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# Parental Bereavement: Heterogeneous Impacts of AIDS in Thailand

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## Abstract

Over the coming decades in Thailand, aging parents whose adult children sicken with AIDS will bear burdens of caregiving and loss. Using demographic microsimulation, we show that the new, lower projections of the HIV/AIDS epidemic still imply that 8% of Thais over the age of 50 in 1995 will lose one or more children to AIDS before their own deaths. The proportion of all losses which are multiple losses can vary from 12% to 33% under a range of assumptions about plausible family-to-family heterogeneity in risks of infection.

*Key words:* AIDS, Aging, Microsimulation, Thailand

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## 1 Introduction

On the outskirts of Chiang Mai City in northwest Thailand, a handsome new condominium tower rises into the sky. Eerily, because, in the wake of Asia's financial crisis, it stands empty, except for one elderly man. Mr. Choroen<sup>1</sup> remains to keep guard against vandals, as grass pushes up into the newly laid concrete. Why, in a country where older persons generally retire and children care for their retired parents, was Mr. Choroen taking such employment? He explained. His three sons had died of AIDS, and so he must work although he was old, patiently guarding the decaying tower.

Much has been written on the subject of AIDS about the sufferers themselves, and some about their spouses and children. Less attention has been devoted to the older generation, to parents whose adult children are infected and die, parents who often bear the responsibility for caregiving and endure the sorrows and consequences of loss.

How common will experiences like Mr. Choroen's be, as the epidemic's shadow extends across the lifetime of today's older generation? How many parents can expect to lose at least one child to AIDS, or two? How many will live with and care for afflicted adult children? How old will parents be? How vulnerable? Answers to these questions are not readily inferred from estimates of HIV prevalence and require demographic modeling.

We recently applied aggregate demographic analysis to survey data from Thailand, constructing period indices of parental bereavement and initiating the study of familial effects by means of microsimulation (Wachter, Knodel, and VanLandingham, 2002). The microsimulations were based on forecasts constructed by the United Nations (1999). In March 2001 the Thai Working Group on HIV/AIDS Projection of the Thai Ministry of Public Health (henceforth TWG) and its collaborators issued a new set of projections based on fresh data and more sophisticated methods. Noting Thailand's success in containing the epidemic, the TWG projected lower AIDS mortality.

In this article, we construct microsimulation forecasts of lifetime loss within families based on the TWG projections, taking into account the difficult but critical factor of heterogeneity. Although data for estimating heterogeneity are sparse, risks of HIV infection surely differ from region to region, from locality to locality, and from family to family and modulate the occur-

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<sup>1</sup>This instance describes an actual encounter experienced by two of the authors; the name is altered to protect confidentiality.

rence of multiple cases of loss within families and communities. We find that the lower infection rates posited by the TWG still imply substantial frequencies of lifetime bereavement for present-day cohorts of older Thais. Families with multiple losses are rare overall, but multiple losses account for a significant fraction of all losses under a range of assumptions about plausible levels of heterogeneity.

## 2 AIDS and its impacts in Thailand

The demographic impacts of AIDS on families, children, and the elderly are only beginning to receive attention, despite long and intensive study of the dynamics of the epidemic itself. Palloni and Lee (1992) have led the way in emphasizing widowhood, orphanhood, and related outcomes from AIDS in Africa. Boonchalaksi and Guest (1993) and Brown and Sittitrai (1995) examine orphanhood in Thailand. Ntozi and Nakayiwa (1999) explore the role of family caregiving for adult Ugandan victims of AIDS, and Sankar et al. (1998) take up this theme more broadly.

