Health Consequences of Forest Fires in Indonesia\textsuperscript{1}

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Abstract

In the last half of 1997, smoke from the worst forest fires in decades blanketed the Indonesian islands of Kalimantan and Sumatra. This paper combines population-based household survey data from the Indonesia Family Life Survey (IFLS) with satellite measures of smoke aerosol levels to assess the impact of the fires on the health of the Indonesian population. The combination of detailed information on multiple dimensions of the health status of each IFLS adult respondent with the ability to carefully measure the intensity, duration and timing of smoke inundation in the community in which each respondent lived at the time of the fires provides a data source that is uniquely well-suited to identifying the causal effect of smoke haze on the population. We focus on the health of adults and find that individuals living in areas affected by the smoke were in worse health in 1997 than their counterparts in other areas. However, exploiting the repeat-observation design of IFLS, we demonstrate that these cross-section results overstate the negative impact of the fires, because health in areas covered with smoke tended to be worse, on average, in 1993 than in other areas. We take this into account by comparing changes in health for individuals in areas affected by smoke with changes for individuals outside the smoke areas and find that the fires had a significant deleterious impact on the health of Indonesian adults. Those living in smoke affected areas tended to have more difficulties with activities of daily living, more respiratory problems and considered their overall health to be poorer. These effects are large at the onset of the smoke inundation but the evidence for longer term effects on these dimensions of health is less clear.
1 Introduction

In late 1997, Southeast Asia experienced the worst forest fires on record. Large tracts of forest and arable land on the islands of Kalimantan (Borneo) and Sumatra were destroyed and parts of those islands were blanketed with thick smoke haze for several months. Analysis of SPOT images suggests that around 5 million hectares of land burned, of which 20% was forested. (Liew et al. 1998)

Fires have occurred during the dry seasons in Indonesia for generations and are the result of land clearing for shifting agriculture. Almost all land clearing is done by burning. Over the last quarter century, the magnitude of fires in the forest areas has increased dramatically as commercial use of this land has expanded. Land clearing has increased in scale, as logging concessions have opened up new areas for small scale farmers who have moved into these areas in large numbers.

The fires in late 1997 were exacerbated by the warming of the Pacific Ocean because of the El Nino Southern Oscillation (ENSO). ENSO brought one of the worst droughts in memory to the eastern islands of Indonesia by delaying the onset of the monsoon and letting the fires burn for several months longer than usual. Delayed rains resulted in peat fields being dried out and becoming easily combustible. Many burned underground for several months and released very thick smoke. It was only with the advent of the monsoon rains at the end of 1997 that the majority of fires were extinguished.

Figure 1 provides a time series of a measure of the level of smoke haze near Palangkaraya, Kalimantan. It is apparent that relative to other years, 1997 was a catastrophe. Moreover, within the region, Indonesia bore the brunt of the effects of the fires although dense smoke haze was felt in Sarawak and Brunei on Borneo, in Singapore and Malaysia and as far afield as Thailand, Viet Nam and the Philippines. Early assessments estimated that the fires caused at least $4.5 billion in damage in the region. (Schweithelm, Jessup, and Glover 1999) The lion’s share of those costs are attributed to the health consequences of the fires and were borne by the Indonesian population where the haze was heaviest and persisted for the longest. These inferences are drawn using evidence on hospitalizations and self treatments in Sarawak,
There are two problems with these conclusions. First, the exposure to haze was substantially lower in Sarawak than in Kalimantan and Sumatra; if the effects of haze are not linear, it is not clear how to interpret extrapolation to the Indonesian population. Second, in poor economies like Indonesia, use of health care is not universal but tends to be higher in urban areas and, tends also to increase with household income. As a result, these estimates of the effects of the haze will likely to miss the poorest and potentially most vulnerable part of the population. Sastry (2002), examines the effects of the smoke on daily mortality in Kuala Lumpur and reports that for 65-74 year olds there was an increase in mortality that lasted several weeks. Mortality is interpreted as a sentinel indicator and the results are “suggestive of wider short-term health impacts, particularly with respect to acute morbidity” although no evidence is presented to support this claim. Sastry speculates that the effects of the smoke haze “in Indonesia itself are likely to be tremendous.”

This paper uses uniquely rich data from Indonesia to directly measure the short-term effects of the fires on the health status of the population that was exposed to the worst haze. Rather than rely on hospitalization, out-patient or mortality data to infer effects on health outcomes, we use population based household survey interview data that were collected at the time of the devastating fires in Indonesia. The Indonesia Family Life Survey (IFLS) is a longitudinal socio-economic and demographic survey which collects detailed information on an array of health indicators. The second wave of IFLS was in the field in the last half of 1997 at the same time as the fires were raging out of control in Kalimantan and Sumatra. These survey data have been combined with satellite-based aerosol measures to produce a rich data source with which we examine the immediate effects of the fires.

Individuals exposed to smoke haze in 1997 are more likely to have difficulties with strenuous activities of daily living and to report themselves to be in poorer health. However, the same people were also more likely to be in poorer health in 1993 indicating that estimates of the effects of the fires based on cross-section comparisons are likely to be contaminated. Since IFLS is a longitudinal survey, it provides an unparalleled opportunity to isolate the causal effect of the fires. Specifically, health status reported several years prior to the fires is compared with health reported by the same person at
the time of the fires. We then contrast the changes among those exposed to the haze in 1997 with those not exposed. We find that the estimated health effects are substantially muted. They are however significant and the longer term deleterious effects on health appear to be greatest for older respondents and for those exposed to the worst haze.

2 Previous Work

The literature suggests that fires may have several different effects on the health and well-being of the population. First, exposure to smoke – much like exposure to air pollution – is likely to affect upper respiratory morbidity. In particular, smoke can cause internal lung lesions and the airway’s natural response to such such damage is generally increasing inflammation that evolves over time. This inflammation reduces the size of the airway and can lead to more severe obstructive breathing disorders (Chretien and Dusser 1996). Very little is known about the long-term effects of smoke exposure.

Aditama (2000) analyzed the 1997 Indonesia forest fires by looking at personal reports of pulmonologists working in fire areas as well as data from province/district health offices and hospitals. He finds evidence of increased bronchial asthma and acute respiratory infection. For example, a report from the Provincial Health Office of Jambi, Kalimantan showed a 51% increase in cases of respiratory disease in that province during the haze period.

Shusterman et al. (1993) and Lipsett et al. (1994) find similar respiratory effects when they examine emergency department and coroner’s records for effects of a two day urban wildfire in Alameda County, California. They report that 61% of the 227 people treated due to the fire had documented bronchospasm. Of this group, two thirds had a history of asthma and 11% had a history of chronic obstructive pulmonary disease. Other reactions to the smoke included irritative reaction and corneal abrasions.

