Epidemiology without borders: an anational view of global health

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Background: Most analyses of global health use country as a unit of observation, not least because countries are intrinsic to health services and to many international organisations. However, this can mask geographical influences on population health, which do not respect political boundaries.

Methods: A global anational database was constructed with one degree cells of latitude and longitude, and used to calculate densities for population and key health indicators. These data were aggregated into 240 15° ansectors, 171 of which were populated. Differences in ansector rank orders between population density and health outcomes (infant, maternal and HIV-related deaths and income) were calculated and mapped as quintiles.

Findings: Individual ansectors contained parts of 1–21 countries. Mapping by ansector showed that the four outcomes analysed were strongly geographically correlated. Sub-Saharan Africa was consistently disadvantaged in terms of health outcomes, while the Indian sub-continent was at an advantage in terms of HIV mortality, despite poverty.

Interpretation: Although in most cases it makes sense to analyse health on a national basis, these findings highlight the often unquestioned assumptions involved in doing so. Even if global patterns of health do not turn out so differently when analysed anationally, some major effects on health, such as climate change, are not nationally based, and should not necessarily be nationally analysed. Progress towards Millennium Development Goals must be evaluated on a population basis, rather than by counting countries achieving targets.

Data files are available in Excel format and attached as separate files to this paper (see Supplementary files under Reading Tools online).

Keywords: epidemiology; global health; national borders; geography; mortality; economics

Epidemiological analyses at the global level are almost always organised by country, or by regional groupings of countries. There are good reasons for this: in particular, health and social services are generally organised at country level and so any consideration of health service impact probably needs to consider country as a factor. In addition, the United Nations and its specialised agencies (such as the World Health Organisation) are essentially membership organisations predicated on countries, and so many of their outputs are naturally organised at country level (1, 2).

From an epidemiological viewpoint, the concept of ‘country’ as a unit of observation presents some problems, however. There is a massive range from the largest, such as China and India, to small island countries and tiny nation states, both in terms of physical size and population. Within some larger countries, such as the USA, there are sub-units (such as California) which are much larger political and economic units than many other nations. In some cases, for example in on-going territorial disputes, the definition of certain countries may be uncertain, and there can be major changes over time – as for example in the break-up of the former Soviet Union into a number of independent countries. National boundaries often ignore natural delineations between ethnic groups and differences in lifestyle, and environmental phenomena such as changes in climate and natural disasters do not respect political boundaries. For all of these reasons, counting numbers of countries can be very misleading.

Epidemiological analyses generally use particular units of observation in two distinct ways: either as key parameters by which to classify outcomes (this is the usual way in which country is used in global analyses) or as factors which are not themselves of prime importance but need to be used within analyses of other parameters.
Country is not normally used in the latter sense, but this paper attempts to give a glimpse of the health of the world’s people on a geographical basis, irrespective of national boundaries. The aim in doing this is partly to provide proof of principle for this approach, but also to foster thinking and debate around the influence of nationality on global health.

Methods
Since so many health data are collected and organised on a country basis, developing a geographical picture of the world’s health is not straightforward. Population and health data exist globally on an inequitable basis, with quality and completeness often determined by economic conditions. In these analyses, the starting point was a global database of land area and population (in 2005) organised on a one degree latitude and longitude grid (3). Unfortunately there is no such geographically detailed global database for population health, and so country-based figures for key parameters such as mortality rates (4) had to be applied to the populations within the one degree cells. Human habitation is found within the latitudinal range 84°N–58°S, by 360° of longitude, giving a grid with 51,480 one degree cells. Near the equator, one degree of latitude or longitude corresponds to approximately 100 km, although because of the spherical surface of the earth there is no fixed relationship between latitude, longitude and distance. Of the 51,480 cells, 32,979 (64%) contain no land and a further 492 are unpopulated. Of the 18,009 populated cells, 2,165 contain parts of more than one country, and these were handled on a pro-rata area basis where national parameters were involved.

As a framework for considering global health anationally, a 15° latitude and longitude grid has been used, containing 240 anational sectors (which are referred to as ‘ancectors’). These are designated east to west by the letters A to X and north to south by the digits 0–9, as shown in Fig. 1. Data on population density and country-based key parameter data applied to populations in the 18,009 populated one degree cells were aggregated into these 240 anectors. Three anctors contained either less than five people or total land masses of 30 km² or less (out of a potential maximum of nearly 3 million km²) and these small areas were incorporated into adjacent anectors, since they contained too little information to be used meaningfully alone. Consequently there remained 171 (71%) anctors which were deemed to be populated; 67 of these only contained territory of a single country while the maximum number of countries in any anctor was 21.

Populated anctors were ranked by population density (people per land area) and other health-related outcomes (infant deaths, maternal deaths, HIV-related deaths and income) were also calculated per land area and similarly ranked by anctor. Differences in rank order between each outcome and population density were calculated for each anctor, and these rank order differences divided into quintiles to categorise anctor outcomes.

