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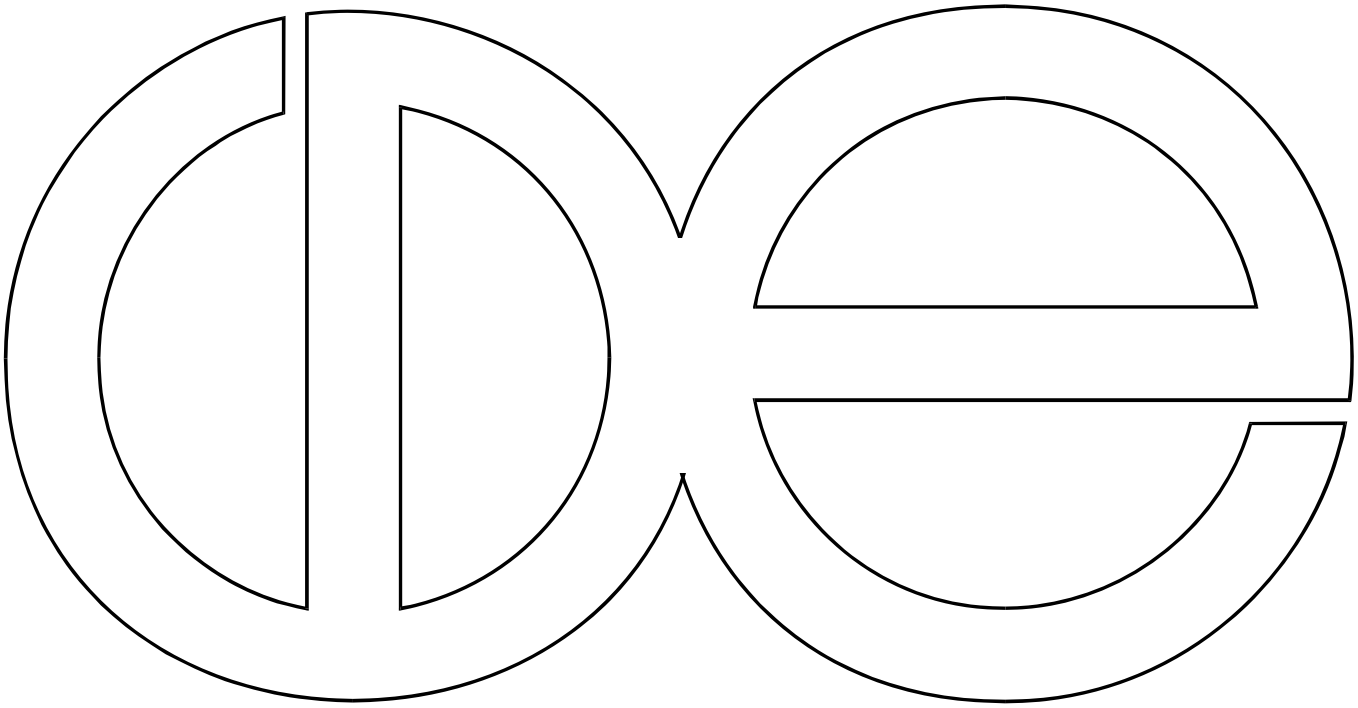

Mortality Decline in the Twentieth Century, Early Life Conditions and the Health of Aging Populations in the Developing World

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Abstract

The dramatic mortality decline of the 1930s-1960s may shed light on the importance of early life conditions for older adult health in the developing world. We collected historical data on life expectancy, infant mortality, GDP per capita, age-specific mortality rates and population growth rates for 19 countries which have population surveys on older adult health. We then developed a classification of demographic regimes to distinguish cohorts of the 1930s-1960s whose survivors at older ages are potentially more influenced by the effects of poor early life conditions. Prior to 1945 and compared with cohorts from earlier (e.g. Argentina, Uruguay) and later regimes (e.g India, Indonesia, China), old-age survivors from cohorts of the late 1920s-early 1940s in mid-demographic regimes (e.g. Puerto Rico, Costa Rica, Chile, Taiwan, South Africa) are more likely to have been influenced by poor early life conditions. Using the classification it is possible to examine early life conditions and adult health with cross national data, controlling for important confounding factors such as standard of living and health care across the life course.

Introduction

In the developed world, an accumulation of evidence has demonstrated that early life conditions can contribute to adult mortality and chronic conditions such as heart disease and diabetes beginning with poor nutrition *in utero* and early infancy (Barker 1998; Eriksson et al. 2001) and continuing with poor socioeconomic conditions and health during childhood (Lundberg 1991; Hertzman 1994; Wadsworth and Kuh 1997; Gunnell et al. 1998; Davey Smith and Lynch 2004; Elo and Preston 1992). Disentanglement of early life effects from other life course effects on older adult health is, however, far from complete. This is particularly true in the developing world which is projected to have large increases in the older adult population in a relatively short period of time (Kinsella and Velkoff 2001), mostly in the context of stagnant improvements in standard of living and fragile institutional support (Klinsberg 2000; Barrientos, 1997; Mesa-Lago, 1994). Findings on the importance of early life exposures have particular significance in developing countries where poor nutrition for mothers and unborn children and childhood health amidst lower standards of living are important health concerns and where projections show large increases in the prevalence of heart disease, diabetes and obesity among older adults (Murray and Lopez 1996; Amos, McCarty and Zimmet 1997; WHO 2000a; Leeder et al., 2004).