Recent work by Sastry (2002) finds that daily increases in 1997 haze levels in two urban areas of Malaysia (Kuala Lumpur and Kuching) are associated with increased mortality rates in these areas. Emmanual (2000) investigates
effects of the 1997 fires on lung health in Singapore using pollution monitor data and morbidity and mortality data from public sector health facilities. He finds relatively moderate affects including a 30% increase in outpatient attendance for haze-related conditions, but no significant increase in overall hospital admissions or in mortality.

A key difficulty with interpreting most of these studies is that they are small scale and based on anecdotal evidence, hospital admissions records, and/or death certificates. This makes it hard to draw conclusions about the overall population from their results.

The air pollution literature also suggests that exposure to the smoke haze may have significant effects on health and mortality. Air pollution often has a similar chemical make up, although the exposure is generally at a much lower level and over a longer period of time. Much research (e.g., see survey (Pope, Dockery, and Schwartz 1995)) finds evidence of health effects of particulate air pollution. Exposure has been associated with increased cardiopulmonary mortality, increased hospitalization for respiratory disease, exacerbation of asthma, increased incidence and duration of respiratory symptoms, declines in lung function, and restricted lung activity.

Many studies ((Chay and Greenstone 1999), (Dockery et al. 1993), (Cropper et al. 1997)) also find that air pollution is correlated with increased mortality. Dockery et al. look at evidence from the Harvard Six Cities Study and find that Total Suspended Particulate (TSP) levels are significantly associated with increased mortality in each of six U.S. cities.

Chay and Greenstone use the variations in air quality attributable to the 1981-82 recession to identify the effects of pollution on infant mortality in the United States. They find that a 1 mg/m$^3$ reduction in particulates results in about 4-8 fewer infant deaths per 100,000 live births at the county level.

Cropper et al. study the health effects of air pollution in one of the most polluted cities in world: Delhi, India. While they find a positive relationship between particulate air pollution and daily nontraumatic deaths, the impacts are smaller than those estimated for other countries; in particular, they find that a 100 microgram increase in TSP leads to a 6 percent increase in nontraumatic mortality. The lower impacts are attributed to differences in
distributions of age and cause of death, as most deaths in Delhi occur before
the age of 65 and are not associated with causes strongly associated with air
pollution.

Smoke from biomass burning causes severe reductions in the UV-A and
UV-B that reach the ground. This radiation is known to have significant
bactericidal and viricidal effects, implying that haze areas might experience
higher than normal infection rates. Mims (1996) finds evidence to support
this hypothesis and shows that different species of mosquitos reproduce at
a higher rate in areas with less light. This includes the summer mosquito
(culex pipiens) which can be an encephalitis vector as well as the anophe-
les mosquito which carry malaria. At the same time, smoke from the fires
induced many people to spend more time indoors where would be less vul-
nerable to infections from either mosquitos or water sources.

3 Data

The combination of household survey data collected while the fires were rag-
ing in late 1997 in Indonesia with information on smoke haze inundation pro-
vides unique opportunities to measure the effects of the fires on the health
and well-being of the Indonesian population. We begin with a description of
the survey and then turn to the measurement of smoke haze.

3.1 Measurement of Health

The Indonesia Family Life Survey (IFLS) is an on-going longitudinal survey
of individuals, households, communities and facilities. The first wave, con-
ducted between August and December, 1993, interviewed over 7,200 house-
holds in 321 clusters (or enumeration areas) across 13 provinces in Indone-

\footnote{See (Frankenberg and Karoly 1995) and (Frankenberg and Thomas 2000) for a de-
scription of the survey.}
The survey is representative of 83% of the Indonesian population; the remaining 17% of the population living in the outer provinces were excluded for cost reasons.

The first follow-up survey was conducted after a four year hiatus. Between August and December, 1997, all 321 of the enumeration areas were visited, the original household was located and all household members were re-interviewed. If a household had moved within the vicinity of the enumeration area (defined as within about 30 minutes by public transport), the interviewer would attempt to track the household and interview members in their new location. Longer distance movers were interviewed later in their new location as long as it was in one of the 13 provinces included in IFLS. Thus, movers to provinces in which there was not a team or movers abroad were not tracked. Interviews with these people were completed at the end of the survey and some of them took place in early 1998.

A similar protocol was adopted for individuals who had split off from the original household. In 1993, the household head, spouse, up to two children and up to two other adults were eligible for an individual interview. In 1997, tracking was restricted to those 1993 household members who had completed an individual interview in the baseline; we refer to them here as "target individuals". If a target individual moved with other, non target household members, all the original household members were interviewed when they were located.

IFLS2 re-interviewed at least one original household member in 95% of households. Nearly 900 split off households were added to the sample and over 33,000 individuals were interviewed. Of those, over 21,000 were "target individuals" from IFLS1.3

In early 1998, the Indonesian rupiah collapsed which presaged tremendous
disruptions.

\[2\]

The provinces are North, South and West Sumatra, Lampung, all of Java, Bali, West Nusa Tenggara, South Kalimantan and South Sulawesi. The enumeration areas are census blocks defined by the Indonesian Badan Pusat Statistik and used to draw their sample surveys. They are never larger than a *desa* and most *desas* contain multiple enumeration areas.

\[3\]94% of target individuals were located during IFLS2. See (Thomas, Frankenberg, and Smith 2001) for a discussion of attrition in IFLS2.
upheaval in the economic, social and political life of the country. In an effort
to measure the immediate effects of the crisis, a 25% sub-sample of households
were interviewed in 1998. (90 of the original 321 enumeration areas were
selected. All households who had lived in those 90 areas in 1993 were eligible
for re-interview.) IFLS3 was conducted in late 2000 and covered all IFLS
households including split offs. The 1998 and 2000 waves of the survey are
not used in this paper; they will be examined in future work in order to
measure the medium and longer term effects of the fires.

In addition to basic demographic and economic characteristics of respon-
dents, IFLS collects very detailed information on health. Respondents are
asked to report their general health status, whether they have difficulties
with activities of daily living, the incidence of a set of morbidities and use
of health care services. In every wave, anthropometry (height and weight)
is measured and since the 1997 wave, physical assessments have been con-
ducted by trained healthworkers. These assessments include measurement
of blood pressure, spirometry (with a peak flow meter), test of mobility and
hemoglobin level in the blood (using Hemocue). As explained below, it is
necessary to have repeat measures in order to pin down the effects of the
fires and so these physical assessments are not included in this study.

