

**GLOBAL DEVELOPMENT AND ENVIRONMENT INSTITUTE**  
**WORKING PAPER No. 06-05**

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A comment on “Economy-wide estimates of the implications  
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September 2006

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# **Can Climate Change Save Lives? A comment on “Economy-wide estimates of the implications of climate change: Human health”**

**Frank Ackerman and Elizabeth Stanton<sup>1</sup>**

Key words: Impacts of climate change; human health; environmental policy

## **Abstract**

In a recent article in this journal, Francesco Bosello, Roberto Roson, and Richard Tol make the surprising prediction that the first stages of global warming will, on balance, save a large number of lives. Bosello *et al.* fail to substantiate this remarkable estimate, and they make multiple mistaken or misleading assumptions. They rely on research that identifies a simple empirical relationship between temperature and mortality, but ignores the countervailing effect of human adaptation to gradual changes in average temperature. While focusing on small changes in average temperatures, they ignore the important health impacts of extreme weather events such as heat waves, droughts, floods, and hurricanes. They extrapolate this pattern far beyond the level that is apparently supported by their principal sources, and introduce an arbitrary assumption that may bias the result toward finding benefits from warming.

## **Introduction**

Could a little bit of global warming be good for human health – and for the world economy? In their article, “Economy-wide estimates of the implications of climate change: Human health,” (*Ecological Economics* 58(3), June 25, 2006, pp.579-591), Francesco Bosello, Roberto Roson, and Richard Tol make the surprising prediction that the first stages of global warming will, on balance, save a large number of lives. Bosello *et al.* estimate that in the year 2050 a global mean temperature 1.03°C higher than today’s will result in 1,760,000 fewer deaths due to cardio-vascular disease, only partially offset by 910,000 additional deaths due to malaria, diarrheal diseases and respiratory illness. The net effect is 850,000 avoided deaths, a huge change in worldwide mortality in a single year.

The estimate of reduced mortality is only part of the ambitious calculation offered by Bosello *et al.* They seek to determine the direct and indirect economic impacts of changes in human health due to climate change, including productivity losses and increased health-care costs (which crowd out other uses) attributable to illness. They find that the direct costs – the monetized value of avoiding death or illness – outweigh the indirect costs. The dominant factor in the direct costs is the value of an avoided

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<sup>1</sup> Partially funded by a research grant from Friends of the Earth-UK.

premature death, which they set at 200 times the per capita income of each region (Bosello, Roson et al. 2006, pp.585). As a result, they estimate that the health effects of the first degree of warming will raise GDP slightly in the regions where mortality declines, namely all developed countries, the former Soviet bloc, China and India. GDP will go down, and mortality will increase, in the rest of the developing world.

This calculation can be criticized for its assumption that avoided deaths are worth more in wealthier regions, raising fundamental problems of equity. Monetization of death and illness is a controversial area, inevitably involving problematical hypotheses about the value of life (Ackerman and Heinzerling 2004). Here we raise a different objection: Despite the complexity and sophistication of the calculation, the bottom line economic impact is directly dependent on the estimate of a large net worldwide decrease in mortality from the first degree of warming.

In our view, Bosello et al. fail to substantiate this remarkable estimate, which depends on multiple mistaken or misleading assumptions.

The issue is important because potential benefits from near-term warming loom large, both in political decision-making about climate policy and in cost-benefit analyses. At a high discount rate, near-term benefits may outweigh enormous long-term damages when expressed in present value terms, offering an effective argument against vigorous emissions reduction efforts (Ackerman and Finlayson 2006). It is, therefore, crucial to be sure that any reported benefits of warming are reliable and well supported. This does not appear to be the case with the purported mortality reduction from the first degree of warming.

We have three criticisms of the analysis of mortality and temperature in Bosello et al.:

- They rely on research that identifies a simple empirical relationship between temperature and mortality, but ignores the countervailing effect of human adaptation to gradual changes in average temperature.
- While focusing on small changes in average temperatures, they ignore the important health impacts of extreme weather events such as heat waves, droughts, floods, and hurricanes.
- They extrapolate this pattern far beyond the level that is apparently supported by their principal sources, and introduce an arbitrary assumption that may bias the result toward finding benefits from warming.