The dramatic mortality decline of the 1930s-1960s may shed light on the importance of early life conditions for older adult health in the developing world. The large upward shift in life expectancy during the period 1930-1960 was mostly a result of factors exogenous to income such as public health interventions and medical technology which largely affected infant and child mortality (Preston 1976; Palloni and Wyrick 1981).[1] Reduction in infant mortality and child mortality produced a larger pool of survivors of poor early childhood conditions over the period 1930-1960. Larger changes in life expectancy and infant mortality were more heavily concentrated in lower income developing countries (Preston 1976) and thus the mortality decline

of the 1930s-1960s created cohorts in lower income countries many of whom had been exposed to poor early life conditions but yet were less affected by mortality-driven selection than the group of cohorts who preceded them. At the beginning of the period (the 1930s), many had been exposed to poor nutrition and infectious diseases in the context of seriously underdeveloped public infrastructures to address problems of water, sewage, housing, and insect control. Yet, at older ages, these cohorts experienced differences in their trajectory across the life course in terms of improvements in standard of living and health care. Because of the compressed nature of aging in the developing world (Kinsella and Velkoff 2001), cohorts born during the 1930s-1960s may be able to provide insights into the degree to which early life experiences become important in later life. If early life conditions do indeed have important effects on adult health, it may be possible to observe the differential effects that early life conditions have on older adult health through comparisons across and within different demographic regimes of the period, controlling for important confounding factors.

[Insert Figures 1 & 2 about here]

The reasons for and the timing and pace of mortality decline during the early 20th century may help distinguish different demographic regimes. Mortality began to decline in the 19th century in England and Wales, the Netherlands and the US. Early declines also began in Argentina, Uruguay, Mexico, Costa Rica, Cuba and Puerto Rico at the beginning of the 20th century and by the 1920s significant mortality decline occurred in Taiwan, Chile, South Africa, Brazil and Barbados but also in Bangladesh, China, Ghana, India and Indonesia (Riley 2005b).[2] However, different patterns of mortality decline emerged. Early, more gradual mortality decline due to higher levels of national income and later, more rapid mortality decline due more to massive public health interventions and medical innovations helped produce differences among

cohorts born in the 1930s-1960s and the degree to which poor early life conditions influenced them.

The level of national income was important in the pattern of mortality decline experienced by higher income countries in the early 20th century. The higher level of economic development (reflected in education, housing and living standards) supported broader efforts at sanitation (water and waste disposal) and other public health measures and led to more gradual improvements in life expectancy (Arriaga and Davis 1969). Approaches to solving health problems were then exported to developing countries (Farley 2004). Adults born in the 1930s in higher income countries such as England and Wales, the Netherlands and the US may have been exposed to poor early life conditions but many improvements in sanitation and public health in the early 20th century resulted in a higher proportion of the population who were in better health at birth by the 1930s. Furthermore, adults born in these countries were not confronted with tropical diseases and conditions. Countries such as Argentina and Uruguay were also at higher levels of economic development and life expectancy or, as in the case of Cuba, had implemented major sanitary reforms at the beginning of the 20th century which significantly lowered infant mortality (Diaz-Briquets 1981). At the beginning of the century there was a concerted effort to use sanitary and public health measures to improve infant and child mortality (Mazzeo 1993; Birn 2005; Diaz-Briquets 1981) and by 1930 a larger proportion of the population was in better health at birth.

Yet, national income or changes in national income do not completely explain improvements in life expectancy (Preston 1976; Cutler, Deaton and Lleras-Muney, 2005; Deaton 2007; Deaton 2004; Soares 2007) because even at lower income levels with little growth in national income some countries experienced mortality decline. Other exogenous factors such as massive public health interventions sponsored by government and other entities, knowledge about better health habits and medical advances such as antibiotics also partially explain mortality decline during

this period. A large proportion of the population born in the 1930s in many low income countries was exposed to poor nutrition, infectious diseases and adverse socioeconomic conditions in early life. However, there were differences among countries that are mirrored by their mortality decline. Some countries with more mid-paced mortality decline conditions steadily improved during the late 1920s-1940s due to intensive public health efforts. In smaller countries such as Costa Rica, Puerto Rico, Chile and Taiwan, sustained mortality decline appeared in the 1920s-1930s as public health efforts began to intensify in the late 1920s and early 1930s in spite of continued difficult economic times and lower levels of income (Rigau Pérez 2000; Jimenez de la Jara and Bossert 1995; Rosero-Bixby 1990; Garnier et al. 1997). Efforts during the late 1920s-early 1930s were preventive in nature (education, public health units, vaccinations for small pox, malaria and hookworm campaigns in tropical countries, building latrines and better laws to regulate public health). Puerto Rico, for example, started to implement public health units at the municipality level during the 1920s and by the end of the 1930s most of the island was covered. In the case of Taiwan (Barclay 1954), mortality declined earlier because of public policy due to foreign intervention, and in the case of South Africa, public health efforts also intensified in the early 1920s although there were important differences between whites and blacks (Beinart and Dubow 1995). These countries experienced a larger increase in survivors of poor early life conditions in the late 1920s.

In larger countries such as Brazil and Mexico, which experienced improvements in life expectancy in the early 20th century (Riley 2005b), more concerted public health efforts on the part of the government began by the 1920s but did not reach a greater coverage of the population until the late 1930s-1940s (Rodrígues de Romo and Rodríquez de Pérez 1998). Barbados, a small island, was able to implement major sanitation and public health measures beginning in the 1920s and strong public educational and health reform produced dramatic mortality decline beginning in the 1930s (Bishop, Corbin and Duncan 1997; West India Royal Commission Report

1945). In these countries, later cohorts experienced a larger increase in survivors of poor early life conditions.

