A similar pattern of tuberculosis mortality decline in the United States and Thailand, before HIV

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Abstract

We compare the decline of tuberculosis mortality in Thailand and in the United States. At present, Thailand is a high tuberculosis mortality country, and the United States has low mortality for this cause. However, adjusting the American data back by 39 years reveals a strikingly similar temporal pattern of tuberculosis mortality decline for the two countries. The choice of reference date for comparison is data-based. This suggests that the decline of infectious disease mortality is an auto-catalytic process that takes similar contours regardless of the

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socio-ecological setting. Nonetheless, it is quite surprising just how similar the mortality decline is for these two countries. To the extent to which there is divergence, it is due to the HIV/AIDS pandemic in Thailand, which has no analogue in the comparable point of tuberculosis mortality decline in the United States. This paper also considers the great gender differences in tuberculosis mortality decline in both countries.

1 Introduction

Tuberculosis was a signature infectious disease of the high-mortality past of the now fully-industrialized countries (Long, 1948; McKeown, 1976; Preston and van de Walle, 1978). Tuberculosis mortality, and its decline, was especially important in society because unlike other major contemporary causes of death (such as smallpox, measles, diarrhoeal disease, and pneumonia), it killed adults, not children or the elderly. In developing economies today, tuberculosis continues to be a major source of morbidity and mortalityDye and Williams (2010).

We present a case study in comparative national historical epidemiology, by examining the decline of tuberculosis mortality in the United States and Thailand. We analyze all the available data for Thailand (1958–2008), and the most-comparable 51-year data window for the United States. Despite the obvious differences between the two countires, we find that they experienced remarkably similar declines in tuberculosis mortality. The biggest single difference between the experience of the two countries is the HIV/AIDS

pandemic in Thailand, which temporarily reversed the decline of tuberculosis mortality.

2 Striking similarities in tuberculosis decline

For the US, data on TB mortality are available from 1900 to the present, and for Thailand, from 1958 to the present (data for 51 years). Before 1933, US data refer to the death registration area of the United States. The Thai vital registration data, adjusted for under-reporting, have been previously validated (Hill et al. 2007), but cannot be considered complete before XXXX.

The first thing is to identify which subset of the American data most closely matches the Thai data. That is to say, which period of TB decline in the US most closely corresponds to the 51 years of Thai data that are available. Using least squares, we determined the year of best fit by comparing the 51 years of Thai data to 51-year subsets of American data, using all possible starting points in the US data. The fitting was done on the age-standardized death rate on log scale, which means that the declines of TB mortality are conceptualized in terms of proportional, rather than absolute, change. Each sex was considered separately, although a single match-date, minimizing squared error over both sexes, was chosen. The fitting exercise indicates that the 51 years of data from the United States that most closely match the Thai data series is 1919–69, and the date is very robust to choice of which standard population is used. Even when rather different population standards are used, the date match changes only ± 1 year. One way to

think about the date of best fit is that Thailand's decline of TB mortality lags that of the United States by 39 years.

Figure 1 illustrates this pattern. This presents the age-standardized death rate for pulmonary tuberculosis (Thailand) and for tuberculosis (all forms) for the United States, for each sex separately. Historical data are not available for pulmonary-only TB death rates for the US, but this form of TB dominates mortality. While it would be preferable to compare pulmonary with pulmonary, using all forms of TB for the US does not essentially alter the comparison. Each data series in figure 1 is plotted on its own horizontal (time) axis, with 1919 for the US (upper horizontal axis) corresponding to 1958 for Thailand (lower horizontal axis); the data series themselves thus "line up" according to the least-squares year of best fit as described above. Given the socio-ecological differences between Thailand and the US, the similarity of the TB mortality decline is striking. Thailand is currently designated by the WHO as a high-TB-burden country (Soonthorndhada 2006), while the US is well known for having undergone a great transition in the 20th century, from a being a high-TB burden country to being a low-TB burden country. Today, the US is typical of other OECD countries, where TB mortality is very low and is dominated by reactivation infections among the elderly (who both lived through the higher TB prevalence era in the past, and for whom treatment is difficult). The TB morbidity situation in the US today is somewhat more complex, especially since the US is a receiving country for international migration, but mortality is quite low because most active TB infections are treated. ADD SOME CITATIONS ON THE TB SITUATION IN US.

