, the presence of multiple children for mothers in the sample permit us to difference across children of the same mother, thereby eliminating mother-specific heterogeneity μ_{hij}. In

---

[8] Infants 0 and 1 years of age are excluded in the analysis because, as suggested by regression estimates discussed below, mothers of children this young do significantly less cooking, perhaps in response to knowledge about the deleterious effects of cooking smoke on infant health.

doing so, we can only identify the coefficient γ_D, which indicates whether and how maternal exposure to smoke and child health varies by child age.

The household fixed effects estimate of the effect of a mother's time cooking on child respiratory symptoms in column (1) of Table 5 is positive and marginally significant at the 5 percent level (t=1.93). We would expect that the effect of a mother's cooking on child symptoms would be greater for younger children, as they are likely to be spend more time closer to their mother than do older children. The estimates of column (2) bear out this hypothesis. The mother fixed-effects estimates in column (3) correct for any correlation between the mother's endowed health, the child's inherent health, and the mother's time allocation, and yield an unbiased estimate of the differential effect of mother's cooking time on younger (2-4 years of age) as compared to older (5-9 years of age) children. This effect is positive and significantly different from zero (t=2.19). This result is additional evidence that (i) it is direct proximity to the point source of indoor air pollution, the cooking fire, that is the cause control of respiratory symptoms, and (ii) indoor air pollution arising from cooking has deleterious effects on the respiratory health of anyone near the point source, in particular, the youngest children of those who cook. Note that the evidence of measurement error presented earlier suggests that estimates of column (3) are lower-bound estimates of the true effect of cooking time on child health.

In the last three columns of Table 5 we present estimates of the effect of mother's time cooking on the report of intestinal symptoms of children. As in the case of the mother's own intestinal symptoms, we find no evidence that the mother's cooking time affects these symptoms for her children.

VI. Who Cooks? The Determinants of Cooking Time

The estimates of cooking time effects on respiratory illness symptoms indicate that greater exposure to point-source pollutants associated with cooking adversely affects the health of the person who cooks, and her young children, especially the youngest. The simple optimizing model which assumes that individuals understand the health consequences of their activities, but have no scope for fuel substitution, as in Bangladesh, will allocate unhealthy tasks to individuals who are for other reasons less capable of contributing to earnings, due to endowments or alternative responsibilities such as child-rearing.

Table 6 presents household random effects and fixed effects estimates of the determinants of cooking time. These estimates establish three things. First, the identifying instruments based on women's relative status in the household – wife of head, daughter-in-law of head, and the interaction of wife with number of daughters-in-law – that were used in the first stage again have power in predicting time spent cooking. Both wives and daughters-in-law spend more time cooking than other women in the household, who are primarily daughters of the head. Second, mothers with children 5-9 years of age cook more, and mothers with children 0-4 cook less. Children in the youngest age group are likely to stay very close to their mothers, and if their mothers cook, these children will be exposed to particulate concentrations similar to that of their mothers. As Table 5 suggests, respiratory symptoms of the youngest children are more sensitive to the cooking time of mothers. Older children (aged 5 - 9 years of age) do not have to be as spatially close to their mothers, but the need to watch over them may make women less efficient (in the sense of Section 2) in alternative chores if those chores keep them from watching their children or put children at some risk. Third, Table 6 reveals that years of schooling and cooking times are negatively related. This is the prediction of the efficient specialization model of Section 2 if, as seems likely, the returns to education in cooking are less than in other tasks. Ten years of schooling reduces a woman's time spent cooking by nearly 75 minutes per day compared to an unschooled woman, using the FE estimates with the women-only sample.

The results in Table 6 are consistent with a pattern of allocation that exposes women who are less productive or less able to fully participate in earnings activities (because of child-rearing responsibilities) to increased health risk, but reduces the particulate exposure of the most vulnerable children. The finding that less <u>educated</u> women cook more, although suggestive of efficiency-based specialization, does not necessarily mean that less <u>healthy</u> women cook. As noted earlier, the sign of the bias resulting from not using instrumental variables does not help resolve this question as the instrumental variable method also corrects for measurement error in the time spent cooking variable, and these two sources of bias are of opposite sign.