Thailand is suited to a study of this kind by the availability of data. It is not among the countries hardest hit by the epidemic, thanks in part to effective prevention efforts described, among others, by Mason et al. (1995) and Mills et al. (1997). UNAIDS (2000) estimates HIV seroprevalence among the adult Thai population aged 15 to 50 years at 2.2% , compared to 0.6% for the United States, 4% for Cambodia, 20% for South Africa, and 35.8% for Botswana. In Thailand, HIV has been spread mainly through heterosexual intercourse. Brown et al. (1994), and Brown and Xenos (1994) describe the beginnings. According to the TWG (2001:30), in the early days around 1990 78% of new infections occurred to male clients of commercial sex workers. By 2000, this percentage had dropped to 12%, with 42% of new infections occurring among women infected by their husbands or other partners, and 18% to male intravenous drug users sharing needles.

VanLandingham et al. (2000) discuss the wide range of ways in which AIDS impinges on older people, particular on parents of adult victims of the epidemic. Sanders (1989), Brown and Sankar (1998), and Mullan (1998) comment on a number of these effects. Parents take on the burdens of caring for their sick children. There are opportunity costs, as they forego market activities for the sake of caregiving. There are losses of anticipated support from the affected children, costs for medical treatment and sustenance. There

are funeral costs, typically substantial in Thailand. There are often responsibilities for raising or providing for grandchildren. There is sometimes shame or social isolation. There is strain, fear, and sorrow.

Knodel et al. (2001) systematically gathered information about impacts of AIDS from key informants across Thailand. That study confirms the view that older parents commonly care for adult children who succumb to AIDS. Nearly two-thirds of all adults reported to have died of AIDS had lived with or next to a parent during the course of their illness. Quite generally, when taken ill with AIDS, afflicted children move back to their parents' homes, for instance leaving dwellings in the cities. Three out of four of the victims with a living parent had received care from a parent. In one case out of two, a parent, ordinarily the mother, had served as chief caretaker, whether rich or poor, robust or frail.

This engagement of older Thais in caring for their afflicted adult children arises within a context of traditional familial support. Older Thais typically live with or near their adult children and in the normal course of events are supported by them. Knodel and Chayovan (1997) found 90% percent of Thais over age 60 living with an adult child or engaging in daily contact with one or more. Over two-thirds report substantial monetary transfers from children living away from their homes. The illness and death of an adult child deprive older people of resources and aid on which they would normally count in their old age.

All these strains and losses are widely observed, but their numerical salience is not easy to gauge from survey data. In terms of the consequences for today's older population, the epidemic is still in a relatively early stage. HIV and AIDS will be increasing among the generation of their children, even as they themselves grow older and their ranks are thinned. The experiences of caregiving and bereavement will be allotted by these interacting demographic processes. How common will these experiences prove to be? We discuss the data and methods underlying our projections, and then turn to the results.

### 3 Data

The source which supplies the data on family structure essential for our microsimulations is the 1995 Survey of the Welfare of the Elderly in Thailand (SWET). The SWET is based on a clustered national probability sample

of 7,708 respondents over age 50 living in private households, described by Knodel and Chayovan (1997). In each household, there is one primary respondent over the age of 50. The mean age of respondents is 63.6 years. A roster of the living sons and daughters of the respondent as of May 1995 is compiled, including ages and information about residence. For each reported child, either the mother or the father is the respondent, but not both.

We form the starting population for our microsimulations from the whole list of SWET respondents and their living children. Each child has one (in effect, randomly selected) parent in the population, not two. Sample weights make the sample representative of the Thai population over the age of 50 region by region. Fathers and mothers and people without children are all given their due weight. It follows that the starting population for the microsimulation is representative of the population over 50, but, though it contains younger people, it is not representative of the young. For example, people orphaned before their parents turned 50 are absent from the population.