These very rich survey data which are representative of the population in
the provinces studies are combined at the community level with information
on exposure to smoke haze. We turn next to a description of those measures.

3.2 Measurement of exposure to smoke haze

The dry seasons in Indonesia are accompanied by fires every year. Typically,
the effects are localised and little noticed outside the forest areas. In the
last two decades of the last century, the incidence and extent of the fires
increased significantly. In 1982 and again in 1994, the fires were much larger,
than in prior years and were exacerbated by the drought associated with
ENSO in those years. However, the magnitude and extent of the fires and
accompanying smoke haze in 1997 was unprecedented.

Fires began in the middle of 1997 and were scattered throughout the
region as indicated by the red areas in Figure 2. The map displays locations of fires that occurred during the second half of 1997, identified by light emissions recorded by the DMSP-OLS satellite. (Fuller and Fulk 2000) Evidence based on burn scars using the AVHRR satellite or SPOT mosaics (Liew et al. 1998) tells much the same story.

There are two reasons why light emissions are not likely to provide good mechanisms for measuring the effects of the fires on health status. First, it is difficult to measure fire intensity and, in fact, it is quite hard to distinguish fires from city lights. Second, the literature suggests that the effects of fires on health are likely to be mediated through the effect on air quality and that is not highly correlated with location of the fire itself because of the influence of winds. Thus, many studies use pollution monitors to measure air quality. Such data are only available in a small number of major urban centers in Indonesia and so there is no coverage of the majority of the areas that were inundated with smoke. In particular, pollution monitor data are not available for any rural areas and so reliance on pollution monitors would restrict this study to urban areas. In order to fully exploit the survey-based data on health of individuals, satellite measures of the smoke haze are used.

The Aerosol Index reported by the NASA Total Ozone Monitoring System (TOMS) provides a good measure for ground-level smoke (Hsu et al. 1996). Recent work ((Hsu et al. 1999) and (Torres et al. 2002)) has shown that this index is linearly correlated with ground-level aerosol optical thickness (AOT), which is itself highly correlated with TSP levels (Brimblecombe 1995). Hsu et al. and Torres et al. compare the TOMS Aerosol Index and a TOMS-derived estimate of AOT with ground-based Sun-photometer AOT measurements made in Africa, South America, and the United States between 1996 and 2000. We are currently verifying that this relationship holds for the 1997 Indonesia forest fire haze by comparing Indonesia pollution monitor and visibility data with TOMS measures for these locations.

Smoke haze levels from TOMS data recorded in late September, 1997, are displayed in Figure 3. Two main points emerge. First, whereas fires were scattered throughout Indonesia, by late September, smoke haze had blanketed much of southern and western Kalimantan and most of southern Sumatra. It is estimated that the haze covered more than 3 million square kilometers. Indeed, whereas the eastern coast of Kalimantan was the site of many fires,
it was relatively free of smoke inundation which is a reflection of the fact that the westerly and north westerly winds that prevail at that time of year played a major role in distributing the haze across the region. It is also clear from the figure that Java, Bali, Sulawesi and most of the eastern islands were relatively unaffected by smoke haze.

Second, aerosol levels in Singapore and Malaysia are much lower than those recorded in the worst affected areas of Kalimantan and Sumatra where vast tracts of land record aerosol indices between 3.0 and 4.0. It is estimated that particle concentration was between 20 and 40 times the normal (non haze) background concentration and visibility was frequently below 100 metres in the worst areas. This corresponds to TSP levels around 1000 µg/m$^3$ in these areas as compared to the WHO established guideline range for cities of 150 to 230 µg/m$^3$ (WHO 1992). In contrast, particle concentration was between 2 and 5 times ambient levels in Singapore and Malaysia and visibility was reduced to around 2 km. (Heil and Goldammer 2001)

By mid to late November, wind and monsoon rains had quenched the fires and removed most of the haze. In early March of 1998, the fires sprang up again in Kalimantan, but the smoke stayed in Kalimantan and this time Sumatra was spared.

During this time, populations in the inundated areas were subjected to smoke haze on a scale and at levels that were unprecedented. We would, therefore, expect to be able to pin down the effects of the smoke haze on health and behaviors far more precisely than would be the case, for example, in Singapore or Malaysia.

The TOMS instruments have several key advantages for this study. First, aerosol levels have been measured on a daily basis since 1978 (although instrument failure resulted in no data being available for Indonesia between mid 1993 and mid 1996). MODIS, the only other satellite-based instrument that reliably measures aerosol levels over land went into operation in February 2000. Second, as noted above, TOMS aerosol indices are highly correlated with ground TSP levels. Third, TOMS measures can be matched to the location of households interviewed in IFLS. The latitude and longitude of each IFLS cluster was recorded with a handheld global positioning system and the location of movers is assigned based on the desa in which they were
interviewed in 1997.

Matching TOMS and IFLS data by interview date and physical location allows us to precisely capture each individual’s exposure to the smoke haze in terms of level of smoke inundation, duration of that exposure and timing of the exposure, and link all of this with health information collected from interviews with the respondents.

The location of IFLS enumeration areas is displayed in Figure 4 which also identifies those areas affected by the smoke haze. Specifically, following standard practice, we treat aerosol levels above 1.5 as indicative of smoke haze inundation and identify all such areas as having been affected by smoke haze (“Haze areas”). These include all enumeration areas in Southern Kalimantan, Northern, Western and Southern Sumatra as well as some areas in Lampung and West Nusa Tenggara. 25% of the IFLS respondents lived in “Haze areas.”

Background characteristics of the sample respondents are reported in Table 1. The sample is restricted to adults age older than 30 in 1997 (or those born prior to 1967) for whom health status is reported in both the 1993 and 1997 waves of IFLS. Smoke haze areas are more likely to be rural, tend to be at higher altitudes; respondents tend to be better educated but have lower levels of household resources (as measured by per capita expenditure). Respondents in haze areas are also slightly less likely to be older adults. In a multivariate context, we found that better educated respondents living at higher altitudes are more likely to be exposed to smoke.

Observable differences between respondents exposed to haze will be controlled in the analyses below. However, there may be unobserved differences in their health status which are not fully captured by our measures of demographic and socio-economic status. One approach to assessing the extent to which this is a concern is to compare indicators of health status that are fixed over time. Height – a measure of longer run nutritional status – is a good candidate as it is correlated with physical strength, incidence of morbidity and expected life. If those people who live in areas inundated with smoke haze in 1997 are intrinsically less healthy than other respondents, then they should be of lower stature. There are no differences between those in smoke haze areas and those not. Body mass index (BMI) which is weight (in kilo-
grams) divided by height (in metres) squared is also predictive of mortality and morbidity. While it does vary over time, it is not obvious that it will be much affected by smoke haze. As with height, there are no differences in the BMI of people living in areas inundated with smoke and those not. This suggests that simple comparisons between these two groups of people should provide insights into the impact of the fires on health. Armed with these data, we turn now to a description of our analytical methods and discussion of the empirical results.