To more directly address the issue of whether health endowments influence the allocation of time in accord with minimizing the household pollution burden, we exploit a unique feature of these data. A randomly-chosen portion of the 2000-2003 survey frame consists of all surviving individuals from the 1981-82 Nutrition Survey of Bangladesh. A key feature of this panel is that it was designed to track and interview all individuals included in the 1981-82 survey, including anyone who departed from the original 14 villages. The panel sample is thus characterized by very low household and individual attrition rates despite the approximate 20-year interval between rounds and the fact that 75 percent of young women in 1981-82 had left the sampled villages. In the 2002-2003 round, 97 percent of all surviving original sample subjects, and 96 percent of all surviving females were found and surveyed.

In Pitt *et al.* (1990), the 1981/82 household survey data were used to obtain a direct measure of the health endowment μ_{ij}. The health endowment was estimated from the residual of a weight-for-height production function including individual-level food consumption, water sources, and the energy intensities of activities as inputs. In that article, the health endowment was shown to significantly affect the intra-household allocation of food and tasks ranked by energy intensity. We can use these individual endowment measures, obtained from the 1981-82 data, to estimate the effects of health endowments on time spent cooking for the panel sub-sample to assess directly whether health endowments matter for the allocation of cooking time.

Is there reason to believe that these 1981-82 endowment measures predict health status in 2002-2003? Appendix Table A presents logit and conditional logit fixed effects estimates of the determinants of death by 2002 of all members of the 1981/82 households. For all estimation procedures - including those controlling for village effects and 1981-82 household effects, the 1982 health endowment is negatively and significantly related to the probability of death. That the health endowment predicts mortality is strong evidence that the estimated health endowment is a meaningful and time-persistent measure of health.

One problem in using the 1981-82 endowment measure to assess household decision rules in 2002-2003 is that the sample size is reduced, and thus the precision with which we can estimate parameters is less. To obtain within-household estimates, moreover, the effective sample size is further reduced because a household can only contribute to identification if it has at least two members in 2000-2003 who were in the 1981/82 survey for the “all adults” sample, and has at least two women from the 1981/82 survey living in the same household in the “all adult women” sample. Such households are obviously selective, but presumably all unmeasured differences between the panel households and others are subsumed in the household fixed effect.

Table 7 presents the household fixed-effect cooking time estimates including the 1981-82 health endowment for the 2002-2003 panel individuals. In column (1), the measured health endowment is negatively and significantly related to time spent cooking (t=-2.77) for the full adult sample – that is, in accord with the model of rational disease burden management, unhealthy women are called upon to do a disproportionate share of health-reducing cooking in the household. The endowment coefficient obtained from the sample including only adult women reported in column 2 has a point estimate twice as large, but the precision of this estimate is lessened by the decreased sample size. Attenuation bias resulting from measurement error in these 20-year old endowment measures implies, however, that these are lower bounds on the absolute values of the estimated endowment effects.

VII. Conclusion

In rural Bangladesh, households do not have a choice of cooking fuels and must use biomass, which prior studies suggest has adverse effects on health, particularly respiratory disease, due to indoor air pollution (IAP). Using a 2000-2003 survey of 1638 rural households with information on detailed person-specific time allocation, we investigated the extent to which the division of household responsibilities, household structure, and the roof and wall permeability and location of kitchen facilities causally affect the health of women and children, taking into account optimizing behavior within households. We also explore whether households behave with respect to the allocation of the burden of the disease induced by IAP as if they are aware of its health consequences and seek to minimize its damage.

The results suggest that proximity to stoves adversely affects the respiratory health of women and the young children they supervise, that households appear to be aware of and attempt to mitigate the health effects of cooking with biomass fuels in their time allocation decisions, including effects on young children, such that women with lower endowed health have greater exposure to smoke and women with very young children have lesser exposure to pollutants. We also find, however, that due to measurement error, conventional estimates of the impact of smoke inhalation are underestimated substantially. Finally, our results suggest that improving ventilation by increasing the permeability of roofs or walls has no significant effect on health, consistent with prior studies examining point-source pollutants and health data. The fact that richer households in rural areas seek to make their houses less permeable thus does not reflect ignorance of the health impacts of IAP or an unwillingness to mitigate its effects.[9] Increasing opportunities for households to substitute biomass for cleaner fuels or to use cheap, pollution-reducing stoves may be more effective in improving the health of women and children in rural areas than programs that promote behavioral change, given existing choices.