The sources which supply demographic rates for our microsimulations are the Thai Working Group (TWG, 2001) and the National Economic and Social Development Board of Thailand (NESDB, 1994 and 1998). The TWG uses the “Asian Epidemic Model” of Brown and Perrapatapanokin to generate projections of HIV infections and AIDS deaths to serve as numerators of demographic rates. The TWG takes denominators from the NESDB population projections in the presence of AIDS (as previously estimated), and so do we. Since all-cause mortality rates were not available to us from NESDB sources, we reconstructed them by taking ratios of cohort sizes in successive cross sections under the assumption of population closure. We subtracted AIDS mortality from all-cause mortality to obtain rates for mortality for causes other than AIDS. The expectation of further life at age 50 in the period lifetable for 1995 is close to 28 years for men and 32 years for women. The average span of life after 1995 for the starting population of SWET respondents with their mixture of ages is 16 years.

The TWG model distinguishes seven adult subpopulations, comprising male clients of commercial sex workers, male injecting drug users who often share needles, male injecting drug users who rarely share needles, other males, female direct commercial sex workers, female indirect commercial sex workers, and other females. Transmission among these groups is calculated taking into account a number of parameters governing contact and infection, circumcision, condom use, needle use, and related considerations. Parameters are estimated by a process of tuning. Alternative projections for subgroups are

compared against data through 1999 until good fits are achieved. Infections are allocated to age groups with fixed distributions for men and for women based on age distributions of the incidence of sexually transmitted diseases. Progression from HIV to symptomatic AIDS is taken to have a waiting-time distribution given by the “slow” UNAIDS schedule with a median of 9 years and 92% progression within 20 years. Our simulations use the TWG baseline scenario. For complete coverage of the last few survivors, we extrapolate the rates out to 2050 with the methods of Lee and Carter (1992), but 98% of bereavements occur before 2020, within the scope of the TWG projections.

The TWG series show a rapid drop in new adult infections from a peak of 141,795 in 1991 to less than one-third as many by 1996. The series estimated by the UN (1999) on which the projections of Wachter et al. (2002) were based, peaks at 168,000 in 1992, and is still over 148,000 in 1996. The TWG sees new infections dropping to around 7,500 by 2020, whereas the UN (1999) series sees new infections persisting at around 50,000. Total adult infections up to 2020 amount to 1.18 million in the TWG series, compared to 2.84 million in the UN series. In the absence of published information, the UN infection series has been reconstructed from the UN series for AIDS deaths using an evolutionary algorithm as described briefly in Wachter et al. (2002).

The TWG projections take advantage of more sophisticated models and accumulating data on the successful reduction of male infections from commercial sex workers. However, there is substantial disagreement between the TWG estimates for total AIDS deaths up to 2000 and the independent estimates of van Griensven (1998:Table 43). Some 55,000 deaths in 2000 in the TWG series compare with 90,000 in Van Griensven’s series, which is close to the UN (1999) projections. Beyond 2010, the TWG predicts tiny levels of new infections, far below what UN forecasters have foreseen. We are not in a position to adjudicate these disagreements. In this article, we work out the consequences for older Thais of the possibility that the epidemic will taper as rapidly as the TWG predicts. As it turns out, for the experience of older Thai parents the lower levels of infection in the TWG series are partly counteracted by the earlier concentration of new infections, so that a considerable burden of bereavement remains in prospect.

The other source important to our study is the Thai AIDS Cases Study (TACS) described in Knodel et al. (2001) and Knodel, Saengtienchai et al. (2000). Community health workers and other knowledgeable local informants were systematically selected and interviewed during 1999 at 85 sites in eight provinces and Bangkok, yielding information on a host of family-level vari-

ables for about 1000 cases of individuals living with or deceased from AIDS. It must be borne in mind that the TACS cases are not a random sample of households or of AIDS deaths. Individuals who sought medical care are more likely to be known to health care workers. Social status and prominence in the community may affect the probability of being reported in either direction. Nonetheless, TACS appears to provide the best information available on actual patterns of parental involvement with children sick with AIDS in Thailand. The TAC study supplies us with rates for coresidence and caregiving for the simulations along with background for understanding the effects of AIDS.