### **The “minimum-mortality temperature”**

For estimates of cardio-vascular and respiratory deaths, Bosello et al. rely on a simple empirical relationship between temperature and mortality: studies in many areas have found that there is a daily temperature that minimizes mortality; more deaths tend to occur when the temperature is either higher or lower. That is, a graph of mortality versus

daily temperature is V-shaped, where the point of the V represents the minimum-mortality temperature.<sup>2</sup>

Bosello et al. represent at least a third generation in the studies of this relationship. In parts of their work, including the treatment of cardio-vascular and respiratory mortality, they adapt the results of Tol (2002), which in turn estimates worldwide impacts of temperature changes by extrapolating from research by Martens (1998). A fundamental problem with this line of research can be seen in the original study by Martens.

Martens performed a meta-analysis of eight earlier studies of the effects of small changes in temperature on cardio-vascular and respiratory mortality. These eight studies look at trends in mortality in a few areas around the world – most of them in cold climates – and report evidence of a “V-shaped” relationship between temperature and mortality. The point of this V – the minimum-mortality temperature – turns out to fall within the normal range of local temperatures, such that some months are generally below it and some above. In Martens’ model, as temperatures warm, fewer days will be spent below the minimum-mortality temperature and more will be spent above it. The left, or cold, side of the V is generally steeper than the right, or warm, side. That is, the reduction in mortality for 1° of warming in cold months is greater than the increase in mortality for 1° of warming in hot months. So as countries move 1° to the right across the V, the reductions in mortality in cold seasons will tend to outweigh the increases in warm seasons. This is the basis for the health benefit of warming in Martens and in those who have built upon his work.

The problem with this analysis is the implicit assumption that the position of the V, and in particular the minimum-mortality temperature, does not change. As Martens himself observes, people adapt to changing temperatures over time: “Acclimatisation may occur in several days, although complete acclimatisation may take up to several years.” (Martens 1998, pp.338) Indeed, the minimum-mortality temperature is not a constant, but varies widely around the world. Martens mentions that it varies from 16.5°C in Amsterdam to as much as 29°C in some studies for Taiwan. A later study of cities in the eastern U.S. found that the minimum-mortality temperature is 9°C higher in Miami than in Chicago (Curriero, Heiner et al. 2002).

Except in the very hottest parts of the world, it is reasonable to expect that people can adapt to gradual increases in average temperature. Since the minimum-mortality temperature varies widely around the world, and appears strongly correlated with average temperature, it seems likely that gradual warming will lead to gradual change in the minimum-mortality temperature as well. If this is the case, then the projections by Martens, and by those who have built on his work, are mistaken, and there will be little or no mortality change from the first degree of warming based on the V-shaped relationship between temperature and death rates. To uphold projections based on the V-shaped

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<sup>2</sup> We are not addressing the estimates of temperature impacts on vector-borne diseases and diarrhea, also presented in Bosello et al. These raise separate analytical issues, and, except in Africa, the impacts of other diseases are generally small in comparison to cardio-vascular and respiratory disease.

relationship, in the manner of Martens and his successors, it would at least be necessary to defend the hypothesis that the point of the V never moves, even as temperatures slowly rise. We have not found any such argument in the literature.

## Extreme weather

Models of climate change predict not only increases in average temperature, but also increased variability of weather conditions and more extreme weather events: more droughts and floods, more heat waves, more powerful storms (IPCC 2001). According to one study, recent climate change has made extreme heat waves two to four times more likely, and over the next 40 years, these extreme heat events will become 100 times more likely (Epstein and Mills 2005).

With moderate changes in temperature and precipitation – such as the average changes forecast for the next few decades – there are good opportunities for human populations to adapt. When it comes to cardio-vascular cold and heat stress, however, it isn't the average temperature that kills, it's temperature extremes. As our climate warms, the most important impact of temperature stress on mortality is unlikely to be avoided cold stress: human populations will adapt to new minimum-mortality temperatures and slightly warmer temperatures will have the effect of cold extremes causing cardio-vascular cold stress, especially in elderly or infirm people who have difficulty adjusting to rapid swings in temperature.