Even though mortality began to decline in countries such as China, India, Bangladesh, Ghana, and Indonesia in the 1930s (Riley 2005b), economic development was slower and the type of public health interventions that benefited a large proportion of the population developed later towards the end of the 1940s or during the 1950s. Thus, later cohorts (late 1940s-1960s) experienced a greater increase in survivors of poor early conditions than did earlier cohorts (1930s-1940s). This occurred in China although they had established a public health infrastructure affecting some urban areas (Campbell 1997; MacPherson 2008; Banister 1987). It also occurred in Indonesia although there were some targeted public health efforts during the Dutch rule (Hull 2008; Nitisastro 1970). It also occurred in India where there were some limited public health measures in the cities in the early 20th century during British rule (Dyson 1997; Ramasubban 2008; Guha 2001) and where conditions in the state of Bengal, India, (a portion of which later became Bangladesh) were reported to have been better than in other parts of India (Guha 2001). Finally, it also occurred in Ghana where modern public health efforts began to slowly improve in the 1920s, mostly in urban areas, but did not have a wider impact in rural areas until in the 1940s and 1950s after colonial rule (Patterson 1979; Patterson 1981).

Even if it is possible to adequately distinguish different demographic regimes to reflect the degree to which poor early life conditions characterize cohorts born during the 1930s-1960s, there are many possible intervening variables at a country-level and at an individual-level that determine adult health. Adult health may be an accumulation of events across the life course and the effects of early life conditions may be mediated by these events (Kuh and Ben-Shlomo, 2004). Any reasonable classification of demographic regimes must thus be able to adequately control for confounding or intervening factors.

Prime among them at a country-level is economic development throughout the life course reflected in socioeconomic conditions, national income levels, mortality levels and access to quality health care. Such may be the case of mid-paced demographic regimes such as Costa Rica and Chile which now have exemplary health care systems (Garnier et al. 1997; WHO 2000b) which were developed in the later half of the 20th century. Costa Rica implemented its first national health plan in the 1970s and it has dramatically helped to improve the health of its citizens (Rosero-Bixby 1990; Garnier et al. 1997). Taiwanese born in the 1930s were exposed to poor early life conditions but as adults lived during the tremendous economic growth experienced by Taiwan in the later 20th century. Later regimes such as Barbados instituted major health and education reforms (Bishop, Corbin and Duncan 1997) and dramatically reduced mortality. Such is also the case for cohorts of individuals born prior to 1945 who were exposed to more preventive health care interventions whereas cohorts of individuals born after 1945 were exposed to antibiotics. There are many potential intervening factors at an individual level but urban/rural differences at birth are particularly relevant in the developing world. Urban/rural differences were particularly pronounced in some countries such as China where unhealthy conditions were more prevalent in rural areas (Campbell 1997). However, urbanization also created unhealthy conditions. This was the case in Puerto Rico during the late 1920s when infant mortality was higher in urban areas than in some rural areas (Fernós Isern and Rodriguez Pastor 1930). It was also true in late regimes such as India (Ramasubban 2008) and Ghana (Patterson 1979).

Classification of Countries

Although general classifications of demographic regimes exist (Omran 1971; Palloni 1981; Palloni et al. 2007), there has been no formal, more quantifiable classification of demographic regimes during the 1930s-1960s. The characteristics of mortality decline in the early 20th century (reasons for, timing and pace of) may provide a clue in defining demographic regimes in

a more precise way. Suitable approximations can be made to estimate the percent of mortality decline due to public health and medical innovation by modeling changes in life expectancy as a function of national income, education, nutrition and other pertinent variables (Preston 1976; Palloni and Wyrick 1981; Rosero-Bixby 1990). Annual absolute gains/reductions; annual percentage decline/increase in IMR or the magnitude of change in IMR during 1930-1960 can distinguish the magnitude of mortality changes at younger ages. In addition, because growth rates of a population are partially a function of conditions at birth (Horiuchi and Preston 1988), estimating cumulative mortality changes between cohorts using growth rates of the older population is another measure to classify regimes. This measure is particularly relevant since a substantial proportion of the growth rate of the older adult population in some Latin American and Caribbean countries is believed to be due to cumulative mortality changes before the age of 60, most of which are concentrated at lower ages (infancy and young childhood) (Palloni et al. 2007). Many low to middle income countries which experienced rapid and late mortality decline during the 1930s-1960s are now experiencing a high rate of increase (close to 3%) of the population over the age of 60 during the 1990s-2020s[3] and thus this measure provides evidence to suggest that a large percentage of those born during the 1930s-1960s who survived until the first decade of the 21st century were exposed to poor early conditions at birth or during childhood.

Comparing countries across demographic regimes so defined may illuminate the strength of the supposition regarding early life conditions. If early life conditions are important to older adult health, as we move from the very early regimes to the later regimes we should see that the effects of early life conditions on older adult health become more predominant in cohorts born in the mid-to-later regimes (low income countries), depending on the time period examined and if important confounding and intervening factors can be controlled. If there is sufficient variation within regimes, a comparison within demographic regimes controlling for economic level and growth, health care system performance, or survival of the older adult population while also

controlling for education, gender, age and adult behavior, may also provide insight into the importance of early life exposures on adult health.

The purpose of this paper is to develop a classification of countries into demographic regimes based on the characteristics of mortality decline (reasons for and the timing and speed of mortality decline). There are relatively no cohort data available in the developing world which can shed light on the importance of early life conditions on older adult health. Examining the effects of early life conditions on older adult health using cross sectional and panel data in the light of demographic regimes has been proposed (Palloni et al. 2007) but not been fully tested. If the classification is reasonable, we expect to observe the following regularities: (1) very early regimes at higher income levels show the smallest change in mortality during the 1930s-1960s; (2) mid-paced demographic regimes show the largest change in mortality for the period prior to 1945 as mortality decline is increasingly due to public health and medical innovation; (3) later demographic regimes show an even larger decline after 1945 as public health and medical innovation explain a very high percentage of mortality decline; and (4) there are sufficient differences within regimes in terms of standard of living and health care over the life course to help control for country-specific and individual-specific confounding variables.