## 4 Methods

### 4.1 Regional Heterogeneity

The published forecasts are all at the national level. Risks of infection vary substantially from region to region as well as from locality to locality and family to family. All these dimensions of heterogeneity are important for estimating multiple loss within families. None are as yet well-measured with empirical data.

For regional heterogeneity, we do have some information, namely, reports of HIV seroprevalence by region among male recruits to the Royal Thai Army from 1991 to 1997 reported by van Griensven et al. (1998) in their Table 23. We use this information to develop region-specific time-varying multipliers on rates of infection from AIDS.

We take differentials in prevalence for the young population of army recruits as indicators of differentials in incidence for the broader population at risk. The reported regional differentials change rapidly at the beginning of the series and settle down toward the end. We assume that they stabilize after 2000 close to 1998 levels. Based as they are on data for males, our multipliers may not capture the details of emerging regional differentials among women as fully as one would wish. Future research might be able to take advantage of data from ante-natal clinics from Thailand's sentinel surveillance system.

To obtain our regional multipliers, we take the TWG series of total adult infections over time, allocate these infections to regions based on the army data, and work forward again with the incubation time distribution to ob-

tain regionally differentiated schedules of progression to symptomatic AIDS. These become the inputs to the microsimulation projections. The microsimulations treat onset of symptomatic AIDS and death from other causes as competing risks in a multiple decrement framework. The UN distributions for progression from symptomatic AIDS to death are implemented directly within the simulations.

Children's region of residence determines their level of risk. The SWET reports each child's presence in the same house or compound as their parents, or next door, or elsewhere in the same village, or the same province, or outside the province, and it reports the province of the parental respondent. The proportion residing outside the province of their parent amounts to 30%. We assume that half of these children resided in another province of the same region, and we assign the rest to the regions at random in proportion to those children whose province is known. The geographic distribution of children's residences reflected in SWET interacts with the geographic distribution of HIV risks reflected in the army recruit data to generate patterns of loss, family by family, across Thailand.

## 4.2 Family-to-Family Heterogeneity

Heterogeneity in risk of HIV is not exclusively a region-by-region phenomenon. HIV infections undoubtedly cluster in some areas and communities and members of some families are at higher risk than others. Even in a setting in which risks were homogeneous and infections of siblings were independent chance events, some families would still lose two, three, or more children. The point of modeling heterogeneity is to estimate the increase in families with multiple losses which results from non-independence, that is, from correlated risks.

Each person in the population who is the child of a respondent in the SWET is given a personal risk multiplier, which multiplies that person's hazard of coming down with symptomatic AIDS at all ages. Hazards vary with age, but the multiplier remains constant. This multiplier is the sum of two components, a family component and a community component. All the children from one family share the same value of the family component. All the children of respondents from the same community share the same community component. SWET is a clustered sample. Each town or village is represented, on average, by about 40 respondents, and each family, on average, by a little less than 5 children. The random variations across

individuals stand in for systematic socioeconomic differentials for which no direct estimates are available, as well as for other unobserved contributors to heterogeneity.

The usual practice in studies of correlated risk and frailty like Yashin, Vaupel, and Iachine (1995) is to draw risk multipliers from gamma probability distributions, and we do so. The gamma is a flexible family with options for tight and for diffuse smooth distributions of positive multipliers. We take each component of our multiplier to be a gamma random variable with the same scale parameter. We choose an overall shape parameter  $k$ , and let the family component have shape parameter  $(3/4)k$  and the community component have shape parameter  $(1/4)k$ , making family-level correlations several times as strong as community-level correlations. The overall multiplier then has shape parameter  $k$ . We rescale so that the mean of the distribution of multipliers is 1.0, so that the standard deviation is  $k^{-1/2}$ . Our baseline case sets  $k$  to 3.0, for a standard deviation of 0.577 for the risk multipliers. We discuss outcomes from alternative assumptions in Section ??.