4 Methods and Results

The literature suggests that older people (and possibly very young people) are more susceptible to the deleterious effects of smoke haze. Thus, all analyses are stratified by age of the respondent. We also separately examine males and females since men are more likely to be working outdoors and in physically arduous tasks and so may be more exposed to smoke haze.

Three indicators of health are examined. We begin with whether the respondent had difficulty carrying out strenuous tasks, turn next to a more general measure of overall health and end with respiratory morbidity.

4.1 Activities of daily living

IFLS asks whether the respondent has difficulties with a battery of activities of daily living (ADLs). Many of these questions are geared towards eliciting information about physical and functional difficulties among older adults. We focus on one which provides information about the respondent’s capacity to perform physically strenuous activities: whether the respondent has difficulty carrying a heavy load. If smoke haze affects upper respiratory functioning, it is reasonable to suppose that strenuous activities will be more difficult.

As reported in the first row of the first column of Table 2, among respondents who lived in areas affected by the haze in 1997, over 40% of older men
report difficulty with this ADL. Over two thirds of older women report such difficulties, as do about one quarter of younger women. Among younger men, carrying a heavy load is difficult for only 6% of the sample.

One approach to measuring the effect of the haze on health exploits the repeat observation dimension of IFLS and compares the health of the respondents at the time of the fires with their health in 1993, when there was no smoke haze. This difference is reported in the third row of the first column of each panel in the table. It is very large and significant for older respondents: one-third more older women and one-quarter more older men report having difficulty carrying a heavy load in 1997 relative to 1993. There are, however, many reasons why the incidence of these difficulties increased during the four year hiatus between the surveys – not least of which is that they are four years older. It is possible to obtain an estimate of this effect by comparing the increased incidence of difficulty carrying a heavy load in those areas that were not inundated with smoke in 1997. The difference is reported in the third row of the second column of each panel. It is also large and significant indicating the simple time series difference does not yield an unbiased estimate of the effect of the smoke.

An alternative approach exploits the spatial variation in IFLS and compares the health of respondents in smoke haze areas in 1997 with those living in areas not affected by smoke at the same time. Those estimates are reported in the first row of the third column in each panel of the table. In all cases, respondents living in smoke haze areas are more likely to have difficulty carrying a heavy load than those living outside the fire areas, and these differences are significant (at a 5% size of test) for all women and older men. Among older women, for example, those in haze areas are nearly 20 percentage points more likely to report difficulty carrying a heavy load.

Recall, from Table 1, that areas affected by smoke haze are not random. The simple differences in health between respondents in the two areas may reflect differences in characteristics of the respondents or the areas in which they live. Controlling observable characteristics turns out to have very little impact on the estimated differences. For example, controlling education and age of the respondent, per capita expenditure (a measure of household resources), location and altitude, the difference in the percentage of older women reporting difficulty carrying a heavy load in 1997 in haze areas is 17.8
(standard error=3) which is trivially different from the uncontrolled estimate shown in the table of 17.9. Contrasts for the other groups are similarly small.

We noted above that height and BMI of respondents in haze areas are not different from those in other areas suggesting that the estimated effects of smoke haze exposure can be attributed to the fires. It is, however, possible to test this inference directly. If the estimated differences in health status are not a reflection of unobserved differences between the exposed and not exposed groups, then it should be the case that the incidence of difficulties carrying a heavy load are the same for haze and no haze areas in 1993. The 1993 estimates are reported in the second row of the table and the difference is in the third column of each panel. It is large and significant indicating that there are, in fact, important unobserved differences between the haze and no haze areas which are correlated with health status.

This suggests that simple comparisons of the exposed and unexposed groups overstate the effects of the fires. It also suggests an alternative strategy: comparing the change in health between 1993 and 1997 of those in haze areas with the change in health of those in areas not affected by the haze. If unobserved differences that are related to health outcomes between respondents in the haze and no haze areas are constant over the period between 1993 and 1997, then these “difference-in-difference” estimates will yield unbiased estimates of the causal “effect” of smoke haze on health status. Unadjusted difference-in-difference estimates are reported in the third row of the third column in each panel.

The estimated effects of smoke are substantially muted relative to the cross section estimates discussed above, but for older adults and prime age women, the effects are still sizeable in magnitude: the haze results in an increase in the incidence of difficulty carrying a heavy load of between 10 and 20 percentage points. However, the effect is significant only for prime age women. The fourth row of the table reports the difference-in-difference estimates after adjusting for observed characteristics of respondents. This adjustment has essentially no effect on the estimates.

There is another way to address the problem of unobserved differences between respondents who are and are not exposed to haze. If those differences are fixed over time – and if they affect health outcomes in a linear
and additive way – then their influence can also be swept out of the estimates by including a person-specific fixed effect in the model. Intuitively, we compare the change in health of an individual who was exposed to haze in 1997 with the change in health of an individual not exposed, controlling all fixed observed and unobserved differences between these two individuals. The estimates are reported in the fifth row of the table. They are very similar to the unadjusted and adjusted differences in the prior rows suggesting that our identification strategy is robust to several sources of potential bias due to unobserved heterogeneity. The benefits of controlling person-specific fixed effects are through efficiency gains as reflected in the greater precision of the fixed effects estimates. Effects of haze are significant for prime age women and older men. The estimates suggest that among older adults and prime age women, exposure to smoke haze caused difficulties with carrying a heavy load for about 5% of the population.

4.2 Intensity of exposure to haze

The estimates discussed thus far have compared respondents exposed to haze with those not exposed. It is, however, reasonable to suppose that the effect of the smoke haze will vary with the intensity of the exposure. One of the advantages of the data that we have compiled is that exposure can be measured in several dimensions.

First, we measure the duration of exposure to haze by identifying the first day in 1997 that the respondent was exposed to a TOMS aerosol index level greater than 1.5 and the last day, prior to the IFLS interview, and calculating the number of months of exposure. The average respondent who was exposed to haze before their interview experienced about one and a half months of haze; only 5% of these respondents were exposed for less than 2 weeks. About a quarter were exposed for over 2 months.