Methods

We collected historical data for the 20th century on life expectancy, infant mortality and GDP per capita (see appendix) for 19 countries which have produced major studies on aging in Latin America and the Caribbean, Asia and Africa and from more developed countries such as the US, the UK, the Netherlands and Taiwan. For the most part, population surveys on older adults are available for those born prior to 1945. Thus, while we examined the entire period 1930-1960, we also examined mortality decline during 1930-1945 (the period for which data on the health of adults who are at least 60 is available) and during 1945-1960 (the period for which there is not yet complete data on the health of older adults).

To develop a classification of demographic regimes to reflect early life conditions during the 1930s-1960s we used multiple approaches. First, we estimated the percent of mortality decline due to public health and medical innovations for several periods of interest (1930-1960, 1925-1945 and 1945-1965) using a shift analysis as done by Preston (1976, see appendix). We then calculated the pace and magnitude of decline in IMR and compared this against the growth rate of the population aged 60 and older and against the percent of mortality decline due to public health and medical innovation. Historical sources on life expectancy and infant mortality came from different sources at times. If multiple sources of life expectancy and infant mortality were obtained, then they were averaged by year to obtain a final estimate. We re-did the shift analysis done by Preston (1976) using more recent estimations of GDP per capita, literacy and life expectancy and included countries which were not included in the original Preston analysis but which now have data on the health of older adults. We calculated the change in life expectancy (infant mortality) as the average yearly gain (decrease) in life expectancy (infant mortality) and as the magnitude of changes in life expectancy between different points of time. We then compared the percent mortality decline due to public health and medical innovations (mortality decline due to exogenous factors) with the magnitude of change and average yearly decrease in infant mortality between 1930 and 1960 (1925-1945). We also decomposed the growth rate of the population aged 60 for those born 1930-1960 using known decomposition methods (Horiuchi and Preston 1988). First, we obtained data on births during these same periods to estimate the growth rate of the 60-year old population in each cohort of interest. We then obtained actual age-specific mortality rates for each country for the different birth cohorts of interest (by comparing historical life tables across time) (1930, 1940 and 1960) and estimated the cumulative difference in mortality rates to age 60. Finally, we divided the cumulative mortality difference by the total estimated growth rate of the 60-year old population between cohorts of interest to obtain an estimate of the percent of growth rate attributed to mortality decline.

To examine the classification of regimes against two important confounding factors (standard of living throughout the life course and health system) we compared historical data on GDP per capita (Maddison 2006), age-specific mortality rates through a series of historical life tables (where possible; see appendix), health system performance data (WHO 2000b), and survivorship information in the year 2000 (WHO 2002).

Results

Speed, timing and reasons for decline

Five demographic regimes were identified using timing and pace for mortality decline: very early demographic regimes such as England and Wales, the Netherlands, and the US (Figures 1 & 2, Pattern A), early regimes such as Argentina, Uruguay and Cuba (Figures 1 & 2, Pattern B), mid-paced regimes such as Costa Rica, Chile, Puerto Rico, Taiwan and South African blacks (Figures 1 & 2, Pattern C), later regimes such as Mexico, Brazil and Barbados (Figures 1 & 2, Pattern D) and very late regimes such as Bangladesh, China, Ghana, India and Indonesia (Figures 1 & 2, Pattern E). At the beginning of the 20th century, in high income countries such as England and Wales, the Netherlands and the US, mortality had already begun to decline but overall in a more gradual, steady pattern with increasing levels of life expectancy and decreasing levels of IMR. They reached a life expectancy close to 50 years at the beginning of the 20th century and throughout the early to mid 20th century mortality decline was steady and graded. At the start of the 1930s, life expectancy was relatively higher than in other countries in that it had increased to over 60 years. Argentina and Uruguay also experienced a more graded improvement in life expectancy and decline in infant mortality at the beginning of the 20th century. Mid-paced countries experienced more rapidly increasing life expectancy and decreasing infant mortality during the 1930s-1960s. They showed significant improvements in the 1920s although beginning at lower levels of life expectancy. While South African blacks fit into this country pattern, South African whites fit more clearly in with regimes that had a much

higher life expectancy. Mexico, Brazil and Barbados are pattern D and very low income countries which began the 1930s at a lower level of life expectancy and while mortality began to decline, by the end of the 1940s, infant mortality was still at very high levels.

[Insert Figures 1 & 2 about here]

The average yearly gain in life expectancy over the period 1930-1960 was smaller in the very early regimes (US, Netherlands, England and Wales), increasing in the early, graded, mid-paced regimes and later regimes and slowly in the very late demographic regimes (Table 1). These gains in life expectancy were particularly larger in the 1940s-1960s than in the 1930s-1940s. Important variations within regimes exist between the 1930s-1940s and the 1940s-1960s. Reductions in IMR show a similar pattern, although with exceptions. The very early regimes showed a smaller average yearly decline in IMR whereas the more mid-paced regimes showed a larger average yearly decline in IMR. The very late regimes showed larger gains in reductions in IMR with the exception of Bangladesh.

[Insert Table 1 about here.]

The plotted relationship between GDP per capita and life expectancy and GDP per capita and infant mortality shows the higher income countries at the beginning of the century (England and Wales, US, Netherlands, Argentina, Uruguay) and the more graded increase in life expectancy (Figure 3) and decline in IMR that occurred over time (Figure 4). Cuba's pattern is slightly different although it was closer to levels of IMR in Argentina and Uruguay than other lower income countries. In other lower income countries and more mid-paced and later regimes it becomes clearer that factors exogenous to GDP per capita are strongly associated with IMR

decline before 1960. In Costa Rica, GDP per capita was fairly steady during the 1920s-1940s although life expectancy increased and IMR declined. In Chile, Mexico and Brazil, a similar pattern emerges whereas in Puerto Rico improvements are associated with growth in income. In very low income countries such as Indonesia, India, China, Bangladesh and Ghana, there are slight improvements in life expectancy beginning in the 1920s but only more dramatic increases several years later. Indonesia GDP per capita was declining during the 1950s while IMR was declining and in China, GDP per capita was stagnant until the 1940s when it declined and then increased in the 1950s while IMR continued to decline.