### 4.3 Simulations

The rates of onset of symptomatic AIDS and of death from other causes by age, sex, region, and year, along with the local multipliers, provide the inputs for the computer microsimulations. The microsimulation program with which we generate our projections is SOCSIM. Originally developed from 1970 onwards under the stimulus of Peter Laslett by E.A. Hammel and K. W. Wachter for studies of historical household structure, it has been refined over the years for a wide range of problems in kinship forecasting. Recent descriptions and applications can be found in Hammel et al. (1991), Wachter, Blackwell, and Hammel (1997), and Wachter (1997). Full current documentation can be found on the web at [www.demog.berkeley.edu/~socsim](http://www.demog.berkeley.edu/~socsim).

The heart of SOCSIM is a population list, which in this application is a list including all respondents to SWET and all their adult children. SOCSIM assigns demographic events month by month to members of the population list in the computer by comparing random numbers to user-specified tables of demographic rates. The living and the dead are all retained in the population list, so that life experiences and kinship links can be recovered and tallied over time. For this project, SOCSIM gives individuals dates of progression to symptomatic AIDS and dates of death. Childbirth, marriage, and migration are irrelevant and are ignored. The simulated population is not augmented as

months pass by births of new individuals or by new cohorts of older persons aging into the over-50 group. We concentrate on the unfolding experience of the strictly delineated group of Thais over 50 in May 1995 as they live out their lives.

## 5 Parental Bereavement

The overall prediction from the simulations based on TWG estimates and baseline assumptions regarding heterogeneity is for one in thirteen or about 718,000 Thais over 50 years of age in 1995 to experience the loss of one or more adult children to AIDS before their own deaths. These TWG-based levels compare with one in eight or 1.2 million such parents losing children under UN assumptions. Deaths before 1995 are not included in the simulations. The TWG-based simulations show 661,000 parents losing exactly one child and 53,000 losing exactly two, with only 4,000 losing three or more, out of a total estimated population of older people of 9,531,000. Roughly 60% of those adult children who eventually die of AIDS die before a (randomly selected) parent's death. About 3 million of these older Thais are predicted to lose some adult child to some cause before their own deaths, so under TWG assumptions AIDS increases the experience of child loss by about 35%.

Table 1: Percentage Distribution of Lifetime Bereavements.

Region	0	1	2	3+	%M	N
Thailand	92.46	6.94	.56	.04	15	7708
Simulation SE	.021	.021	.007	.002	.138	
Sampling SE	.417	.394	.158	.001	3	
Upper North	85.10	12.98	1.73	.18	24	548
Northeast	93.72	5.91	.34	.02	11	1808
Central	91.80	7.58	.58	.03	14	2243
South	94.86	4.86	.27	.01	11	1106
Bangkok	93.62	5.96	.40	.02	13	882
Lower North	95.06	4.69	.24	.01	9	1121

Each entry of Table ?? shows the percentage of Thais over age 50 in 1995 who lose specified numbers of children to AIDS during their lifetimes. The percentages are means over 400 replicate simulations with baseline assumptions regarding heterogeneity and TWG-based demographic rates. The rows giving standard error estimates labeled “Simulation SE” and “Sampling SE” will be discussed later in this section. The column labeled %M is the percentage of multiple losses, that is, the ratio of the number of losses in families with two or more losses to the number of losses in families with one or more losses. The column labeled N is the sample size of the sample of older Thais in the SWET survey which supplies the initial population for the simulations. Each sampled household has a sampling weight, and all estimates are weighted up to the population of Thailand.

Regional heterogeneity in risks for children produces substantial differences from region to region for parents in the frequency of single and multiple loss shown in Table ?. The Upper North, including the city of Chiang Mai, suffered most at the beginning of the epidemic. There 13% of the target group of parents are projected to lose one child during their lifetimes, and 2% to lose two or more. Nearby, in the Lower North, less than 5% lose any child. In Bangkok, lower early rates of incidence, if the army data are to be trusted, go along with higher later rates, leading to intermediate levels of loss. Regional contrasts are starker with TWG rates than with UN rates, because the TWG sees infections concentrated in early years when regional contrasts are strongest. The milder epidemic projected by the TWG still implies substantial levels of parental bereavement for today’s older Thais.