Second, as a measure of the magnitude of the haze, we calculate the average aerosol level during each individual’s period of exposure. It is slightly below 2.0. Exposure was relatively light for around a quarter of the sample (<1.0) and very heavy (> 3.0) for 20% of the sample. Figure 4 shows the distribution of the average magnitudes for each of the IFLS enumeration areas.
IFLS provinces are lighter colored and the enumeration areas are marked by circles. White circles indicate there was no measured haze inundation in that area; darker circles indicate greater Haze Magnitude. The haze is concentrated in Kalimantan and Sumarta – particularly South and West Sumatra – with a small amount of exposure in West Nusa Tenggara.

As the magnitude of haze and duration of exposure increase, the intensity of the haze exposure increases. To assess whether prolonged, thicker smoke haze had a different effect on health outcomes, we have re-estimated the fixed effect models including the two covariates described above as well as a linear term for time since exposure ended. In the first and second rows of that part of the table, we have computed the marginal effect of the haze at the 75th and 90th percentiles of the distribution of magnitude and duration.\(^4\) It is apparent that older men and, especially, older women were more affected by a heavier dose of exposure to haze. Note that for prime age women, the effect of a more intense exposure is apparent only at very high levels of dosage. For prime age men, the effect of smoke haze does not vary with intensity.

### 4.3 Timing of exposure to haze

Thus far, the timing of exposure to haze has been ignored as we have simply compared health status of respondents who were exposed to smoke haze with the health status of those who were not. Enumeration areas in IFLS were interviewed in sequence and the sequence was determined to minimize cost, avoid logistical difficulties and maximize the probability of finding respondents. The timing of the interviews was determined in early 1997, well ahead of the start of the fires and without any knowledge of the likely haze inundation. Thus, interviews were conducted before, during and after the smoke haze had inundated our enumeration areas and, from the perspective of the haze, the timing of the IFLS interviews can be treated as having been randomly assigned.

\(^4\)Estimates of the effects at the mean of magnitude and duration replicate the estimates in the sixth row and so are not reported. The 75th percentile of the distribution corresponds to a 2.2 aerosol index and a 1.6 month duration. The 90th percentile corresponds to a 3.2 aerosol index and the same duration.
This fact, in combination with the availability of daily measures of aerosol levels from TOMS, provides an opportunity to examine variation in the effects of exposure over time. Results, presented in the third section of the table, are reported from the regression models that include individual specific fixed effects.

The timing of exposure is summarized with four indicator variables. First, respondents who were interviewed during the smoke haze inundation are identified and we distinguish those who have been exposed to haze for less than a month from those who have had a longer exposure. Second, respondents who were interviewed after the haze had cleared are identified, distinguishing those who were living in areas affected by haze within the last month from those interviewed at least one month after the haze had cleared. Respondents not exposed to haze are the reference category.

Thus, the first row of coefficients can be interpreted as measuring the immediate effect of the smoke haze. They provide an estimate of the difference in the change in health between 1993 and 1997 of respondents who were exposed to haze at the time of the IFLS interview and had been exposed for less than a month, relative to the change in health of respondents not exposed by the time of the IFLS interview. The effects are very large and significant for all males: older males are 17 percentage points more likely to have difficulty carrying a heavy load soon after the appearance of haze; the probability is 8 percentage points higher for prime age males. The effects are very short lived since they disappear after the first month of exposure to haze, whether or not the haze is still present in the community. This suggests that males become accustomed to the haze after the first month of exposure and either no longer have difficulties carrying a heavy load (which seems unlikely) or they no longer recognise the elevated difficulty as such. It is also possible that after the first month of exposure, males change their behavior so that they reduce physically strenuous activity. This seems an unlikely explanation for the evidence since they are asked hypothetically whether they would have difficulty carrying a heavy load and presumably the answer would be in the affirmative whether or not they have reduced their physically strenuous activities in response to the haze.

The immediate effects of haze are smaller for women and significant only for prime age women (at a 10% size of test). However, after the first month
of exposure, older women report greater difficulty carrying a heavy load and this persists into the first month after the haze has cleared. For prime age women, the effect of the haze is approximately constant over time and persists beyond the first month after the haze has cleared.

The evidence suggests that haze has a large, immediate effect on the ability of males to do physically strenuous work but this effect disappears very quickly. For women, the effects are smaller but appear to accumulate over time and persist well after the haze has cleared.

### 4.4 General health status

Before discussing specific morbidity, we examine the effect smoke haze has on general health status (GHS), an indicator of overall health. Each adult respondent is asked to rate his or her own health (as very good, good, fair or poor). About one third of older adults report they are in fair or poor health as do about one in ten prime age adults. Results are reported in Table 3.

In 1997, older respondents living in areas that were inundated with smoke haze were 10% more likely to report being in fair or poor health than respondents in other areas. Prime age adults were also slightly more likely to report fair or poor health. The cross-section estimates suggest a substantial effect of the smoke haze on general health status. However, all respondents in these areas were more likely to be in fair or poor health in 1993 indicating, again, that estimates of the effects of the smoke haze based on cross-section estimates are biased upwards.

The difference-in-difference estimates, in the fourth and fifth rows of the table, indicate that exposure to smoke haze results in improved health (or reduced incidence of fair or poor health) for older adults and prime age women.

Whereas ADLs have been shown to perform well in interview surveys in low income settings ((Strauss et al. 1993), for example) the interpretation of GHS is not so clear cut. ADLs ask about specific, concrete tasks which are readily understood by the respondent. GHS is more nebulous and studies
have noted that the meaning of “poor” health likely varies in a systematic way with an individual’s socio-economic status (SES). Studies have suggested that in addition to providing information about intrinsic health, reported GHS may be related to, for example, information about health, the health of the reference population with whom a respondent compares him or herself, and so on. (Thomas and Frankenberg 2002b) Indeed, in many studies from low income settings, reported GHS has been shown to be unrelated to SES or even decline with SES (Thomas and Frankenberg 2002a). To the extent that perceptions of and information about health do not change over time, the inclusion of an individual fixed effect in the model should sweep out these individual idiosyncratic effects. The fixed effect estimates in the sixth row of the table are identical to the difference-in-difference estimates suggesting that time invariant differences among respondents are not contaminating the estimates.

It is very difficult to reconcile the fact that older adults and prime age women report more difficulty with strenuous physical activity because of smoke haze but the same people report being in better overall health. The lower half of the table reports the time path of estimated effects of the haze.

The results are striking. There is no evidence that GHS is affected by smoke haze during the first month of exposure. After the first month of exposure, older adults who are still exposed are 10 percentage points less likely to report being in fair or poor health. This is also true during the first month after the haze has cleared and while the effect is smaller (and not significant) the pattern persists in later months. Fewer prime age women report being in fair or poor health only after the haze has cleared. GHS of prime age males is unrelated to haze.