[Insert Figures 3 & 4 about here.]

Adding reason for mortality decline, a grouping of countries comparing the percent of mortality decline due to exogenous causes with the magnitude of decline in IMR during 1930-1960 is presented in Figure 5. On the x-axis appears the magnitude of the decline in infant mortality rate across countries which is much smaller (less than 60) for the very early regimes than it is for the mid-paced to later regimes (greater than 60). The graph shows on the y-axis, as expected (Preston 1976), that a high proportion of the reason for mortality decline during the period of the 1930s-1960s can be attributed to public health interventions or medical advances. The proportion in the graph ranges from 40% in the case of Puerto Rico to nearly 100% in the case of China. The remaining proportion not shown is then attributed to improvements in standard of living as measured by GDP per capita. The early, graded mortality decline regimes cluster in the left hand portion of the graph; the early, mid-paced regimes appear towards the center of the graph and the later, rapid decline countries appear on the right hand side of the graph. When countries are grouped according to the average yearly decrease in IMR between 1930 and 1960, the pattern remains the same except for the case of Bangladesh which now

appears clustered with the earlier regimes (Figure 6). The grouping of countries is also very similar when grouped according to the growth rate of those ages 60 and older with the magnitude of decline in IMR during 1930-1960 (Figure 7).

[Figures 5, 6 & 7]

Confounding Factors

Examples of how the classification of regimes can be used to control for confounding factors such as standard of living and health care using GDP per capita, the WHO health care rating and life expectancy at the age of 60 in the year 2000 are shown in Table 2. South African whites had more favorable early life conditions in the early 1930s-1960s but now live within a health care system ranked much lower than other upper middle or high income countries. Argentina and Uruguay also had more favorable early life conditions but now rank lower than Cuba in health care and life expectancy. Puerto Rico, Costa Rica and Chile are ranked higher in health care and have higher life expectancy than South African blacks. Barbados also is ranked higher in health care in comparison with Mexico and Brazil. India, China and Indonesia are now lower middle income countries as compared with Bangladesh and Ghana yet Bangladesh and Indonesia have a more highly rated health system.

[Insert Table 2]

Discussion

Historical data on life expectancy, infant mortality, GDP per capita, age-specific mortality and growth rate for the population aged 60 plus were collected to develop a classification of countries according to demographic (mortality) regimes in the early to mid 20th century. The

classification of countries indicates that the effects of poor early life conditions may be more clearly manifested in cohorts born in the late 1920s-early 1940s in mid-demographic regimes (e.g. Puerto Rico, Costa Rica, Chile) as compared with earlier (e.g. Argentina, Uruguay) or later regimes (e.g. India, Indonesia); however, these effects may become even more pronounced for those born in later regimes during the 1945-1960s when mortality decline was even more rapid and steep. There are sufficient differences across and within regimes to control for confounding factors such as standard of living, mortality level or health care throughout the life course.

By developing a more formal and quantifiable classification of demographic regimes we build on more general classification of regimes (Omran 1971; Palloni 1981; Palloni et al. 2007). The classification suggests a tip of the iceberg of things to come because cohorts born after 1945 may manifest even stronger effects of poor early life conditions. However, the cohorts born after 1945 were exposed to antibiotics and thus it is not clear how this different type of intervention may affect the importance of early life conditions on adult health. In the developing world these effects have become less important with improvements in standard of living and health conditions (Costa, 2005).

The high degree of mortality decline in the higher income countries due to public health and medical innovation during the 1930s-1960s is surprising. This may merely reflect that these countries had the resources to invest in more public health and medical innovation even though they experienced smaller improvements in life expectancy. It may also suggest the need for examination of alternative models that can provide a better fit for countries at very high life expectancy. The case of Chile also appears surprising as it clusters around non-Latin American countries. However, this may reflect errors in the data more than a realistic clustering.

The classification may be in error because the data on early life expectancy and IMR are not precise and are often incomplete for some countries. In addition, mortality decline is complex and did not produce identical patterns and thus it is difficult to group countries by regimes and

there may be large variation within regimes. Nevertheless, the classification appears to be reasonable and is sufficiently flexible to permit alternative classifications; there is also sufficient variation within regimes to help control for important confounding factors such as standards of living and health care experienced throughout the life course.

A test of the supposition regarding the effects of poor early life conditions using cross-national data should be able to more clearly show the circumstances under which early life conditions affect older adult health. In that light, the results provide the basis by which to examine available cross-national data on the health of older adults in the 19 countries described in this article. There are indeed difficulties in cross-national comparisons; prime among them is the quality and comparability of the data across countries. Morbidity is underestimated in self-reported health measures; however, other studies have shown that the underestimation provides more conservative estimates but not extremely so (Banks et al. 2006; Goldman, Weinstein and Lin 2003; Beckett et al., 2000). Selectivity bias and cultural idiosyncrasies could also be problems in the cross-national data set. Nevertheless, by examining general patterns of effects across and within a reasonable classification of demographic regimes these limitations may be at least partially addressed.