Bereavements fall less heavily on parents born early in the century. Their adult children were already old enough to escape the worst risks of infection as the epidemic spread, and their own deaths were more imminent. Only 4.6% of parents born in the 1920s are projected to experience loss, compared to a peak of 9.5% for parents born in the 1930s. A slight drop in bereavements is indicated for parents born between 1940 and 1945, presumably a harbinger of fewer losses within the smaller families of later cohorts, born after Thailand’s dramatic fertility decline and coming of age as chances of infection diminish. Though numbers of bereavements will be smaller, the chances of losing all one’s sons or daughters will be greater for parents of these later generations.

For the group of Thais over 50 in 1995, the experience of child loss is spread out over the next fifteen or so years. About 24% of their bereavements have already taken place by 2000, 80% by 2010, and 98% by 2020. Bereavements for this particular group of older Thais occur quite late in life.

Our simulations show a mean age at bereavement close to 69 years, less than the mean age based on the UN forecasts, but still striking. It must be borne in mind that this group is selected to be over 50 in 1995. Their adult children tend to be older than the general population exposed to HIV. For this group of older people, the late ages at which caregiving responsibilities and sorrows occur make them more vulnerable and amplify the strains and burdens that fall upon them.

The dominant source of uncertainty in our estimates is the uncertainty in the projections of AIDS infections. The differences between the TWG (2001) and the UN (1999) projections amount to a difference of five percentage points in the estimated number of the target group of older Thais losing one or more children to AIDS before their own deaths. These uncertainties should gradually be resolved, especially if the TWG projections are borne out by further scrutiny and future experience. Our estimates of differentials are less sensitive than overall levels to the projected rates.

Some uncertainty is also contributed by the Monte Carlo nature of the simulations. This uncertainty is minimized by taking averages over large numbers of replications. The percentages in Tables ?? and ?? are based on 400 replications. Each simulation has a population size of 7708 older Thais and 36,852 adult children. The standard errors are mainly between one and two times the standard errors one would calculate from simple binomial variability with 7708 independent cases. Standard errors for the percentages in the first row of Table ?? are shown in the second row labeled "Simulation SE". They are nearly negligible.

The limited sample size of the SWET survey and the corresponding initial population for the simulations also imposes uncertainty due to sampling error. This sampling error affects the estimates of overall levels, although it is unlikely to have much effect on estimated differentials. Bootstrap estimates of this sampling error for the first row of Table ?? are shown in the third row labeled "Sampling SE".

We combine simulation data with information from the TAC study to estimate the frequency with which parents will be living with or taking care of adult children afflicted with AIDS. The TACS gathered retrospective information on residence and caregiving for Thais who had already died of AIDS at the time of the survey. We calculate age-specific rates of coresidence and caregiving separately for mothers and for fathers and investigate the levels implied by the assumption that these rates continue into the future.

On the basis of the projections, among Thai men and women over age 50

in 1995, 3.6% of women and 1.1% of men are likely to be the principal caregiver for a child sick with AIDS one or more times before their own deaths. Some 4.9% of women and 4.1% of men will reside with such a child. In Thailand, death follows rapidly on the presentation of symptoms of AIDS. The mean duration of illness in the simulations, based on UN schedules, is one year. Whether resource-intensive therapies will eventually prolong and ameliorate the periods of illness is an open question, but any such developments will not come early enough to affect most of our target group of older Thais. Although periods of caregiving may not be extended, they are undoubtedly often intense. Caregivers themselves run a risk of infection. If parents' health and survival were unaffected by the illness of their children, there would be an average gap of about 13 years between the death of the first infected child and the parent's death according to the simulations. The aftermath of caregiving may well shorten this interval, especially if transmission of HIV to caregivers is not rigorously forestalled.