The most plausible interpretation of the evidence is that an individual compares his (or her) health with the health of those “around” him (in his reference group) and also with his own prior health. The weights accorded to one’s own health and that of the reference group are likely to depend on the salience of each. The evidence on difficulty carrying a heavy load indicated that smoke haze inundation had an immediate deleterious impact on health. Since everyone in the community is likely to have been thus affected, and there is probably a good deal of discussion in the community about the effect of haze on health, the health of others in the community is likely to
be salient in the assessment of one’s own health. Thus, on average, reported GHS will be no better or worse than among those not affected by haze.

However, after a month of exposure and certainly after the haze has cleared, a respondent is likely to feel in better health than at the onset of the haze. Thus, respondents interviewed at these times are likely to compare their health at the time of the interview with their own health at the onset of the haze in which case they are likely to report being in better health.

If this interpretation is correct, it suggests that interpretation of GHS is very complex and depends on both time invariant and time varying characteristics of respondents. The results suggest that GHS is affected by haze but these effects are short lived (for older adults and prime age women).

4.5 Respiratory problems

Each adult respondent was asked about a battery of symptoms. Exposure to smoke haze has been associated with elevated upper respiratory problems and so we focus on self-reports of coughing during the 4 weeks prior to the survey.

Between a third and half of respondents report having a cough in the 1997 survey. The difference between people living in areas that were inundated with smoke haze and those in areas not inundated is trivial. However, in 1993, older respondents who were living in areas that had haze in 1997 were 10% more likely to report a cough. Clearly, this cannot possibly be attributed to the fires in 1997 but is a reflection of differences in the health environment in areas that were exposed to smoke in 1997 relative to other areas. The difference-in-difference estimates of the effect of smoke are reported in Table 4. The fact that these estimates are negative indicates that coughing is less prevalent among respondents exposed to the smoke. These effects are significant for all respondents in the model that includes individual fixed effects.

As in the case of GHS, the probability a respondent reports a particular morbidity is likely to depend on the person’s information about health and
perception of the meaning of good health. Studies have shown that reports of morbidities are often positively correlated with SES in low income settings. As with the GHS, the fixed effects sweep out time invariant individual specific propensities to report morbidities but these estimates remain prone to bias because of time varying reporting behavior. We turn, therefore, to time specific estimates reported in the lower half of the table.

They indicate that during the first month of smoke, prime age males and females are more likely to report respiratory problems (although significance is marginal). However, after the smoke has cleared, respondents who were previously exposed to haze are much less likely to report respiratory problems. The effect is smaller during the first month after exposure has ended which is a reflection of the fact that the question in the survey refers to the prior 4 weeks. Respondents who were interviewed over one month after the haze had cleared are around 20 percentage points less likely to report coughing than respondents who were interviewed at the onset of the haze. This is a very large effect and suggests the haze had a substantial impact on the respiratory functioning of all adult respondents.

5 Conclusions

The fires in Indonesia in late 1997 were an environmental disaster. The effects of those fires on population health have been difficult to pin down because of a paucity of survey data on health status of individuals and exposure to the effects of the fires. By combining information collected in health interviews in IFLS with satellite measures of aerosol levels, the effects of smoke haze inundation on three domains of health status of adults have been examined.

We find that comparing health of the population living in areas that were inundated by smoke haze with the health of people living in other areas results in a substantial over-estimate of the “effect” of the fires because of time-varying location specific unobserved heterogeneity in health status. We thus exploit the repeat observation nature of IFLS and compare changes in health between the two groups.
Smoke haze had an immediate deleterious impact on physical functioning as measured by self reported difficulty carrying a heavy load. This effect is particularly large on males. For them, however, the impact – at least as they report it – appears to dissipate quickly. Among females, the effect appears to persist for several months.

We are also able to detect a large, negative effect on overall health status as well as on the incidence of respiratory morbidity at the onset of smoke haze. Interpretation of these health indicators is complicated by the fact that an individual’s propensity to report health problems is apparently affected by their own prior health experiences and the health environment.

The evidence presented in this paper provides insights into the nature of data that are likely to be necessary to measure the effects of economic, social, environmental or political changes (be they negative or positive). It is abundantly clear that cross-section based comparisons of groups is fraught with difficulties and can be seriously misleading. High quality longitudinal survey data that can be matched with administrative or other data sources are of tremendous value in this context. It is also clear that interpretation of self-reported health status is not straightforward; there are likely to be substantial benefits from the collection of physical health measures and biomarkers. These data are available in the 1997 and later waves of IFLS but, unfortunately, were not collected in 1993.

Finally, it is of considerable interest to measure the economic consequences of the fires. Studies have estimated the effects at a macro level but there is no evidence on the impact of the fires on the economic status of individuals and their families. IFLS is ideally suited for this task and ongoing research examines the issue while also taking into account behavioral responses to the fires.
References


Figure 1: The TOMS Aerosol Index between June 1996 and June 2002 near Palangkaraya, Kalimantan
Figure 2: Fires in Indonesia during the second half of 1997. Source: DMSP-OLS
Figure 3: Smoke Levels over Indonesia on September 29, 1997. Source: NASA-TOMS
Figure 4: Average TOMS Aerosol Index in IFLS Enumeration Areas. IFLS provinces are lighter colored and enumeration areas are marked by circles. Darker red circles indicate enumeration areas where individuals received higher smoke exposure, and light red circles indicate minimal exposure.
<table>
<thead>
<tr>
<th></th>
<th>1997 Haze</th>
<th>1997 No Haze</th>
<th>Δ</th>
<th>1993 Haze</th>
<th>1993 No Haze</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td># EA's</td>
<td>80</td>
<td>248</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Individuals</td>
<td>2688</td>
<td>8181</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender/Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Older adults (≥56 yrs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Male</td>
<td>12.6</td>
<td>14.6</td>
<td>-2.0</td>
<td>(0.7)</td>
<td>(0.4)</td>
<td>(0.8)</td>
</tr>
<tr>
<td>% Female</td>
<td>13.0</td>
<td>15.3</td>
<td>-2.3</td>
<td>(0.7)</td>
<td>(0.4)</td>
<td>(0.8)</td>
</tr>
<tr>
<td>Prime age adults (31-55 yrs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Male</td>
<td>33.9</td>
<td>31.1</td>
<td>2.7</td>
<td>(1.0)</td>
<td>(0.5)</td>
<td>(1.1)</td>
</tr>
<tr>
<td>% Female</td>
<td>40.5</td>
<td>38.9</td>
<td>1.5</td>
<td>(1.0)</td>
<td>(0.6)</td>
<td>(1.2)</td>
</tr>
<tr>
<td>% Urban</td>
<td>37.6</td>
<td>46.3</td>
<td>-8.7</td>
<td>(1.0)</td>
<td>(0.6)</td>
<td>(1.2)</td>
</tr>
<tr>
<td>Altitude (m)</td>
<td>282.8</td>
<td>154.7</td>
<td>128.1</td>
<td>(7.8)</td>
<td>(2.5)</td>
<td>(8.2)</td>
</tr>
<tr>
<td>Education (yrs)</td>
<td>5.3</td>
<td>4.5</td>
<td>0.7</td>
<td>(0.1)</td>
<td>(0.1)</td>
<td>(0.1)</td>
</tr>
<tr>
<td>Per Capita Expenditure (Rupiah)</td>
<td>136.1</td>
<td>172.5</td>
<td>-36.4</td>
<td>(6.3)</td>
<td>(10.5)</td>
<td>(12.3)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>153.7</td>
<td>153.9</td>
<td>-0.1</td>
<td>(0.2)</td>
<td>(0.1)</td>
<td>(0.2)</td>
</tr>
<tr>
<td>BMI (Kg/m²)</td>
<td>21.8</td>
<td>21.9</td>
<td>-0.0</td>
<td>(0.1)</td>
<td>(0.0)</td>
<td>(0.1)</td>
</tr>
</tbody>
</table>