---

[9] In our data higher-income households have less permeable homes and spend no less time cooking on average, but exhibit no more respiratory disease symptoms than do poorer households.

References

Ahmed K,Hassan N, eds. (1983). Institute of Food Science and Nutrition. Nutrition Survey of Rural Bangladesh 1981-82, Dhaka, University of Dhaka.

Biswas WK, Lucas NJD. (1997). Energy Consumption in the Domestic Sector in a Bangladesh Village. Energy 22(8): 771-776.

Bruce N, Perez-Padilla R, Albalak R. (2000). Indoor air pollution in developing countries: a major environmental and public health challenge. Bulletin of the World Health Organization 78(9): 1078-92.

Cain, Mead, Syeda Royeka Khanam, and Shamsun Nahar (1979). Class, Patriarchy, and Women's Work in Bangladesh. Population and Development Review 5(3): 405-438.

Chowdhury, A. (1995). Families in Bangladesh. Journal of Comparative Family Studies (26):27-41.

Dasgupta S, Huq M, Khaliquzzaman M, Pandey K, Wheeler D. (2004a). Indoor air quality for poor families: new evidence. World Bank Policy Research Working Paper 3393, September 2004.

Dasgupta S, Huq M, Khaliquzzaman M, Pandey K, Wheeler D. (2004b). Who suffers from indoor air pollution? Evidence from Bangladesh. World Bank Policy Research Paper 3428, October 2004.

Ezzati M, Saleh H, Kammen DM. (2000). The contributions of emissions and spatial microenvironments to exposure to indoor air pollution from biomass combustion in Kenya. Environmental Health Perspectives 108(9): 833-9.

Ezzati M, Kammen DM. (2001). Quantifying the Effects of Exposure to Indoor Air Pollution from Biomass Combustion on Acute Respiratory Infections in Developing Countries. Environmental Health Perspectives 109(5):481-88.

Ezzati M, Kammen DM. (2002). The Health Impacts of Exposure to Indoor Air Pollution from Solid Fuels in Developing Countries: Knowledge, Gaps, and Data Needs. Environmental Perspectives, 110(11):1057-1068.

Fafchamps, Marchel and Agnes R. Quisumbing (2001). Social Roles, Human Capital, and the Intrahousehold Division of Labor: Evidence from Pakistan. Oxford University, manuscript.

Gauderman WJ et al. (2004). The effect of air pollution on lung development from 10 to 18 years of age. The New England Journal of Medicine 351 (11): 1057-1067.

Pitt MM, Rosenzweig MR, Hassan N. (1989). Productivity, Health and Inequality in the Intra-Household Distribution of Food in Low Income Countries. American Economic Review 80(5): 1139-1156.