The databases used in these analyses were handled using Microsoft FoxPro, and the open-access Diva

![Fig. 1. Population density (quintiles) by anctor.](image-url)
GIS system (www.diva-gis.org) was used for mapping. Supplementary files (in Microsoft Excel format) accompany this paper, which contain the anational data at the one degree cell level (onedeg.xls) and the ansector level (ansector.xls), respectively.

Results
Table 1 shows the minimum, median and maximum values for a range of parameters by country and for populated ansectors. Population density was used as the underlying basis for subsequent analyses, calculated as the population divided by the land area within each one degree cell or ansector. Fig. 1 shows the overall distribution of population density, shaded by quintiles, for populated ansectors. Population density by ansector varied from very low values, less than 1/1,000 km\(^2\) in parts of the arctic north, through 13 km\(^{-2}\) as a median value and reaching 406 km\(^{-2}\) in ansector R5, which includes southern India and Sri Lanka.

Four key health indicators have been chosen as examples for these analyses, on the basis both of data availability and their relevance to global health and the Millennium Development Goals (MDGs). These are infant deaths (deaths under one year of age); maternal deaths; HIV-related deaths and income. The minimum, median and maximum values of the geographic densities for each of these are also shown by country and by ansector in Table 1.

Figs. 2–5 show the ansector rank order differences between each of these four health indicators and the rank order for population density, by quintiles. For each indicator, the quintile of ansectors in which the indicator rank order represents the greatest disadvantage in terms of outcome density versus population density is coloured deep red through pale red, yellow and pale green, to the opposite quintile which represents the greatest advantage and is coloured in deep green. Thus, for each indicator, the figures give a clear visual impression on a global basis of advantage (green) and disadvantage (red), against a reference of population rather than nationality.

Having characterised population geographically in the database, it was also possible to consider the differences between the polar (>67° latitude), temperate (23°–67° latitude) and tropical (<23° latitude) zones of the world. Table 2 shows population density and rates for the key indicators by zone.

Discussion
Although there is considerable diversity between ansectors in terms of how indicators are distributed, as is also the case between countries, the geographical approach taken here means that at least to some extent the national influences on population parameters are reduced. The mapped representations of density by ansector also have the advantage that in areas of the world where there is little land mass, for example among the Pacific islands, meaningful levels for health indicators can be visualised, which would otherwise be invisible on a world map. The approximately similar total numbers of countries and ansectors is convenient in that both have some equivalence in magnitude. The annational approach tends to dilute the disproportionate effects of the largest countries: while China and India together account for 37% of the world’s population and Russia and Canada for 18% of the land area, the two most populated ansectors contain just 20% of the world’s population and the two largest just 4% of the land area.

Table 1. Minimum, median and maximum values for key characteristics by country and ansector

| Characteristic       | Country (n = 217) | Ansector (n = 171) |
|----------------------|------------------|--------------------|
| Population           | Minimum 1,418 (Tokelau) | 12 (J2) |
|                      | Median 5,343,227 (Sierra Leone) | 2,260,429 (M1) |
|                      | Maximum 1,206,273,798 (China) | 583,168,321 (T3) |
| Land area (km\(^2\)) | Minimum 15.2 (Tokelau) | 63.6 (D7) |
|                      | Median 91,257 (Portugal) | 472,358 (E4) |
|                      | Maximum 16,681,771 (Russia) | 2,747,943 (H6) |
| Population density (km\(^{-2}\)) | Minimum 1.8 (Mongolia) | <0.01 (Many) |
|                      | Median 73.1 (Georgia) | 12.8 (N5) |
|                      | Maximum 1,792 (Maldives) | 405.5 (R5) |
| Infant deaths (1,000 km\(^{-2}\)) | Minimum 0.1 (Iceland) | <0.1 (Many) |
|                      | Median 37 (Tokelau) | 4.0 (D3) |
|                      | Maximum 1,774 (Maldives) | 466.5 (R5) |
| Maternal deaths (1,000 km\(^{-2}\)) | Minimum <0.001 (Australia) | <0.001 (Many) |
|                      | Median 1.3 (Mayotte) | 0.11 (G3) |
|                      | Maximum 155 (Rwanda) | 50.0 (K5) |
| HIV/AIDS deaths (1,000 km\(^{-2}\)) | Minimum 0.2 (Mongolia) | <0.001 (Many) |
|                      | Median 12.4 (Taiwan) | 1.2 (H7) |
|                      | Maximum 1,234 (Barbados) | 1,024 (O8) |
| Income ($km\(^{-2}\)) | Minimum 1,271 (Mongolia) | 9 (F0) |
|                      | Median 144,089 (Ecuador) | 45,149 (X6) |
|                      | Maximum 22,949,000 (Singapore) | 7,542,716 (V3) |
Comparing the four indicators mapped as examples, namely infant deaths, maternal deaths, HIV-related deaths and income, the most striking finding is the close geographic correlation between the indicators. Sub-Saharan Africa consistently shows as the area of greatest disadvantage, and, although this is perhaps not surprising, it conveys a somewhat stronger message than national approaches, which tend to emphasise differences between neighbouring countries and sometimes imply an unhelpful sense of blame towards particular nations.