(Standard Errors are in parentheses)

Table 1: Indonesia Family Life Survey Sample Characteristics of Adults born before 1967 and interviewed in both 1993 and 1997
### Table 2: Difficulty Carrying Heavy Load (0 or 1): Effects of Haze

<table>
<thead>
<tr>
<th>Any Exposure</th>
<th>Males, ≥ 56 yrs</th>
<th>Females, ≥ 56 yrs</th>
<th>Males, 31–56 yrs</th>
<th>Females, 31–56 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Haze</td>
<td>No Haze</td>
<td>∆</td>
<td>Haze</td>
</tr>
<tr>
<td>1. 1997</td>
<td>0.425</td>
<td>0.290</td>
<td>0.134</td>
<td>0.674</td>
</tr>
<tr>
<td></td>
<td>(0.029)**</td>
<td>(0.014)**</td>
<td>(0.032)**</td>
<td>(0.027)**</td>
</tr>
<tr>
<td>2. 1993</td>
<td>0.178</td>
<td>0.108</td>
<td>0.070</td>
<td>0.359</td>
</tr>
<tr>
<td></td>
<td>(0.022)**</td>
<td>(0.010)**</td>
<td>(0.024)**</td>
<td>(0.028)**</td>
</tr>
<tr>
<td>3. 97 – 93</td>
<td>0.247</td>
<td>0.182</td>
<td>0.065</td>
<td>0.316</td>
</tr>
<tr>
<td></td>
<td>(0.037)**</td>
<td>(0.017)**</td>
<td>(0.040)**</td>
<td>(0.039)**</td>
</tr>
<tr>
<td>4. Adjusted D-in-D</td>
<td>0.069</td>
<td>0.048</td>
<td>0.012</td>
<td>0.060</td>
</tr>
<tr>
<td></td>
<td>(0.050)</td>
<td>(0.051)</td>
<td>(0.013)</td>
<td>(0.024)**</td>
</tr>
<tr>
<td>5. FE D-in-D</td>
<td>0.065</td>
<td>0.058</td>
<td>0.012</td>
<td>0.053</td>
</tr>
<tr>
<td></td>
<td>(0.032)**</td>
<td>(0.037)</td>
<td>(0.010)</td>
<td>(0.016)**</td>
</tr>
</tbody>
</table>

**Intensity of Exposure**

| 1. FE D-in-D, 75%     | 0.076           | 0.140             | 0.013            | 0.048             |                  |                  |                  |                  |                  |                  |                  |
|                       | (0.041)*        | (0.047)**         | (0.012)          | (0.020)**         |                  |                  |                  |                  |                  |                  |                  |
| 2. FE D-in-D, 90%     | 0.113           | 0.159             | 0.013            | 0.104             |                  |                  |                  |                  |                  |                  |                  |
|                       | (0.061)*        | (0.069)**         | (0.018)          | (0.030)**         |                  |                  |                  |                  |                  |                  |                  |

**Timing of Exposure**

| 1. D-in-D during 0-1  | 0.170           | 0.050             | 0.076            | 0.068             |                  |                  |                  |                  |                  |                  |                  |
|                       | (0.073)**       | (0.105)           | (0.024)**        | (0.038)*          |                  |                  |                  |                  |                  |                  |                  |
| 2. D-in-D during ≥ 1  | 0.002           | 0.136             | 0.004            | -0.027            |                  |                  |                  |                  |                  |                  |                  |
|                       | (0.056)         | (0.062)**         | (0.016)          | (0.027)           |                  |                  |                  |                  |                  |                  |                  |
| 3. D-in-D; exposure   | 0.073           | 0.121             | -0.003           | 0.092             |                  |                  |                  |                  |                  |                  |                  |
|                       | (0.051)         | (0.064)**         | (0.016)          | (0.027)**         |                  |                  |                  |                  |                  |                  |                  |
| 4. D-in-D; exposure   | 0.058           | -0.069            | 0.007            | 0.089             |                  |                  |                  |                  |                  |                  |                  |
|                       | (0.058)         | (0.061)           | (0.017)          | (0.028)**         |                  |                  |                  |                  |                  |                  |                  |

(Standard Errors are in parentheses)

* Coefficient is significant 10% level
** Coefficient is significant 5% level
### Table 3: Fair or Poor GHS (0 or 1): Effects of Haze

<table>
<thead>
<tr>
<th>Any Exposure</th>
<th>Males, ≥ 56 yrs</th>
<th>Females, ≥ 56 yrs</th>
<th>Males, 31–56 yrs</th>
<th>Females, 31–56 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Haze</td>
<td>No Haze</td>
<td>Δ</td>
<td>Haze</td>
</tr>
<tr>
<td>1. 1997</td>
<td>0.346</td>
<td>0.252</td>
<td>0.094</td>
<td>0.349</td>
</tr>
<tr>
<td>(0.028)**</td>
<td>(0.013)**</td>
<td>(0.031)**</td>
<td>(0.028)**</td>
<td>(0.013)**</td>
</tr>
<tr>
<td>2. 1993</td>
<td>0.346</td>
<td>0.156</td>
<td>0.190</td>
<td>0.382</td>
</tr>
<tr>
<td>(0.028)**</td>
<td>(0.011)**</td>
<td>(0.030)**</td>
<td>(0.028)**</td>
<td>(0.012)**</td>
</tr>
<tr>
<td>3. 97 – 93</td>
<td>0.000</td>
<td>0.096</td>
<td>-0.096</td>
<td>-0.033</td>
</tr>
<tr>
<td>(0.039)</td>
<td>(0.018)**</td>
<td>(0.043)**</td>
<td>(0.039)</td>
<td>(0.018)**</td>
</tr>
</tbody>
</table>

| 4. Adjusted D-in-D | -0.087 | -0.107 | -0.004 | -0.056 |
|                   | (0.051)** | (0.052)** | (0.020) | (0.023)** |

| 5. FE D-in-D | -0.096 | -0.111 | -0.002 | -0.058 |
|              | (0.034)** | (0.035)** | (0.015) | (0.016)** |