Average temperatures tell us nothing about the frequency of extreme divergences, hot or cold, from the local minimum-mortality temperature. Mounting evidence from climate scientists, however, indicates not only that recent temperatures have been more variable with more extremely hot temperatures (or big upward divergences from the minimum-mortality temperature), but that the variability of temperatures and the frequency of heat waves is likely to accelerate in the coming decades (IPCC 2001). While Bosello et al. (2006) ignore the importance of extreme weather to an analysis of climate change's future effects on mortality, Martens' original study took care to acknowledge it: “[C]limate change is likely to increase the frequency or severity of heat waves...although this study focused on the long-term influence of climate changes upon health risk...research on heat wave-related mortality suggests an increase in predominantly cardiorespiratory mortality and illness.”(Martens 1998, pp.342)

No single weather event can be unambiguously linked to climate change, since there have always been climate fluctuations and occasional extremes. But climate change is increasing the frequency and intensity of extreme weather, causing a sharp upswing in weather-related deaths (Hales, Edwards et al. 2003). As many as 50,000 people died in the 2003 heat wave in Europe (Brücker 2005). This was an unusually high toll, in part reflecting a lack of preparation which has since been corrected. But extreme weather events routinely cause large numbers of deaths. The U.S. suffered 1,800 deaths from

Hurricane Katrina in 2005,<sup>3</sup> and more than 700 fatalities from a 1995 heat wave in Chicago (Klinenberg 2002). The heat waves of summer 2006 killed at least 1,000 in the Netherlands and 200 in the US.<sup>4</sup> Heat waves in India, in which temperatures sometimes reach 49°C, have killed more than a thousand people on several occasions in recent years (De, Dube et al. 2005).

Bosello et al. base their model on small changes in average temperature, not extreme weather events. Following Martens, they use average monthly temperatures instead of the daily temperature range, as employed by other researchers on this topic (Campbell-Lendrum, Corvalan et al. 2003, pp.142). Average monthly temperatures have little value in predicting whether or not the temperature on a given day will diverge very far from the minimum-mortality temperature and therefore cause cold or heat stress. It is the extremes in local temperature variation that are of concern in predicting changes in cardio-vascular stress, not averages over the course of a month.

### **Unexplained differences**

Even if one accepts that the early stages of warming will lead to a reduction in mortality, based on the V-shaped relationship, the magnitude of the effect is quite different in Martens (1998), Tol (2002), and Bosello et al. (2006) – and generally much larger in Bosello et al. than in the earlier studies. The problem is particularly severe for China and India, but affects the worldwide estimates of Bosello et al.

Martens does not produce worldwide estimates, but projects the effect on cardio-vascular and respiratory mortality from a 1.2°C warming in 20 major cities located in 17 countries. Assuming that the cities are typical of the countries as a whole, he offers projections for the 17 countries. For China, where his projection is based on data for Beijing and Guangzhou, he estimates a mortality reduction of 4 per 100,000 population. For China's population of roughly 1.25 billion, this implies 50,000 avoided deaths from 1.2°C warming. Likewise, we calculate that his estimate implies roughly 60,000 avoided deaths in the U.S., and 10,000 avoided deaths in Japan.<sup>5</sup>

Tol extrapolates Martens' forecasts to the rest of the world, to obtain global estimates. As shown in Table 1, his estimates for changes to cardio-vascular mortality from a degree of warming in OECD-America (excluding Mexico) and OECD-Pacific (excluding South Korea) are roughly in line with Martens' estimates for the U.S. and Japan, respectively. However, his projection for “centrally planned Asia,” which is almost entirely China, is much higher than Martens' China estimate. Since Martens

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<sup>3</sup> As of August 2, 2006, the Louisiana Department of Health and Hospitals reported 1,464 deaths in Louisiana, and 346 deaths in other states, due to Hurricane Katrina.