## 6 Heterogeneity

The simulation results presented so far incorporate data-based allowances for regional heterogeneity in risks of HIV infection, and they incorporate a baseline assumption of mild heterogeneity from community to community and family to family. We know of no quantitative data on which to base direct estimates of local and family-level heterogeneity. One would expect such heterogeneity to be a pivotal determinant of multiple loss within families.

Table ?? shows proportions of the population of Thais over age 50 in 1995 who lose zero, one, two, three, or four or more children to AIDS before their own deaths, for varying assumptions about heterogeneity. Each row is based on 400 replicate simulations with rates derived from the TWG. The level of heterogeneity is labeled by the standard deviation  $\sigma$  of the distribution of risk multipliers as well as by the gamma distribution shape parameter  $k$ . The mean of the multipliers is always 1. The rows with  $\sigma = 0$  and  $k = \infty$  correspond to simulations with no community and family heterogeneity. The rows with  $\sigma = .577$  and  $k = 3$  correspond to our baseline case of mild heterogeneity. The remaining rows correspond to moderate and moderately strong heterogeneity. The first set of rows labeled "All" show percentages for all Thailand. The last set of rows labeled "UpN." show percentages for the Upper North. As before, %M is the percentage of all losses that are multiple

Table 2: Heterogeneity and Percentages of Multiple Child Loss.

Region	$\sigma$	k	0	1	2	3	4+	%M
All	0.00	$\infty$	92.23	7.27	0.48	.03	.00	12
All	0.58	3	92.46	6.94	0.56	.04	.00	15
All	1.41	1/2	92.88	6.12	0.85	.13	.02	26
All	2.00	1/4	94.11	4.84	0.84	.17	.04	33
UpN.	0.00	$\infty$	85.85	12.67	1.36	.11	.00	20
UpN.	0.58	3	85.10	12.98	1.73	.17	.01	24
UpN.	1.41	1/2	87.21	10.41	1.98	.34	.06	33
UpN.	2.00	1/4	87.73	9.23	2.26	.56	.22	43

losses within families.

By concentrating risk, greater heterogeneity increases the proportion of parents that escape losing any child to AIDS. Higher values of  $\sigma$ , for the most part, go with higher percentages in the first column. Greater heterogeneity tends to decrease the proportion losing a single child in the second column, and tends to increase the proportion incurring two, three, or more losses in the later columns.

The column with %M presents multiple loss from the child's point of view. For Thailand as a whole, under baseline assumptions, 15% of those dying of AIDS before their parent's death have a sibling who does also. Under the alternative of moderately strong heterogeneity with  $\sigma = 2$  in the Upper North, as many as 43% of such children would have a sibling with the same outcome.

The TAC study gives some information on multiple loss as of 1999. For about half of the sites visited, key informants reported at least one case of multiple siblings infected. Overall, multiple siblings accounted for 7% or 8% of the total cumulative number of AIDS cases estimated by the key informants (unpublished results). Simulation estimates tabulated as of the end of 1999 for comparison show mean %M values of 3.9%, 7.8%, and 11.4% for levels of  $\sigma$  of 0.58, 1.41, and 2.00. Our moderate heterogeneity assumption with  $\sigma = 1.41$  and  $k = 1/2$  would match the TAC observations well. Key informants may overstate siblings' deaths, since such cases may be especially prominent in their memories. The number of TAC cases is not large, and

the epidemic is still in its early years. Nonetheless, the comparison suggests that the range of assumptions about heterogeneity that have been tested is a plausible one.

The family-to-family variability in risk modeled by the risk multipliers interacts with family size. Larger families have more chances for multiple losses. The interaction is non-linear, but its essential features can be examined with a simplified closed-form model.