Appendix

Data Sources

The data to test the conjecture come from two major sources: (1) historical data on life expectancy, infant mortality rates (IMR), literacy rates, and GDP per capita, and (2) comprehensive national representative surveys of older adults or household surveys. The historical data on life expectancy and IMR come from a variety of sources which are listed in the next section of the appendix, some of which were identified through extensive bibliographies (Riley 2005a). It was not always possible to obtain life expectancy or IMR in the early years of the twentieth century for some countries and thus published research studies were used in these cases. Sources for literacy rates came primarily from UNESCO (1953, 1965, 1977) but also Preston (1976, 1980) and the source for GDP per capita was Maddison (2006). In some cases interpolation was used to bridge the gap between estimates of life expectancy, IMR, or GDP per capita.

Major sources for life expectancy and infant mortality rates from 1900-2000

Shown in the table are references with years covered. Complete citations are found in the references section.

Country	Reference with reference date in parentheses	Years covered
Argentina	Astorga, Berges, and Fitzgerald (2005)	1900-2000
	UN (2002)	1950-2000
	CEPAL/CELADE (2001)	1950-2000
	WHO (2002)	2000
Bangladesh	UN (2002)	1950-2000
	Max Planck Institute (2007)	1970s
	Dyson (1997)	Prior to 1950
	WHO (2002)	2000
	Mitchell (2003a)	1900-1960
Barbados	UN (2002)	1950-2000
	Mitchell (2003b)	1900-1960
	Bishop, Corbin & Duncan (1997)	Prior to 1950
	WHO (2002)	2000
	West India Royal Commission Report (1945)	1940s
Brazil	Astorga, Berges, and Fitzgerald (2005)	1900-2000
	Arriaga (1968)	1900, 1920, 1940, 1950,

		1960
	UN (2002)	1950-2000
	CEPAL/CELADE (2001)	1950-2000
	WHO (2002)	2000
Chile	Astorga, Berges, and Fitzgerald (2005)	1900-2000
	Arriaga (1968)	1907, 1920, 1930, 1940, 1952, 1960
	UN (2002)	1950-2000
	CEPAL/CELADE (2001)	1950-2000
	WHO (2002)	2000
China	Max Planck Institute (2007)	1929
	UN (2002)	1950-2000
	Banister (1987)	Prior to 1950
	Coale (1984)	1984
	WHO (2002)	2000
Costa Rica	Astorga, Berges, and Fitzgerald (2005)	1900-2000
	Arriaga (1968)	1927, 1940, 1950, 1963
	Rosero-Bixby and Caamaño (1984)	1900, 1910, 1920, 1930, 1940, 1950, 1960, 1970, 1980
	UN (2002)	1950-2000
	CEPAL/CELADE (2001)	1950-2000
	WHO (2002)	2000
Cuba	Astorga, Berges, and Fitzgerald (2005)	1900-2000
	UN (2002)	1950-2000
	CEPAL/CELADE (2001)	1950-2000
	WHO (2002)	2000
England and Wales	Max Planck Institute (2007)	1900-2000
	UN (2002)	1950-2000
	WHO (2002)	2000
Ghana	UN (2002)	1950-2000
	Patterson (1981)	1981
	Caldwell (1967)	Prior to 1950
	WHO (2002)	2000
India	Max Planck Institute (2007)	1901, 1911, 1921, 1931, 1941, 1951, 1961, 1971, 1981, 1991, 1995
	UN (2002)	1950-2000
	WHO (2002)	2000
	Dyson (1997)	Prior to 1950
	Mitchell (2003b)	1900-1960
Indonesia	Preston (1976)	1930
	UN (2002)	1950-2000
	Nitisastro (1970)	Prior to 1950
	WHO (2002)	2000
Mexico	Astorga, Berges, and Fitzgerald (2005)	1900-2000
	Arriaga (1968)	1900, 1910, 1921, 1930, 1940, 1950, 1960
	UN (2002)	1950-2000

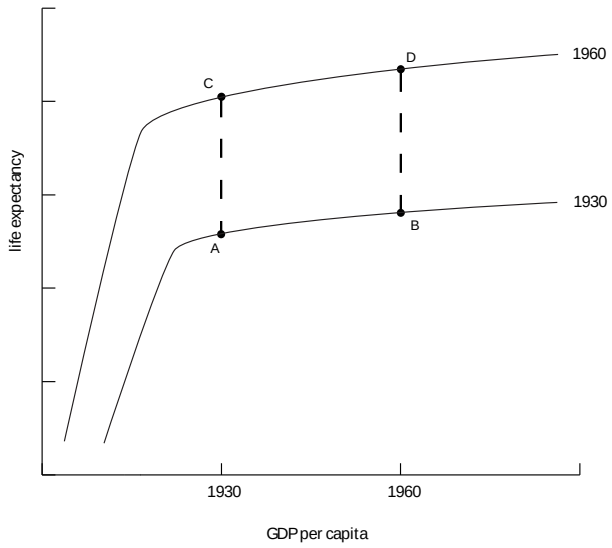
	CEPAL/CEDLADE (2001)	1950-2000
	Preston (1976, 1980)	1935, 1940
	WHO (2002)	2000
Netherlands	Max Planck Institute (2007)	1900-2000
	UN (2002)	1950-2000
	Preston (1976, 1980)	1931, 1940
	WHO (2002)	2000
	Mitchell (2003c)	1900-1960
Puerto Rico	Vásquez Calzada, Morales, and Janer (1963)	1900-1985
	Preston (1980)	1976, 1980
	UN (2002)	1950-2000
	WHO (2002)	2000
South Africa	Max Planck Institute (2007)	1920, 1940-1970
	UN (2002)	1950-2000
	Van Tonder and Van Eeden (1975)	1975
	WHO (2002)	2000
Taiwan	Barclay (1954)	early 20th Century
	Max Planck Institute (2007)	1930-2000
	WHO (2002)	2000
US	Max Planck Institute (2007)	1900-2000
	UN (2002)	1950-2000
	WHO (2002)	2000
Uruguay	Astorga, Berges, and Fitzgerald (2005)	1900-2000
	UN (2002)	1950-2000
	CEPAL/CELADE (2001)	1950-2005
	Migliónico (2001)	1908-1999
	WHO (2002)	2000

Shift analysis using Preston (1976) approach

Preston (1976) observed a shift in the relationship between income and life expectancy from 1930-1960 and using a very simple approach attributed the observed shift as mostly due to factors exogenous to national income. Using this approach (Preston 1976, pages 72-73), we re-did this analysis updating data where necessary on countries and then estimated the degree to which the shift in life expectancy between selected years was due to factors exogenous to GDP per capita. The basic model was: life expectancy= f(ln GDP per capita) but we also estimated models including literacy rates. We examined several different time periods between 1900 and 1960 (results not shown).