<http://www.dhh.louisiana.gov/offices/page.asp?ID=192&Detail=5248>

<sup>4</sup> Heidi Cullen, “Heat Wave Death Toll Numbers Trickling In,”

[http://www.weather.com/blog/weather/8\\_10348.html](http://www.weather.com/blog/weather/8_10348.html)

<sup>5</sup> We have rounded off all mortality figures to the nearest 10,000 in order to avoid spurious precision and to focus on the overall magnitudes of these projections.

modeled a larger temperature change ( $1.2^{\circ}\text{C}$  versus  $1.0^{\circ}\text{C}$ ), Tol's China estimate is roughly twice as large as Martens' when adjusted to a comparable amount of warming.

**Table 1. Cardio-vascular mortality changes from  $1.0 - 1.2^{\circ}\text{C}$  of warming**

Martens	China	-50,000
Tol	centrally planned Asia	-80,000
Martens	US	-60,000
Tol	OECD-America	-50,000
Bosello et al.	US	-170,000
Martens	Japan	-10,000
Tol	OECD-Pacific	-10,000
Bosello et al.	Japan	-70,000

Source: Martens 1998; Tol 2002; Bosello et al. 2006; Martens' estimates are our calculations from Martens' rates per 100,000 population.

The difference between Martens' and Tol's results might reflect Tol's surprising assumption that cardio-vascular heat-related deaths occur only in urban areas, whereas cold-related deaths occur in both rural and urban areas (Tol 2002, pp.60). The asymmetric treatment of rural areas has little effect on heavily urbanized societies such as the U.S. and Japan, but has a major impact on China with its huge rural population. The assumption of no heat-related cardio-vascular deaths in rural areas is introduced by Tol without citation or justification, and appears to bias his results toward finding net benefits from warming. Tol's assumption might be inspired by the more limited, well-known conclusion that the same regional temperature can be more painful in urban areas, due to urban heat island effects. The evidence on India's frequent heat waves, however, should be studied carefully before assuming that rural death rates are so little affected by heat (De, Dube et al. 2005).

The estimates by Bosello et al. for the U.S. and Japan, also shown in Table 1, are sharply higher than either Martens or Tol. One difference is that Bosello et al. are modeling impacts in 2050, when the world's population will be larger and a greater proportion of the population will be elderly and, therefore, more susceptible to cold and heat stress. Tol, on the other, is modeling the effect of a static temperature increase on today's world. This is important to the results of these models because almost all temperature related mortality – 80 to 90 percent in most countries – is attributable to people 65 and over, and this group is expected to more than double in size by 2050 (Martens 1998; UN-DESA 2004).

The difference between the estimates by Tol and Bosello et al. is explored further in Table 2, highlighting the puzzling nature of the estimates for China and India. Tol's

“south and southeast Asia” region encompasses more than India, of course, but his two Asian regions, shown in the table, provide an approximate match to the Bosello et al. “China and India” region. For Tol, the two Asian regions together experience 130,000 fewer cardio-vascular deaths per year, per degree of warming, offset by an increase of 200,000 in respiratory deaths. For Bosello et al., China and India experience 810,000 fewer cardio-vascular deaths, but only 90,000 additional respiratory deaths. The coming demographic shift in India and China explains part, but not all, of the difference between the estimates by Tol and Bosello et al.: India and China’s joint over-65 population is expected to quadruple, but Bosello et al. estimate cardio-vascular mortality six times that of Tol. In addition, if an aging population is meant to explain the difference between the results reported by Tol and Bosello et al., we would expect the change in respiratory mortality to be larger, not smaller, in Bosello et al. (see Table 2).

**Table 2. Change in mortality in China and India per degree of warming**

		cardio-vascular	respiratory
Tol	centrally planned Asia	-80,000	60,000
	South and SE Asia	-50,000	140,000
	subtotal, 2 Asia groups	-130,000	200,000
Bosello et al.	China and India	-810,000	90,000

Source: Tol 2002; Bosello et al. 2006.