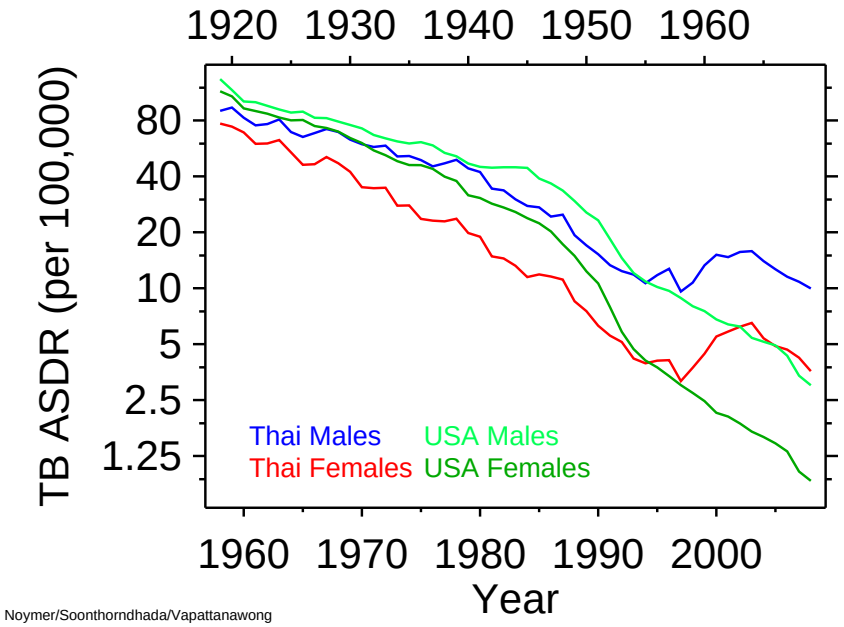


Figure 1: Age-standardized death rate for tuberculosis, for Thailand, 1958–2008, and for the United States, 1919–1969.

Of course, figure 1 does not compare Thailand today with the US today. It compares the most recent 51 years for which data are available in Thailand, with the best-matching 51 year period in the US. Nonetheless, the similarities are striking. The trends are largely parallel, meaning similar percentage declines per year in both countries during the relevant time periods. Moreover, the absolute levels of decline are comparable, meaning the graphs almost overlap. We attribute the wider gap between the sexes in Thailand to the use of tobacco. Other researchers have implicated tobacco in the maleness of TB (Watkins and Plant 2006). Due to the later date, tobacco was more broadly available in Thailand, 1958–2008, than in the US, 1919–69, particularly in the first 20 years or so of each period. In both countries during the relevant time period, tobacco use shows a more male profile.

The most obvious divergence between the two countries occurs in the mid-1990s (for Thailand, as compared to the late 1950s and early 1960s for the US). This is due to the mortality consequences of the global HIV/AIDS pandemic in Thailand, and will be discussed in more detail below. Nonetheless, figure 1 shows, starkly, that, up to the unfortunate intercession of the HIV/AIDS pandemic, the decline of TB mortality followed a similar pattern in Thailand as had been traced in the US about 40 years previously. Thailand's status as a high-burden TB country is not an inevitable consequence of its status as a middle-income tropical country. For many years it followed a pattern of TB decline that mirrored that of the US.