Fig. 2. Density of infant deaths in relation to population: ansector rank order differences by quintile.

Fig. 3. Density of maternal deaths in relation to population: ansector rank order differences by quintile.
fact that poverty is closely mapped to three very different mortality outcomes emphasises that achieving better overall health for the world’s people is probably more closely related to economics than to medical advances.

At a more detailed level, important differences in geographical distribution between the indicators can be seen. Disadvantages in infant and maternal deaths (Fig. 2 and Fig. 3) are very similarly distributed, but HIV-related

Fig. 4. Density of HIV-related deaths in relation to population: ansector rank order differences by quintile.

Fig. 5. Density of income in relation to population: ansector rank order differences by quintile.
deaths follow a very different pattern within the Indian sub-continent (Fig. 4) despite economic disadvantages (Fig. 5) in that area. South America has greater disadvantages in mortality than in economic terms.

Splitting population into the conventional polar, temperate and tropical zones reveals some surprising results. The population in the arctic region emerges with the highest economic status, since that part of the world does not contain any seriously impoverished populations. This may be a misleading result in that many of the relatively few people living at high latitudes may be part of minority groups and possibly locally disadvantaged compared with the general populations of the countries involved (5). South Africa exerts a disproportionate influence on the southern temperate region, having a relatively large population, with high fertility and mortality rates compared with other countries in those latitudes. Nevertheless, on a global basis it is clear from Table 2 that people living in the tropics continue to have huge disadvantages in terms of health and economic status, even if the impact of classic ‘tropical diseases’ may be declining (6).

From a methodological perspective, these results are intended to be more a proof of principle for the anational approach, rather than a systematic analysis. The main obstacle relating to the compilation of these databases was the lack of detailed geographic data available on health outcomes, necessitating the incorporation of national estimates for some parameters. Although in principle it could have been possible to use sub-national data for countries where such data exist – and this would potentially include some of the geographically largest nations – there would be a risk of introducing some degree of bias between richer countries which typically have sub-national data and poorer ones which may not. Doing so would also mean that no single global data source could have been used for key parameters, and, at a technical level, the CIESIN population density database did not contain sub-national boundary data that would also be needed. Nevertheless, since most of the populated ancestors contain parts of more than one country, the effects of national-level data tend to be reduced. There may however be some erroneous effects, such as the income level for the arctic region, as discussed above.

There is currently considerable interest and effort in tracking the MDGs, which in turn involves a complex mixture of national and population-based considerations of the underlying targets. While much of this work is being undertaken in a very rigorous way (7), there is considerable likelihood as we move towards 2015 of seeing summaries and headlines relating to the number of countries reaching MDG targets (8). However, it is clear from the anational analyses that any consideration of numbers of countries as outcome measures for MDGs could be very misleading.

The increasingly important effects of climate change on health (9), which are necessarily geographically rather than nationally determined, will also require epidemiological approaches that do not confuse location with political boundaries.

### Table 2. Population health indicators by geographical zone

|                      | Arctic | Northern temperate | Northern tropics | Southern tropics | Southern temperate |
|----------------------|--------|--------------------|------------------|------------------|--------------------|
| Land area 1,000 km²  | 5,693  | 63,921             | 25,880           | 23,780           | 11,436             |
| Population 1,000     | 1,724  | 3,340,313          | 1,687,087        | 565,503          | 162,086            |
| Population density km⁻² | 0.3    | 52.3               | 65.2             | 23.8             | 14.2               |
| Infant deaths /1,000 | 0.120  | 0.585              | 1.766            | 2.211            | 0.785              |
| MMRᵃ/100,000         | 21     | 206                | 567              | 651              | 234                |
| HIV deaths/1,000     | 0.10   | 0.07               | 0.47             | 1.82             | 2.46               |
| GNI $ per capita     | 18,935 | 10,740             | 1,475            | 1,531            | 7,985              |

ᵃMaternal mortality ratio: maternal deaths per 100,000 live births.

### Conclusion

Although there is no question that most global health analyses will and should continue to be country-based, very often reflecting health service factors in addition to purely population-based observations, the possibility of looking at population health separately from the dominant effects of nationality is attractive. As would be expected, global patterns of health indicators in these anational analyses are broadly similar to nationally based results. To some extent, this suggests that the conventional country-based approach to global health may be reasonably robust. However, the anational approach raises questions around the often overlooked issues of how our understandings of the world’s people and their health are influenced by political systems, even though health also depends to a large extent on geography. Efforts to evaluate progress towards the MDGs and other indicators need to be clearly thought about and portrayed in terms that go beyond documenting national targets. Current interest in the effects of climate change on health, which are largely geographically determined,
may mean that more geographically based methods are appropriate. Raising questions about the effects of nationality on population health, and the ways in which considerations of country are often not made epidemiologically explicit, is important.

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