### Intensity of Exposure

| 1. FE D-in-D, 75% dose | -0.110 | -0.135 | 0.012 | -0.037 |
|                        | (0.044)** | (0.045)** | (0.019) | (0.020)** |
| 2. FE D-in-D, 90% dose | -0.126 | -0.214 | 0.009 | -0.040 |
|                        | (0.066)** | (0.065)** | (0.028) | (0.029)** |

### Timing of Exposure

| 1. D-in-D during 0-1 mth | -0.014 | 0.015 | 0.027 | 0.039 |
|                         | (0.079) | (0.099) | (0.036) | (0.037) |
| 2. D-in-D during ≥ 1 mth | -0.131 | -0.098 | 0.035 | -0.008 |
|                         | (0.060)** | (0.059)* | (0.024) | (0.026) |
| 3. D-in-D; exposure ended 0-1 mths ago | -0.119 | -0.196 | -0.033 | -0.112 |
|                         | (0.055)** | (0.061)** | (0.025) | (0.026)** |
| 4. D-in-D; exposure ended ≥ 1 mth ago | -0.076 | -0.085 | -0.030 | -0.103 |
|                         | (0.063) | (0.058) | (0.026) | (0.027)** |

(Standard Errors are in parentheses)

* Coefficient is significant 10% level
** Coefficient is significant 5% level
### Table 4: Cough (0 or 1): Effects of Haze

<table>
<thead>
<tr>
<th>Any Exposure</th>
<th>Males, ≥ 56 yrs</th>
<th>Females, ≥ 56 yrs</th>
<th>Males, 31–56 yrs</th>
<th>Females, 31–56 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Haze</td>
<td>No Haze</td>
<td>Δ</td>
<td>Haze</td>
</tr>
<tr>
<td>1. 1997</td>
<td>0.517</td>
<td>0.495</td>
<td>0.022</td>
<td>0.432</td>
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<tr>
<td></td>
<td>(0.029)**</td>
<td>(0.015)**</td>
<td>(0.033)</td>
<td>(0.029)**</td>
</tr>
<tr>
<td>2. 1993</td>
<td>0.404</td>
<td>0.317</td>
<td>0.087</td>
<td>0.395</td>
</tr>
<tr>
<td></td>
<td>(0.029)**</td>
<td>(0.014)**</td>
<td>(0.032)**</td>
<td>(0.028)**</td>
</tr>
<tr>
<td>3. 97 – 93</td>
<td>0.113</td>
<td>0.178</td>
<td>-0.065</td>
<td>0.037</td>
</tr>
<tr>
<td></td>
<td>(0.041)**</td>
<td>(0.021)**</td>
<td>(0.046)</td>
<td>(0.040)</td>
</tr>
<tr>
<td>4. Adjusted D-in-D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.067</td>
<td></td>
<td>-0.112</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
<td></td>
<td>(0.052)**</td>
<td></td>
</tr>
<tr>
<td>5. FE D-in-D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.064</td>
<td></td>
<td>-0.119</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.043)</td>
<td></td>
<td>(0.040)**</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intensity of Exposure</th>
<th>Males, ≥ 56 yrs</th>
<th>Females, ≥ 56 yrs</th>
<th>Males, 31–56 yrs</th>
<th>Females, 31–56 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. FE D-in-D, 75%</td>
<td>-0.002</td>
<td>-0.087</td>
<td>0.019</td>
<td>0.013</td>
</tr>
<tr>
<td>dose</td>
<td>(0.055)</td>
<td>(0.050)*</td>
<td>(0.032)</td>
<td>(0.030)</td>
</tr>
<tr>
<td>2. FE D-in-D, 90%</td>
<td>-0.017</td>
<td>-0.053</td>
<td>-0.021</td>
<td>0.035</td>
</tr>
<tr>
<td>dose</td>
<td>(0.082)</td>
<td>(0.074)</td>
<td>(0.048)</td>
<td>(0.043)</td>
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</table>

<table>
<thead>
<tr>
<th>Timing of Exposure</th>
<th>Males, ≥ 56 yrs</th>
<th>Females, ≥ 56 yrs</th>
<th>Males, 31–56 yrs</th>
<th>Females, 31–56 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. D-in-D during 0-1 mth exposure</td>
<td>0.019</td>
<td>-0.043</td>
<td>0.081</td>
<td>0.100</td>
</tr>
<tr>
<td></td>
<td>(0.099)</td>
<td>(0.112)</td>
<td>(0.063)</td>
<td>(0.054)*</td>
</tr>
<tr>
<td>2. D-in-D during ≥ 1 mth exposure</td>
<td>0.065</td>
<td>-0.029</td>
<td>0.051</td>
<td>-0.030</td>
</tr>
<tr>
<td></td>
<td>(0.076)</td>
<td>(0.066)</td>
<td>(0.041)</td>
<td>(0.038)</td>
</tr>
<tr>
<td>3. D-in-D; exposure ended 0-1 mths ago</td>
<td>-0.122</td>
<td>-0.181</td>
<td>-0.076</td>
<td>-0.057</td>
</tr>
<tr>
<td></td>
<td>(0.069)*</td>
<td>(0.068)**</td>
<td>(0.043)*</td>
<td>(0.038)</td>
</tr>
<tr>
<td>4. D-in-D; exposure ended ≥ 1 mth ago</td>
<td>-0.178</td>
<td>-0.173</td>
<td>-0.214</td>
<td>-0.111</td>
</tr>
<tr>
<td></td>
<td>(0.078)**</td>
<td>(0.065)**</td>
<td>(0.045)**</td>
<td>(0.040)**</td>
</tr>
</tbody>
</table>

(Standard Errors are in parentheses)

* Coefficient is significant 10% level

** Coefficient is significant 5% level