The model restricts attention to a collection of families in which, in the absence of the risk multipliers, each child would be subject to the same uniform hazard  $h$  of dying of AIDS before his or her parent's death. In effect, the model conditions on the ages of parents and children and the changing profile of risk over region and time which would produce family-to-family variability beyond what is taken into account in the multipliers and in the model. Let  $Z$  be the gamma-distributed risk multiplier for a family with standard deviation  $\sigma$  and shape parameter  $k = 1/\sigma^2$ , so that  $hZ$  is the hazard that applies to all the children within the family. Let  $n$  be the number of children in a family and  $X$  be the random variable giving number of losses in the family. Integrating a binomial distribution for  $X$  over the gamma distribution for  $Z$ , we obtain

$$P(X = 0) = a_0 \tag{1}$$

$$P(X = 1) = n(a_1 - a_0) \tag{2}$$

$$P(X = 2) = (n(n-1)/2)((a_2 - a_1) - (a_1 - a_0)) \tag{3}$$

where

$$a_j = (1 + (h/k)(n-j))^{-k} \tag{4}$$

These expressions yield multiple losses as functions of  $h$ ,  $\sigma$ , and  $n$ .

The model brings into focus the tradeoffs between family size and heterogeneous risk as determinants of multiple loss. A one-child increase in family size from 4 to 5 raises the percentage of multiple loss by the same amount as an increase in  $\sigma$  from 0.58 to 0.92 when  $h = 0.04845$ . This  $h$  is the hazard rate required to make the model match the mean total losses from the baseline simulations in the Upper North. The difference between 4 and 5 is the difference between median family sizes in the Upper North and in the whole of Thailand in the SWET survey. Averaging over the full parity distribution for the Upper North and for the whole of Thailand gives about the same difference in multiple loss. It follows that family size is important,

but it is not as potent a determinant of multiple loss as the assumed level of heterogeneity across the range of alternatives considered here.

It is instructive to compare predictions from the model to mean levels observed in the simulations when regional variability is suppressed and all cases are from the Upper North. For the four settings of the standard deviation in Table ??, we obtain 16% compared to 20%, 22% compared to 24%, 36% compared to 33%, and 47% compared to 43%. The model calculations average over the observed distribution of parities and tune the hazard  $h$  to yield the observed level of total loss. Predictions are reasonably close to observations. When we combine all regions, we expect the omission of regional heterogeneity to make the model underestimate multiple loss. The differences between predictions and observations live up to expectations, for instance 11% compared to 15% for the baseline case and 27% compared to 33% for the high-heterogeneity alternative.

Among the most interesting findings from this study is the sensitive dependence of the index of multiple loss %M on the level of family-to-family heterogeneity. The percentage of all losses that are multiple losses within families is a statistic that is potentially amenable to measurement in surveys. Using such survey information to infer levels of heterogeneity could be especially valuable for future projections of the course of AIDS epidemics. Stratification into subpopulations at differing levels of risk may be the dominant consideration in realistic forecasts of long-run HIV prevalence in Africa and elsewhere.

As we have noted throughout our discussion, the cohorts turning 50 before 1995 are still experiencing early effects of the AIDS epidemic among their adult children. Their own childbearing preceded Thailand's dramatic decreases in fertility, so their families are larger than the families of those who will encounter later stages of the epidemic. For these cohorts, virtually no one should expect to lose all their children to AIDS without the operation of some particular set of risks concentrated on the family itself. Families from these cohorts will occasionally lose all their daughters or all their sons to AIDS. We estimate that only a couple of hundred parents across all Thailand might find themselves in Mr. Choroen's condition, losing all of three sons to AIDS before their own deaths. Such vivid tragedies are relatively rare. But losing one child from AIDS is not rare, and multiple loss is not negligible. As later cohorts with smaller families arrive at older ages the impact of losing children may well be greater. Even in the face of the falling numbers of new infections projected into the future by the Thai Working Group, arduous

caregiving, bereavement, and deprivation will be taking a heavy toll on the old age experience of Thai men and women.

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