Figure 1: Proportion of Males and Females with Cough Symptoms, by Age Group

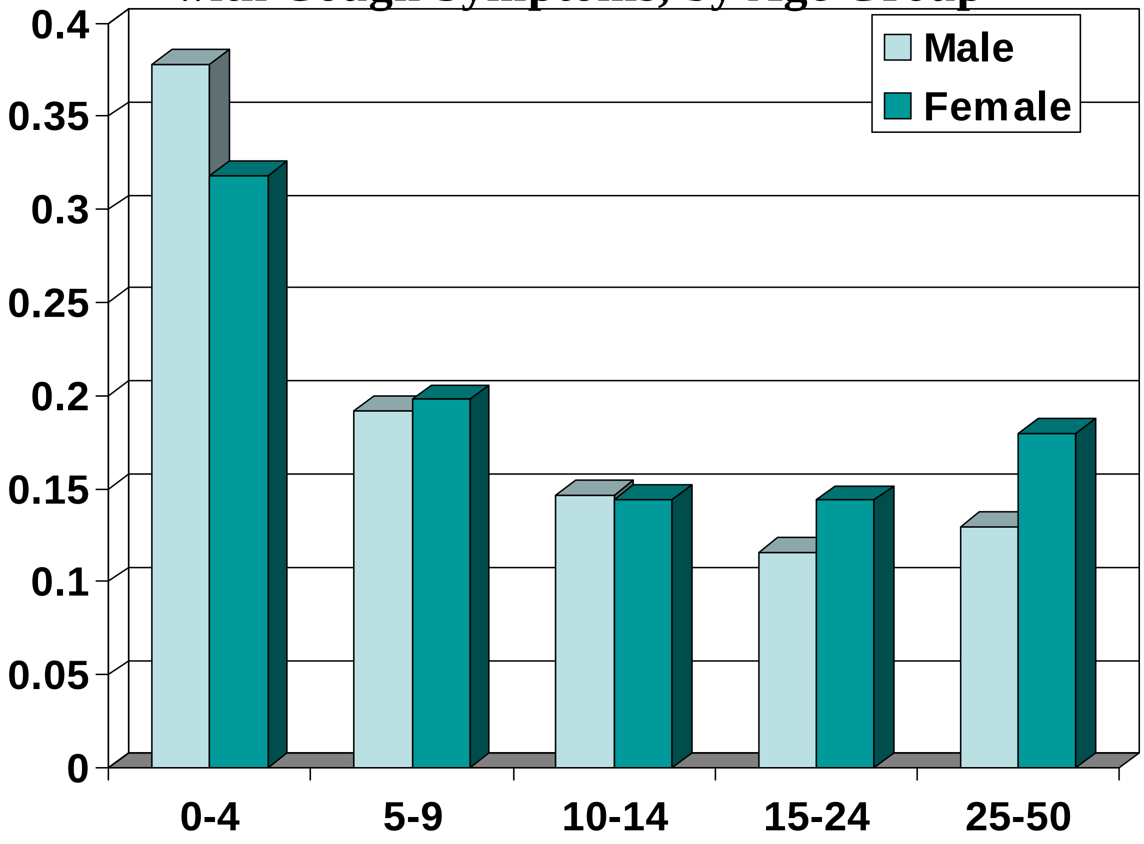

Figure 2: Mean Minutes per Day Spent in Cooking Chores, by Age Group and Gender

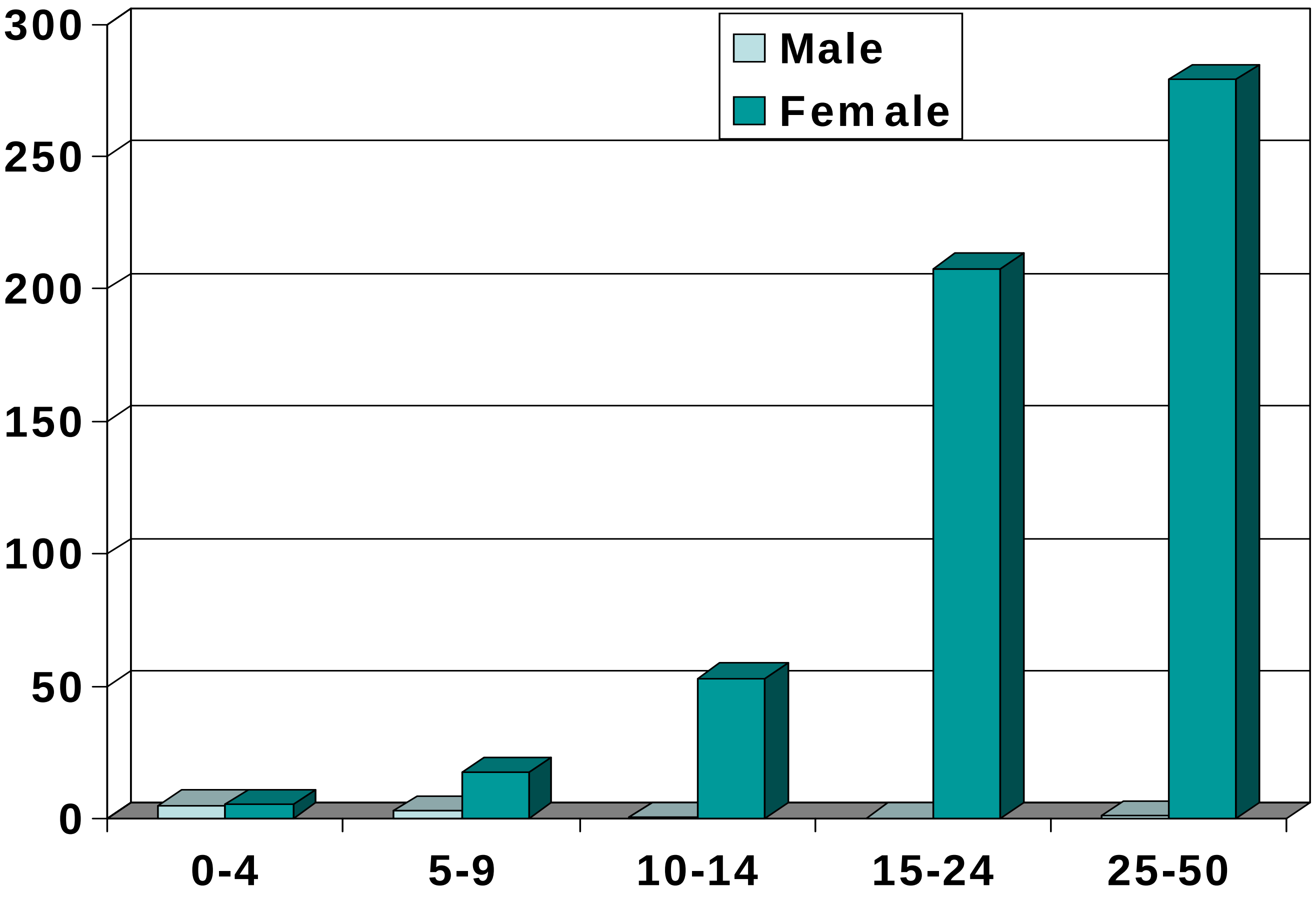

Table 1
Sample Characteristics

Variable	All Adults Aged 16+	Children 2-9
Respiratory symptoms	.154	.221
	(.361)	(.415)
Intestinal symptoms	.0489	.0694
	(.216)	(.254)
Age	36.0	6.09
	(15.8)	(1.98)
Education (years)	3.51	.515
	(4.14)	(.939)
Female	.477	.485
	(.500)	(.500)
Mother with children<5	.242	-
	(.563)	
Mother with children<10	.418	-
	(.857)	
Wife of head	.278	-
	(.448)	
Daughter-in-law of head	.0517	-
	(.221)	
Total hh expenditures (taka per month)	4797	4558
	(4176)	(4856)
Permeable roof	.205	.224
	(.403)	(.417)
Permeable walls	.326	.377
	(.469)	(.484)
Kitchen outdoors	.262	.292
	(.440)	(.455)
Number of individuals	4026	1365
Number of households	1198	780

Table 2

The Effects of Cooking Time on the Incidence of Respiratory Symptoms, All Adults and Women Only, by Estimation Procedure

