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Transboundary health impacts of transported global air pollution and international trade

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Abstract

Millions of people die every year from diseases caused by exposure to outdoor air pollution[1,2,3,4,5]. Some studies have estimated premature mortality related to local sources of air pollution[6,7], but local air quality can also be affected by atmospheric transport of pollution from distant sources[8,9,10,11,12,13,14,15,16,17,18]. International trade is contributing to the globalization of emission and pollution as a result of the production of goods (and their associated emissions) in one region for consumption in another region[14,19,20,21,22]. The effects of international trade on air pollutant emissions[23], air quality[14] and health[24] have been investigated regionally, but a combined, global assessment of the health impacts related to international trade and the transport of atmospheric air pollution is lacking. Here we combine four global models to estimate premature mortality caused by fine particulate matter ($PM_{2.5}$) pollution as a result of atmospheric transport and the production and consumption of goods and services in different world regions. We find that, of the 3.45 million premature deaths related to $PM_{2.5}$ pollution in 2007 worldwide,

about 12 per cent (411,100 deaths) were related to air pollutants emitted in a region of the world other than that in which the death occurred, and about 22 per cent (762,400 deaths) were associated with goods and services produced in one region for consumption in another. For example, $PM_{2.5}$ pollution produced in China in 2007 is linked to more than 64,800 premature deaths in regions other than China, including more than 3,100 premature deaths in western Europe and the USA; on the other hand, consumption in western Europe and the USA is linked to more than 108,600 premature deaths in China. Our results reveal that the transboundary health impacts of $PM_{2.5}$ pollution associated with international trade are greater than those associated with long-distance atmospheric pollutant transport.

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Contributions

Q.Z., J.L. and K.H. conceived the study. Q.Z. led the study. Z.Lu and D.G.S. provided emissions data. M.B., A.v.D. and R.V.M. provided $PM_{2.5}$ exposure data. D.T., H.Z., T.F. and D.G. calculated emissions. G.G. conducted GEOS-Chem simulations. X.J. conducted estimates of health impacts. Q.Z., X.J., S.J.D., G.G. and J.L. interpreted the data. Q.Z., X.J., D.T., S.J.D., H.Z. and G.G. wrote the paper with input from all co-authors.

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Ethics declarations

Competing interests

The authors declare no competing financial interests.

Additional information

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Extended data figures and tables

Extended Data Figure 1 Definition of the 13 world regions used here.

Extended Data Figure 2 Global distribution of premature mortality in 2007 due to production-related $PM_{2.5}$ air pollution.

a–**i**, Maps show the number of deaths related to air pollution produced (that is, emitted) in the rest of east Asia (**a**), the rest of Asia (**b**), Russia (**c**), eastern Europe (**d**), Canada (**e**), the Middle East and north Africa (**f**), Latin America (**g**), sub-Saharan Africa (**h**) and the rest of the world (**i**).

Extended Data Figure 3 Global distribution of premature mortality in 2007 due to consumption-related $PM_{2.5}$ air pollution.

a–**i**, Maps show the number of deaths related to goods and services consumed in the rest of east Asia (**a**), the rest of Asia (**b**), Russia (**c**), eastern Europe (**d**), Canada (**e**), the Middle East and north Africa (**f**), Latin America (**g**), sub-Saharan Africa (**h**) and the rest of the world (**i**).

Extended Data Figure 4 Differences in worldwide premature mortality in 2007 between production- and consumption-related $PM_{2.5}$ air pollution.

a–**d**, Maps show the number of deaths worldwide related to consumption in the given region minus the number of deaths worldwide related to production in that region, for China (**a**), western Europe (**b**), the USA (**c**) and India (**d**).

Extended Data Figure 5 Uncertainty ranges.

a, **b**, Uncertainties relating to Fig. 2. The ranges at the top of each panel represent the 95% CI for the number of attributable deaths in the region indicated by the column. The ranges at the right of each panel represent the 95% CI for the total number of worldwide deaths caused by pollution produced in the region indicated by the row (**a**) or related to the consumption of products in that region that are produced there or elsewhere (**b**). Each cell in the grid shows the standard deviation

of the fraction of deaths (%); darker shading in the off-diagonal cells highlights larger standard deviations.

Source data

Extended Data Figure 6 Summary of global premature mortality per capita due to transported $PM_{2.5}$ pollution and traded products.

a, **e**, Worldwide mortality due to pollution produced (that is, emitted) in each region (**a**) or related to products consumed in each region (**e**). **b**, **f**, Mortality in each region due to pollution produced in that region (**b**) or related to products consumed in that region (**f**). **c**, **g**, Mortality in all other regions due to pollution produced in each region (**c**) or related to products consumed in each region (**g**). **d**, **h**, Mortality in each region due to pollution produced elsewhere (**d**) or related to products consumed elsewhere (**h**). All data are normalized according to regional populations (reported as deaths per one million people). Error bars denote 95% CIs, determined by uncertainties in the GEOS-Chem-simulated fractional contribution of $PM_{2.5}$ exposure and in the total $PM_{2.5}$-related mortality.

Source data

Extended Data Figure 7 Methodology framework to access $PM_{2.5}$ mortality from production and consumption for each region.

Extended Data Table 1 Premature mortality related to $PM_{2.5}$ air pollution in 2007

Supplementary information

Supplementary Information

This file contains Supplementary Text and Data, additional references, Supplementary Figures 1-10, Supplementary Tables 5, 7 and 8 (see separate excel files for Supplementary Tables 1-4 and 6). (PDF 3234 kb)

Supplementary Table 1

This file contains country lists in the alternate emission inventory and the GTAP model, and the corresponding classification of 13 regions. (XLSX 18 kb)

Supplementary Table 2

This file contains the sources category of the emission inventory in this study. (XLSX 14 kb)

Supplementary Table 3

This file contains mapping structure from emission inventory to GTAP sectors. (XLSX 22 kb)

Supplementary Table 4

This file contains mapping structure from EDGAR sectors to GTAP sectors. (XLSX 13 kb)

Supplementary Table 6

This file contains camparison of transboundary transport of $PM^{2.5}$ with the HTAP study. (XLSX 12 kb)

PowerPoint slides

PowerPoint slide for Fig. 1
PowerPoint slide for Fig. 2
PowerPoint slide for Fig. 3
PowerPoint slide for Fig. 4

Source data

Source data to Fig. 1
Source data to Fig. 2
Source data to Fig. 3
Source data to Extended Data Fig. 4
Source data to Extended Data Fig. 5

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