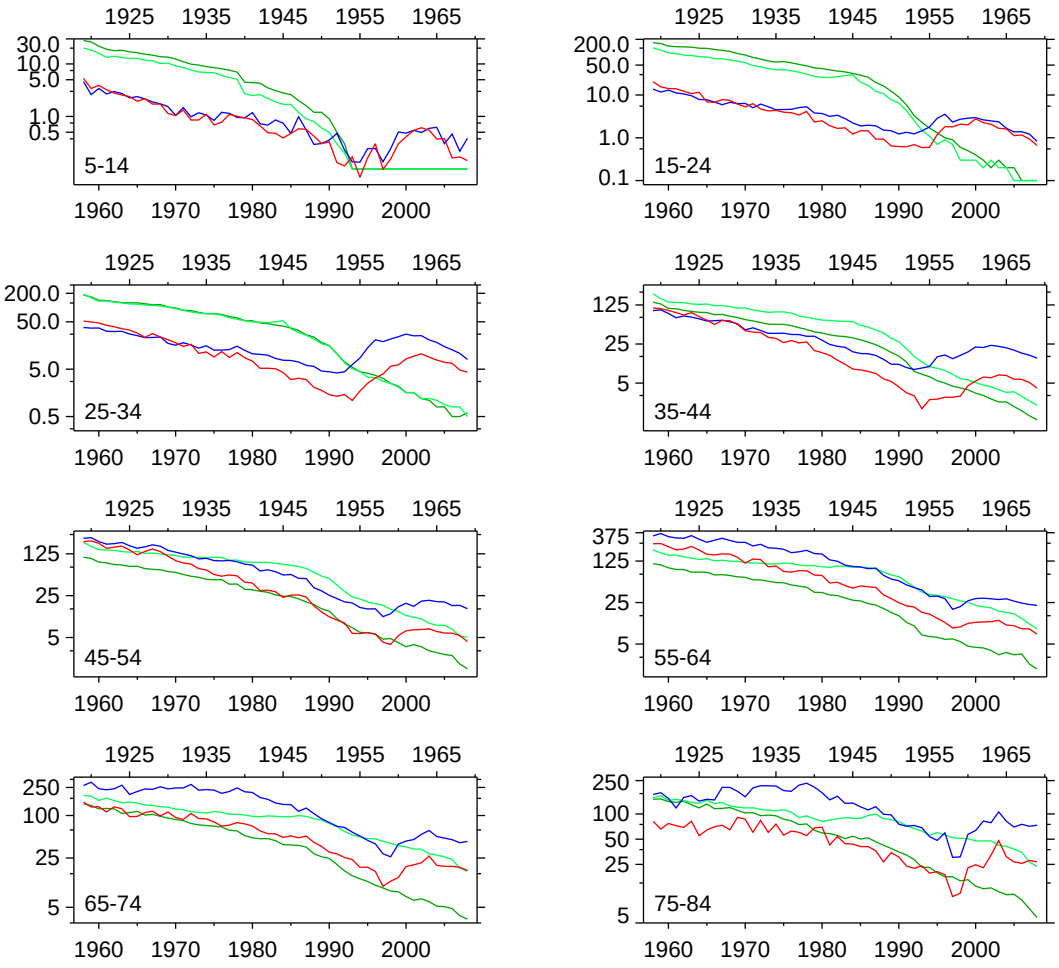
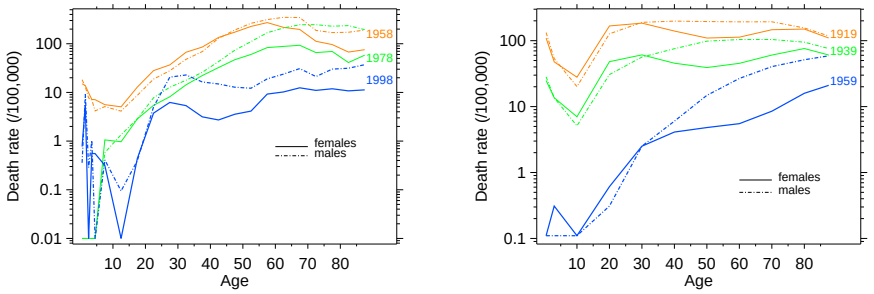


Figure 2: Age-specific death rates for tuberculosis, for Thailand, 1958–2008, and for the United States, 1919–1969. Age groups as indicated in panel labels.

3 Patterns by age, over time

Figure 2 shows the same data as figure 1, but disaggregated by age groups as opposed to as a single, age-standardized rate. While no age group in Thailand was spared the reversal of fortune of TB mortality that accompanied the HIV/AIDS epidemic, the patterns by age are very revealing. By far the most important change occurred in the 25–34 age bracket. In Thailand, the death rates in this age group during 1958–1991, were *lower* than those seen in the US in the analogous time period as defined by the fitting exercise discussed in § 2 (1919–62). But the 1990s saw a tenfold increase in TB death rates in Thailand in this age group; this is the biggest absolute or relative setback of any age group. It is also the age group most consistent with an HIV/AIDS interaction, especially when one considers that these are mortality, not incidence, statistics (with mortality skewing somewhat older than incidence). Changes in TB mortality are seen in age groups not associated with HIV/AIDS, as well, and this is likely to be the echo effect throughout the population of increased HIV-associated TB transmission. The fact that the reversal-of-fortune of TB mortality peaks and declines is reflective of the apogee of the HIV/AIDS epidemic in Thailand in the late 1990s. What is more, the non-HIV-related age groups show later post-1990 peaks in TB mortality, which is consistent with the echo effect.