	All Adults Aged 16+			Women Aged 16+		
Estimation procedure	(1) RE	(2) FE-Household	(3) FE-IV	(4) RE	(5) FE-Household	(6) FE-IV
Cooking time ($x10^{-3}$)	.152	.0871	.349	.159	.170	.455
	(2.77)	(1.56)	(2.72)	(2.68)	(2.51)	(2.58)
Age	.00107	.00113	.00146	.00069	.00178	.00284
	(2.84)	(2.77)	(3.37)	(1.12)	(2.41)	(2.96)
Education	-.00357	-.00106	-.00011	-.00276	.00465	.00892
	(2.09)	(0.50)	(0.05)	(0.95)	(1.14)	(1.87)
Female	.00093	.0157	-.046	-	-	-
	(0.06)	(0.92)	(1.43)			
Total expenditures ($x10^{-5}$)	-.380	-	-	-.511	-	-
	(1.88)			(1.78)		
Permeable roof	-.0115	-	-	-.0384	-	-
	(0.66)			(1.59)		
Permeable walls	.00225	-	-	.0125	-	-
	(0.15)			(0.59)		
Kitchen outdoors	.015	-	-	.00948	-	-
	(0.94)			(0.42)		
Number of individuals	4590	4590	4590	2202	2202	2202
Number of households	1371	1371	1371	1368	1368	1368

Table 3

FE-IV Estimates: Do House Materials or Kitchen Location Ameliorate the Effects of Cooking Time on the Incidence of Respiratory Symptoms?