The simple graph below using 1930 and 1960 income and life expectancy illustrates how to estimate the change due to increases in income and the change due to a shift in the relationship

between life expectancy and income. The 1930 curve represents predictions for life expectancy given 1930 income levels. We assume for the moment that the relationship between income and life expectancy was the same in 1960. Then, what we have plotted on this curve are points A (predictions for life expectancy in 1930 for a particular country) and B (predictions for life expectancy using 1960 income for that same country). The difference in life expectancy between the two points is an estimate of the change due to increases in income from 1930 to 1960 assuming that the conditions of 1930 were the same in 1960. Likewise, the 1960 curve represents predictions for life expectancy given 1960 income levels. We make the same assumption that the relationship between income and life expectancy was the same in 1930. On the 1960 curve are points C (predictions for life expectancy using 1930 income) and D (predictions for life expectancy using 1960 income). The difference in life expectancy between the two points is an estimate of the change due to increases in income from 1930 to 1960 assuming the relationship between the two does not change. If we then take the average between these two sets of differences (i.e. B-A and D-C), we obtain an estimate of the change in life expectancy due to increases in income (AVGSES). The estimated average change due to the shift in the relationship between income and life expectancy is then found by taking the following differences: C-A and D-B (AVGSHIFT). If we add the two averages, we obtain the total change in life expectancy (TOTAL) and if we divide AVGSHIFT/TOTAL we obtain an estimate of the percent of the change in life expectancy that was due to a shift in the relationship between income and life expectancy.



The sources of the shift analysis are shown in the table above. We updated the data used by Preston when possible and used estimates of GDP per capita from Maddison (2006). We collected life expectancy and GDP per capita data from as early in the 20th century as possible for as many countries as possible. Countries were first identified using the United Nations life expectancy numbers for the year 1960 and working backwards to collect historical data. Complete data on life expectancy and GDP per capita were obtained for 12 countries in 1900, 29 countries in 1930, 36 countries in 1940, and 53 countries in 1960. When literacy rates were added, sample sizes changed to 28 (1930), 28 (1940), and 52 (1960).

Notes

1. The main reason for mortality decline during the 1930s-1960s has been largely attributed to public health interventions and improved medical advances. It is estimated that between 50 and 70% of the mortality decline that took place after 1945 was associated with medical interventions such as antibiotics (Preston 1976; Palloni and Wyrick 1981). The remaining decline was probably associated with better standards of living, increased knowledge about exposure, resistance to illnesses and assorted other factors. Furthermore, a large fraction of these gains was concentrated early in the life of individuals, between birth and age 5 or 10.

2. There are now several comprehensive surveys that have individual-level data on health. In this paper, we use as examples countries where these data are readily available. From Latin America there are the Mexican Health and Aging Study (**MHAS**, first wave, n=7171), Puerto Rican Elderly: Health Conditions (**PREHCO**, first wave, n=4293), Survey on Health, Well-Being and Aging in Latin America and the Caribbean (**SABE**, n=10,597), and Costa Rican Study of Longevity and Healthy Aging (**CRELES**, first wave, n=2827). From Asia there are the China Health and Nutrition Study (**CHNS**, n=5772), Chinese Longitudinal Healthy Longevity Survey (**CLHLS,** third wave, n=16,064), Indonesia Family Life Survey (**IFLS**, wave 2000, n=3998), Matlab Health and Socio-Economic Survey (**MHSS**, n= 3721), WHO Study on Global Ageing and Adult Health Study in India (**WHO-SAGE**, first wave, n=6559) and China (**WHO-SAGE**, first wave, n=5149), and Social Environment and Biomarkers of Aging Study (**SEBAS**, n=1023). From Africa there are the WHO Study on Global Ageing and Adult Health Survey from Ghana (**WHO-SAGE**, first wave, n=5000) and South Africa (**WHO-SAGE**, first wave, n=3150). From the developed world there are the Health and Retirement Study (**HRS**, wave 2000, n=12,527), Wisconsin Longitudinal Study (**WLS**, wave 2004, n=6378), English Longitudinal Study of Ageing (**ELSA**, second wave, n=8780), and Survey of Health, Ageing and Retirement-Netherlands (**SHARE-Netherlands**, first wave, n= 2979).

3. Growth rates for those aged 60 and above in the year 2000: Argentina (1.7) experienced a peak in growth rate during the 1950s and since then growth rate has declined; Bangladesh (3.2) has yet to reach its peak growth rate and so this segment of the population continues to grow; Brazil has maintained a steady growth rate (3.6) and will continue to grow; Chile experienced a decline in its growth rate (3.0) but is projected to rise again; China (2.7) is still increasing; Costa Rica (3.5) continues to increase; Cuba (3.3) fluctuates but still appears to grow; Ghana (3.5) will maintain a high rate of increase; India (3.1) will maintain a high rate of increase; Indonesia (3.6) also high; Mexico (3.2); Netherlands (1.1); Puerto Rico (2.7); South Africa (3.5); England and Wales (0.4); US (1.0); Uruguay (1.0); Barbados (0.5) (author's calculations using United Nations data) (United Nations Statistics Division 2008).