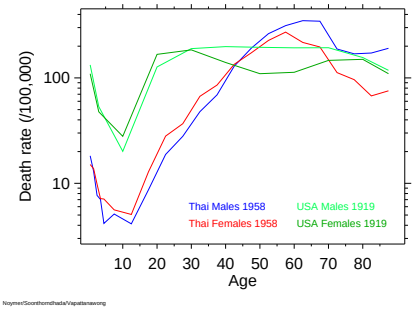
Thailand United States

Figure 3: Age-mortality profiles, tuberculosis, for Thailand, 1958, 1978, 1998 (left panel), and for the United States, 1919, 1939, 1959 (right panel).

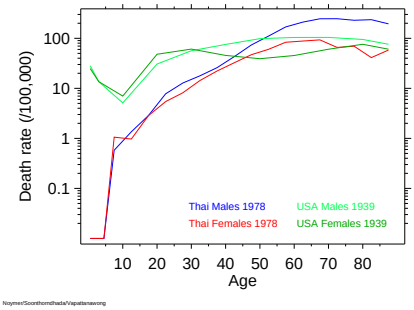
4 Age-mortality profiles

Figure 3 presents age-mortality profiles for TB for each country for three points in time, spanning 40 years: 1958, 1978, and 1998 for Thailand (left panel), and 1919, 1939, and 1959 for the United States (right panel). The Thai data are noisy at young ages because pulmonary TB is an atypical cause of death below age 5. Note the commonality of both countries that, as TB death rates decline, the relative difference between the sexes becomes more pronounced. Females enjoy proportionally lower death rates as TB mortality declines. As mentioned above, tobacco use likely plays a role in that. The other key feature of figure 3 is that, whereas the American curves show monotonic decline (each subsequent age-mortality profile is nested below the prior one), the Thai curves show that the HIV/AIDS set back the mortality profile back by 20 years for some age groups.

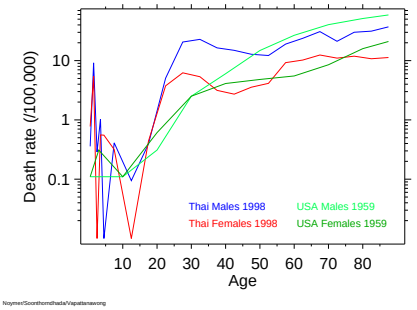
Figure 4 presents a different way to view essentially the same data. Here we plot age-mortality profiles for the two countries on the same axes. In



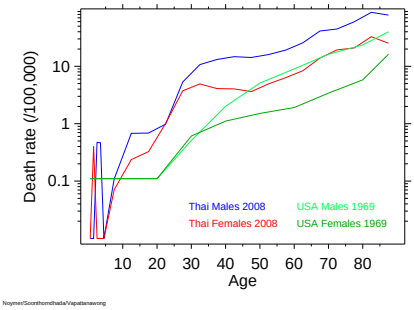
1919 (US) and 1958 (Thailand)



1939 (US) and 1978 (Thailand)



1959 (US) and 1998 (Thailand)



1969 (US) and 2008 (Thailand)

Figure 4: Age-mortality profiles, TB, for Thailand and the US, plotted on the same axes.

the top row, we see that in the early period, American data show a flat age-mortality profile, with death rates rising in the teenage years and then plateauing at older ages. This is the archetypal pattern of TB mortality that establishes TB as an important cause of *adult* mortality (viz., as distinct from elderly). In the pre-HIV era, this made TB an important outlier from other infectious causes of death, which typically kill children or the elderly or both, but which do not exhibit modal death rates at adult ages.