All Adults and Women Only

	(1) All Adults Aged 16+	(2) Women Aged 16+
Cooking time ($x10^{-3}$)	.418	.343
	(2.89)	(1.59)
Cooking time x permeable roof ($x10^{-3}$)	-.0857	.638
	(0.78)	(1.47)
Cooking time x permeable walls ($x10^{-3}$)	.0517	.0634
	(0.52)	(0.16)
Cooking time x kitchen outdoors ($x10^{-3}$)	-.0212	-.0183
	(0.20)	(0.03)
Age	.00168	.00336
	(3.66)	(2.94)
Education	.000749	.0122
	(0.32)	(2.08)
Female	-.0506	-
	(1.46)	
Test statistics, no house effects $\chi^2(3)$,(p-value)	0.93, (.818)	2.43 (.488)
Number of individuals	4590	2202
Number of households	1371	1368

Table 4

The Effects of Cooking Time on the Incidence of Intestinal Symptoms, All Adults and Women Only, by Estimation Procedure

	All Adults Aged 16+			Women Aged 16+		
Estimation procedure	(1) RE	(2) FE-Household	(3) FE-IV	(4) RE	(5) FE-Household	(6) FE-IV
Cooking time (x10^{-3})	.0855	.0872	.0391	.0850	.0949	.0852
	(2.54)	(2.51)	(0.49)	(2.38)	(2.16)	(0.76)
Age	.000832	.000816	.000755	.000378	.000844	.000808
	(3.61)	(3.22)	(2.80)	(1.03)	(1.77)	(1.32)
Education	.000208	.00125	.00108	-.00103	.000894	.000748
	(0.21)	(0.95)	(0.80)	(0.61)	(0.34)	(0.25)
Female	-.0150	-.0136	-.00226	-	-	-
	(1.46)	(1.29)	(0.11)			
Total expenditures (x10^{-5})	-.176	-	-	-.0480	-	-
	(1.64)			(0.33)		
Permeable roof	.0145	-	-	.00647	-	-
	(1.51)			(0.49)		
Permeable walls	-.00500	-	-	-.00849	-	-
	(0.60)			(0.75)		
Kitchen outdoors	-.0101	-	-	-.0242	-	-
	(1.14)			(1.98)		
Number of individuals	4590	4590	4590	2202	2202	2202
Number of households	1371	1371	1371	1368	1368	1368

Table 5

The Effects of Mother's Cooking Time on the Incidence of Respiratory and Intestinal Symptoms of Her Children 2-9, by Estimation Procedure

	Respiratory Symptoms			Intestinal Symptoms		
Estimation procedure	(1) FE-Household	(2) FE-Household	(3) FE-Mother	(4) FE-Household	(5) FE-Household	(6) FE-Mother
Mother's cooking time (x10^{-3})	.608	.524	-	-.0909	-.102	-
	(1.93)	(1.65)		(0.38)	(0.42)	
Cooking time x Child<5 (x10^{-3})	-	.311	.460	-	.0415	.00858
		(1.55)	(2.19)		(0.27)	(0.05)
Child age	.0241	.119	.173	-.0114	.0012	.-.0121
	(0.52)	(1.55)	(2.18)	(0.32)	(0.02)	(0.20)
Child age squared	-.00404	-.0105	-.0143	.000461	.000395	.000633
	(1.06)	(1.86)	(2.47)	(0.16)	(0.09)	(0.14)
Child female	-.0595	-.0594	-.0541	-.0142	-.0141	-.0303
	(1.93)	(1.93)	(1.72)	(0.60)	(0.60)	(1.28)
Mother's education	.0149	.0152	-	.0319	.0320	-
	(0.59)	(0.61)		(1.67)	(1.67)	
Number of children	1365	1365	1365	1365	1365	1365
Number of mothers	889	889	889	889	889	889