Using Martens temperature-related change in deaths per 100,000 for the population under and over 65, we extrapolated to 2050 using the appropriate size and shares of the under- and over-65 population (see Table 3).<sup>6</sup> The estimated reduction in mortality using this method was 400,000 in India and China, 130,000 in the US, and 30,000 in Japan – still much smaller than the Bosello et al. results.

<sup>6</sup> We used demographic projections from the UN-DESA’s World Population Prospects database. For India, Martens’ deaths per 100,000 in China were applied. Since Martens finds generally lower rates in tropical countries, this is likely to be an overestimate for India. For China’s mortality in the under-65 group – absent from Martens’ results – we inferred an estimate of 1 death per 100,000 population, which appears roughly consistent with his other data.

**Table 3: Changes in temperature-related mortality from 1.0 – 1.2°C of warming, with demographic transition**

Martens (extrapolated to 2050) Bosello et al.	China and India China and India	-400,000 -810,000
Martens (extrapolated to 2050) Bosello et al.	US US	-130,000 -170,000
Martens (extrapolated to 2050) Bosello et al.	Japan Japan	-30,000 -70,000

Source: Martens 1998; Tol 2002; Bosello et al. 2006; Martens' estimates are our calculations from Martens' rates per 100,000 population.

One further innovation can be seen in the more recent study. Bosello et al. mention, in a single sentence unsupported by citation or evidence, that they assume there are no heat-related deaths in rural areas (pp.583). This suggests that they have extended Tol's asymmetric treatment of rural areas to respiratory deaths – assuming that the rural population suffers only cold-related, but never heat-related, respiratory as well as cardiovascular deaths. Since China and India include a large fraction of the world's rural population, the effects would show up most markedly in these countries, reducing the number of heat-related respiratory deaths included and increasing the estimates of avoided deaths reported by Bosello et al. As with Tol's more limited version of the same assumption, this introduces a bias toward finding net benefits of warming – and needs to be tested against empirical evidence on heat waves in countries such as India.

To summarize this intricate comparison, Tol appears to be consistent with Martens on developed country estimates, but has roughly doubled Martens' estimate for China, perhaps due to his unsupported assumption of no heat-related cardio-vascular deaths in rural areas. Bosello et al. have increased Tol's estimates by a factor of almost four for cardio-vascular deaths avoided by warming for most of the world, and by a factor of six in China and India, a difference that can only partially be explained by demographic transition. At the same time, they have sharply reduced Tol's estimate of the increased respiratory deaths in China and India due to warming, perhaps as a result of extending Tol's unsupported assumption about the absence of heat-related rural deaths to respiratory diseases. Quite apart from our skepticism about the validity of Martens' assumption of a constant minimum-mortality temperature discussed in the previous sections, we do not understand the escalation of the estimated impacts from one study to the next.

## Conclusions

The model presented by Bosello et al. predicts that the number of lives saved by climate change will be far greater than the number of lives lost. This conclusion seems to rely heavily on three faulty assumptions. First, human populations are assumed to be

unable to adapt to new climatic conditions, continuing to respond as they do today even as average temperatures gradually climb. Second, the focus on slow changes in average temperatures ignores the important issue of mortality and other impacts of extreme weather events related to climate change. Third, the incidence of increased heat-related cardio-vascular and respiratory mortality is restricted to urban areas while decreases in cold-related cardio-vascular mortality are assumed to occur in both urban and rural areas. Even with these assumptions, however, we could not reproduce the huge estimates made by Bosello et al.

Like other predictions of benefits to be derived from climate change, estimates of reduced mortality from warming have an importance outside of the scholarly realm. Policy-makers around the world respond to such predictions when making decisions regarding the type and extent of institutions created to combat climate change; predictions of large benefits from warming inevitably suggest that the problem is not so urgent to address. A model that more accurately predicts the likely effects of climate change on mortality is essential to the formulation of climate and energy policies in countries around the world and to the future of international agreements regarding limits to the production of greenhouse gases. False optimism may have dangerous and long-lasting consequences.

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