By 1959, the pattern of TB mortality in the United States had shifted to resemble the ever-increasing death rates by age, that are seen throughout the Thai data. It is hard to know for sure, but it is likely that Thailand went through a phase, some time before 1958, where the TB age-mortality profile was also plateau-like, such as the US data in 1919 and 1939. (Some insights on this may be garnered from some historical data on TB mortality in another Southeast Asian country, the Philippines, that I have.) If that is correct, it indicates that TB death rates must have been falling in Thailand long before 1958, and, by the same logic, were quite high during the Siam period in the early 20th century. In the USA, TB death rates have been falling since at least the mid-19th century (linking Massachusetts state data to national data), so a similar pattern in Thailand would not be atypical.

We compare 1998 in the Thai data to 1959 for the US (lower left hand panel of figure 4. Here again, the data are strikingly similar, showing that the US-Thai comparison is not misplaced. Nonetheless (and, given the dates, predictably), the age groups at which there is poor concordance between Thailand (1998) and the US (1959) are 20–35, in keeping with the effects of the HIV/AIDS epidemic. The final comparison, in the lower right panel, is

1969 (US) and 2008 (Thailand). By 2008, the excess bulge in HIV-associated Thai TB mortality had ameliorated relative to 1998. However, the echo effect — of increased TB mortality at a broad range of ages, due to increased TB transmission — shows itself in the form of the Thai age-mortality profile now broadly lagging the analogous historical trend in the United States. Whereas in 1998 the biggest difference was at the HIV-impacted ages, in 2008 there are differences at every non-childhood age. The mortality impact of the HIV/AIDS epidemic in Thailand has been broader than HIV/AIDS deaths that are coded as such.

5 Lexis surface analysis

A Lexis surface plots vital rates cross-classified by age and period (Arthur and Vaupel, 1984). Figure 5 shows falsecolor Lexis surfaces, with varying intensities of red signifying high values and varying intensities of blue signifying low values. The midpoint, where the two color schemes meet, is colored white[1] The shading scheme is called falsecolor because color is used as an indicator of numerical value as opposed to having an intrinsic visual meaning, as in a photograph (e.g., blue and red could be swapped and the same information would be conveyed).

These Lexis surfaces can be regarded as encapsulating, in four plots, the information in all the previous graphs. The time domain plot (figures 1–2) and the age-mortality profile (figures 3–4) are such ingrained demographic techniques that they are not likely to be made obsolete by figure 5, but nonetheless the Lexis surfaces convey much information, compactly. Broadly,

the two countries show similar patters, with the surface declining (becoming more blue) over time. In a Lexis surface, (birth) cohorts move at a 45° angle from lower left to upper right. This is seen as a "staircase" pattern in the US male data and, most prominently in the Thai male data, in the slope of the high-mortality (red) region. This was one of the central insights of one of the most famous papers ever written on tuberculosis decline (Frost 1939). Tuberculosis mortality has a strong cohort tendency, especially in the pre-chemotherapeutic era. This is due to long latency and the long delays from incidence to mortality. Birth cohorts which grow up during high-TB prevalence eras have high latency rates and have a strong tendency to reactivate later in life. Thus, even as TB declines, higher mortality rates are still seen among older cohorts. The upward-sloping region of high mortality among Thai males is an excellent example of this.

The more broad profile of TB mortality among the US population is also clearly visible in the Lexis surfaces. As noted above, one can speculate that this was also the case in Thailand in the early 20th century, but, lacking data on age- and cause-specific mortality in this time period, it is difficult to know for sure. The reasonably abrupt transition to low mortality in the US data (viz., the fact that the red region of the US surface does not extend as far upward at a 45° angle) has also to do with an after-effect of the 1918 influenza pandemic in the US (Noymer 2009, 2010). In the Thai case, the reversal of TB mortality decline is also discernable as white regions reappearing after the mid-1990s (more prominently in the male surface). This is one example of how the time domain plot is still useful, because the recent reversal is more clearly visualized there; it is important as a percentage re-

treat in TB decline, which is captured better by the log scale of figure 2. The Lexis surfaces demonstrate well the notion that the decline of TB mortality in Thailand — up to the intercession of the HIV — follows the classic pattern of cohort TB decline. Ironically, even more so than the US, where this pattern was first identified. To finish on an optimistic note, nothing in the data suggest that the decline of TB mortality in Thailand cannot get back on track. This is not to minimize the challenges ahead, but nothing indicates that the setbacks that HIV/AIDS introduced cannot themselves be reversed, and, indeed, there are signs of this already in the data.