Table 6
Who Cooks? The Determinants of Cooking Time, All Adults and Women Only, by Estimation Procedure: Full Sample

	All Adults Aged 16+		Women Aged 16+	
Estimation procedure	(1) RE	(2) FE-Household	(3) RE	FE-Household
Age	-.551 (6.36)	-.566 (4.80)	-1.59 (7.14)	-2.11 (5.68)
Education	-1.46 (4.29)	-2.01 (3.36)	-4.31 (4.46)	-7.46 (3.87)
Female	139.2 (24.90)	144.1 (30.32)	-	-
Mother with children<5	-11.3 (1.77)	-22.8 (3.72)	-14.6 (2.20)	-54.7 (3.64)
Mother with children<10	26.9 (5.85)	37.4 (8.53)	24.3 (5.16)	59.1 (5.42)
Wife of head	126.1 (15.07)	117.7 (19.5)	128.7 (13.77)	95.5 (7.58)
Daughter-in-law of head	80.8 (2.31)	132.7 (5.47)	55.38 (1.49)	103.4 (1.77)
Number of daughters-in-law	-3.89 (2.05)	-	-20.76 (1.68)	-
Wife x number of daughters-in-law in hh	-52.5 (5.16)	-55.4 (8.21)	-31,71 (1.99)	-19.9 (0.98)
Daughter-in-law x Number of daughters-in-law	-4.28 (-0.36)	-25.44 (2.59)	9.44 (0.53)	-14.44 (0.54)
Is there a wife of head?	-20.58 (3.91)	-	-53.13 (4.37)	-
Daughter-in-law x Is there wife of head?	-17.27 (0.58)	-35.8 (1.84)	7.92 (0.25)	-10.99 (0.21)
Total hh expenditures (x10^{-5})	127.8 (3.63)	-	293.9 (3.26)	-
Permeable roof	5.53 (1.76)	-	10.3 (1.63)	-
Permeable walls	-5.24 (1.98)	-	-11.32 (2.07)	-
Kitchen outdoors	2.95 (1.02)	-	3.56 (0.59)	-
Number of individuals	4590	4590	2202	2202
Number of households	1371	1371	1368	1368

Table 7
Who Cooks? Within-Household Determinants of Cooking Time, All Adults and Women Only: Panel Sample with Endowments

	All Adults Aged 16+	Women Aged 16+
Age	-.596 (2.01)	-2.82 (2.14)
Education	-.615 (0.40)	-6.04 (0.96)
1982 health endowment	-60.9 (2.77)	-140.1 (1.85)
Female	167.7 (13.91)	-
Mother with children<5	-11.78 (0.51)	65.6 (0.98)
Mother with children<10	42.93 (3.11)	12.31 (0.29)
Wife of head	77.2 (5.11)	86.9 (2.17)
Daughter-in-law of head	-3.44 (0.01)	-155.6 (0.31)
Wife x number of daughters-in-law in hh	-26.7 (2.18)	-5.96 (0.13)
Daughter-in-law x number of daughters-in-law	81.73 (0.47)	160.48 (0.51)
Daughter-in-law x Is there a wife of head	-247.14 (0.92)	-152.9 (0.29)
Number of individuals	922	371
Number of households	449	291

Table A
Logit and Conditional Logit Estimates: The Effects of the 1982 Health Endowment on the Probability of Death by 2002, Panel Sample with Endowments

Estimator	Logit	Conditional Logit: Village FE	Conditional Logit: HH FE
Age in 1982	.0653	.0655	.0589
	(12.8)	(13.6)	(10.1)
1982 health endowment	-1.33	-1.45	-1.44
	(2.95)	(3.07))	(2.45)
Female	-.0459	-.0408	-.149
	(0.27)	(0.23)	(0.73)
Household head literate - 1982	-.355	-.324	-
	(2.01)	(1.66)	
Land owned - 1982	.000108	.0001	-
	(0.35)	(0.02)	
Household income - 1982 ($x10^{-3}$)	-.108	-.130	-
	(0.76)	(0.83)	
Number of individuals	1539	1539	727