6 Preston Curves for TB

7 Conclusions

The project is to compare the long-run trend of the decline of tuberculosis mortality in two different settings: the United States in the early 20th century and Thailand in the late 20th century. We have identified a number of key similarities — as well as some differences — between the declines of tuberculosis mortality in Thailand and in the United States (US).

Our key findings may be summarized as follows:

1. The decline of tuberculosis mortality in Thailand and in the United States is strikingly similar. This is somewhat akin to the finding of similar patterns of mortality decline among industrialized countries (Tuljapurkar et al., 2000), but is in many ways more surprising, because it applies to one cause of death and therefore is not subject to smoothing

by compensatory deviations among various causes. What is more, the socio-ecological differences between Thailand and the United States are larger than among the industrialized countries.

2. The analogous decline of tuberculosis mortality in Thailand and in the United States only holds up to a point. The HIV/AIDS pandemic in Thailand acted to interrupt the decline in TB mortality. This buttresses the point by Grmek (1969,1989) that diseases must be considered together.

3. Sex differences are paramount both as empirical realities and as ways to understand the social forces affecting the vital rates.

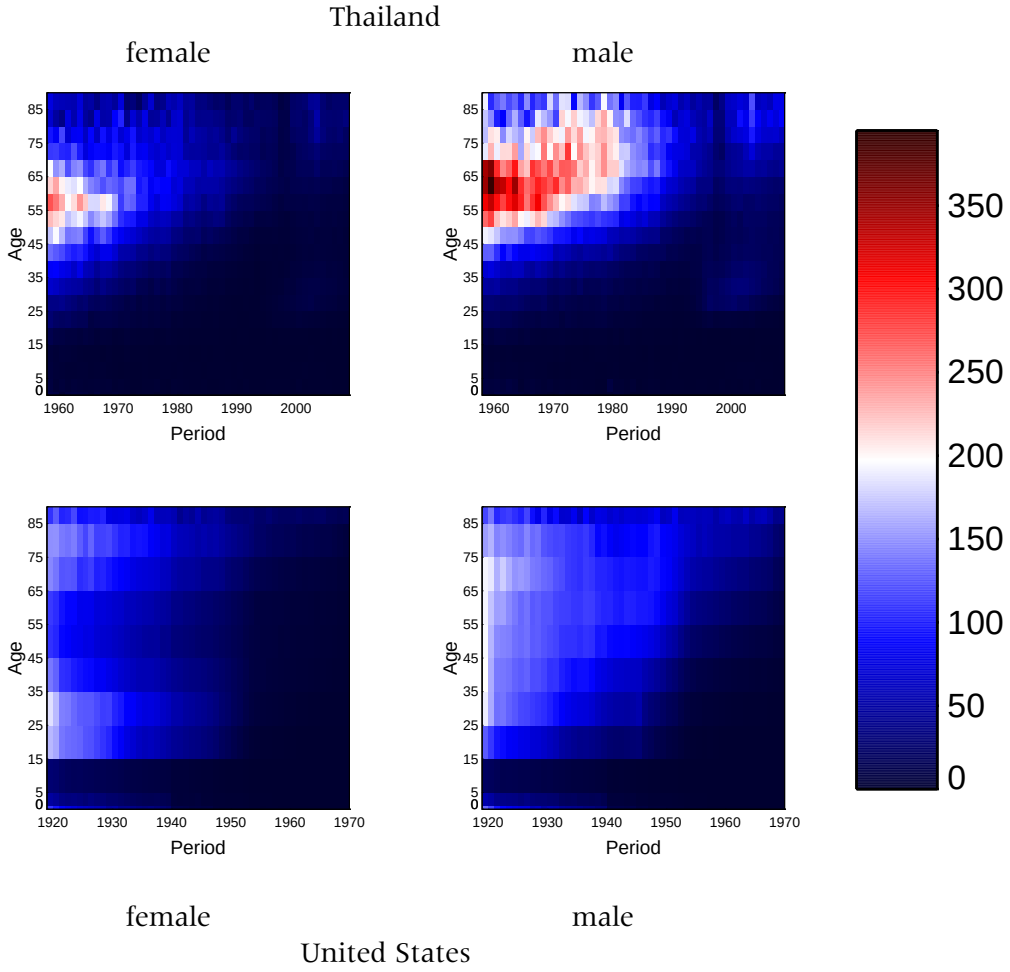


Figure 5: Lexis surfaces (age × period falsecolor-diagrams) of TB death rates. Clockwise from upper left: Thai females, Thai males, US males, US females. Dates as before: Thailand, 1958–2008; US, 1919–69. Legend at right (same falsecolor scale for all four panels); rates per 100,000.

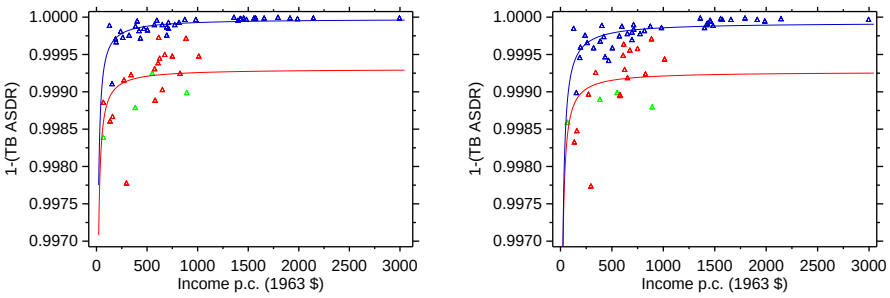


Figure 6: Preston curves for TB.

Notes

[1]The utility of the 2-color approach is discussed by Cleveland (1993) and Rogowitz and Treinish (1998). In short, compared to multicolor schemes, the 2-color surface has less potential to mislead.

Works Cited

Arthur, W. Brian and James W. Vaupel. 1984. "Some general relationships in population dynamics." *Population Index* 50(2):214–226.

Cleveland, William S. 1993. *Visualizing data*. Hobart Press, Summit, New Jersey.

Dye, Christopher and Brian G. Williams. 2010. "The population dynamics and control of tuberculosis." *Science* 328(5980):856–861.

Frost, Wade Hampton. 1939. "The age selection of mortality from tuberculosis in successive decades." *American Journal of Hygiene* 30-§A(3):91–96.

Grmek, Mirko D. 1969. "Préliminaires d'une étude historique des maladies." *Annales. Économies, Sociétés, Civilisations* 24(6):1473–1483.

———. 1989. *Diseases in the ancient Greek world*. Johns Hopkins University Press, Baltimore. Orig. publ. 1983 as *Les Maladies à l'aube de la civilisation occidentale*. Trans. by Mireille Muellner and Leonard Muellner.

Hill, Kenneth, Patama Vapattanawong, Pramote Prasartkul, Yawarat Porapakkham, Stephen S. Lim, and Alan D. Lopez. 2007. "Epidemiologic tran-

sition interrupted: A reassessment of mortality trends in Thailand, 1980–2000." *International Journal of Epidemiology* 36:374–384.

Long, Esmond R. 1948. "The decline of tuberculosis as the chief cause of death." *Proceedings of the American Philosophical Society* 92(3):139–143.

McKeown, Thomas. 1976. *The modern rise of population*. Edward Arnold, London.

Noymer, Andrew. 2009. "The 1918–19 influenza pandemic affected tuberculosis in the United States." *Biodemography and Social Biology* 54(2):125–133.

———. 2010. "Epidemics and time: Influenza and tuberculosis during and after the 1918 epidemic." In Alan C. Swedlund and D. Ann Herring (eds.), *Plagues and epidemics: Infected spaces past and present*, chap. 8, pp. 137–152. Berg, Oxford.

Preston, Samuel H. and Etienne van de Walle. 1978. "Urban French mortality in the nineteenth century." *Population Studies* 32(2):275–297.

Rogowitz, Bernice E. and Lloyd A. Treinish. 1998. "Data visualization: The end of the rainbow." *IEEE Spectrum* 35(12):52–59.

Soonthorndhada, Amara. 2006. "TB policy in Thailand: A civil society perspective." Public Health Watch Monitoring Report, Open Society Institute, New York.

Tuljapurkar, Shripad, Nan Li, and Carl Boe. 2000. "A universal pattern of mortality decline in the G7 countries." *Nature* 405:789–792.

Watkins, R. E. and A. J. Plant. 2006. "Does smoking explain sex differences in the global tuberculosis epidemic?" *Epidemiology and Infection* 134(2):333–339.