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Table 1. Patterns of mortality decline from 1930-1960

	Life Expectancy							IMR						
		Year			Pace		Level		Year			Pace		Level
Regime	**1930**	**1940**	**1960**	**30-40**	**40-60**	**30-60**	**1930**	**1930**	**1940**	**1960**	**30-40**	**40- 60**	**30-60**	
Very early decline, graded (late 1800s)														
Netherlands	66	62	73	-0.4	0.55	0.23	Vhigh	51	39	18	1.2	1.05	1.1	Vlow
UK	60.8	61.6	71	0.08	0.47	0.34	Vhigh	60	57	22	0.3	1.75	1.3	Vlow
US	61	63.7	69.7	0.27	0.3	0.29	Vhigh	61	49	25.2	1.2	1.19	1.2	Vlow
SA-whites	66		70.4	0.2	0.12	0.15	High	67	50	30	1.7	1	1.2	Vlow
Early decline, graded (prior to 1920s)														
Argentina	53	56	65	0.3	0.45	0.4	High	100	90	62	1	1.4	1.3	Low
Uruguay	50	58	68	0.8	0.5	0.6	High	100	86	47	1.4	1.95	1.8	Low
Cuba	42	45	64	0.3	0.95	0.73	Mid	113	104	59	0.9	2.25	1.8	Low
Early decline, mid-paced (1920s-1940s)														
Puerto Rico	40	45	69	0.5	1.2	0.97	Mid	133	114	43	1.9	3.55	3	Mid
Costa Rica	42	49	62	0.7	0.65	0.67	Mid	155	132	71	2.3	3.05	2.8	Mid
Taiwan	40.9	43.4	67.5	0.25	1.205	0.89	Mid	181	158	45	2.3	5.65	4.5	Mid
SA-blacks	42.9		58.5	0.71	0.425	0.52	Mid	197		129	1.7	2.55	2.3	High
Chile	35	38	57	0.3	0.95	0.73	Mid	234	217	125	1.7	4.6	3.6	High
Early/later decline, rapid (1930s-40s)														
Mexico	34	39	57	0.5	0.9	0.77	Low	144	132	81	1.2	2.55	2.1	Mid
Brazil	34	37	55	0.3	0.9	0.7	Low	262	239	117	2.3	6.1	4.8	High
Barbados	38	40	66	0.2	1.3	0.93	Low	231	180	60	5.1	6	5.7	High
Later decline, rapid (1950s)														
India	30.9	35	45.5	0.41	0.525	0.49	Vlow	226	188	140	3.8	2.4	2.9	Vhigh
Bangladesh	30.9	35	41.2	0.41	0.31	0.34	Vlow	226		174	0.6	2.3	1.7	Vhigh
China	30		44.6	0.2	0.63	0.49	Vlow	300		121	1	8.45	6	Vhigh
Ghana	30	35	46	0.1	0.25	0.2	Mid	240		124	1	5.3	3.9	Vhigh
Indonesia	32.6	40	42.5	0.74	0.125	0.33	Vlow	294	294	166	0.4	6.2	4.3	Vhigh

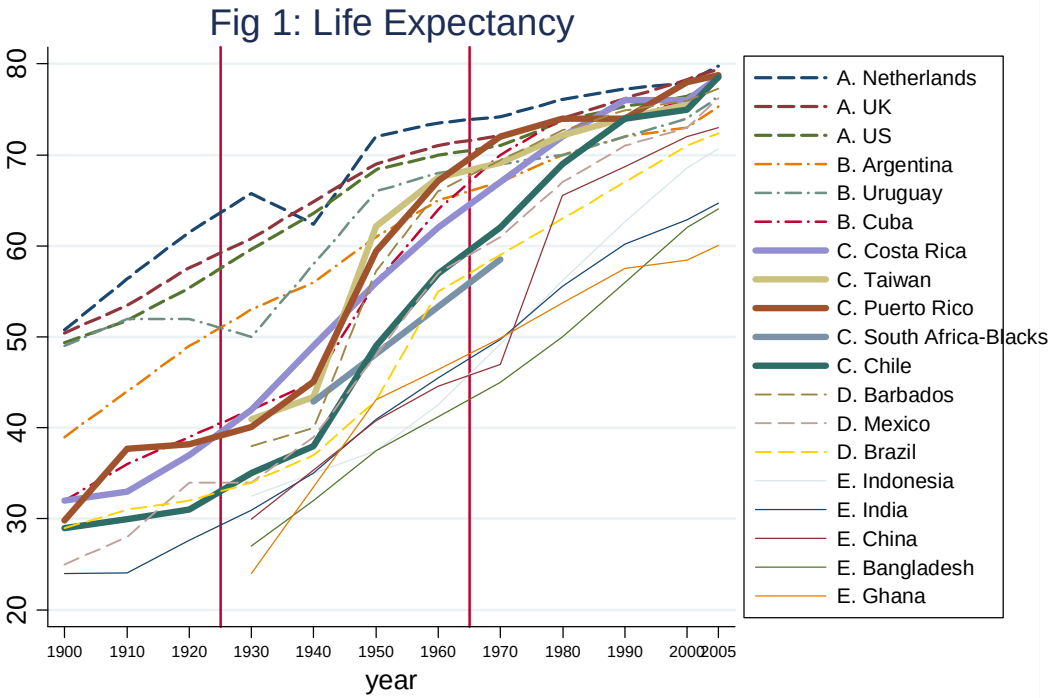
Note: Sources for life expectancy and infant mortality are in appendix. SA=South Africa.

Table 2: Examples of variation within regimes in standard of living and health care in 2000

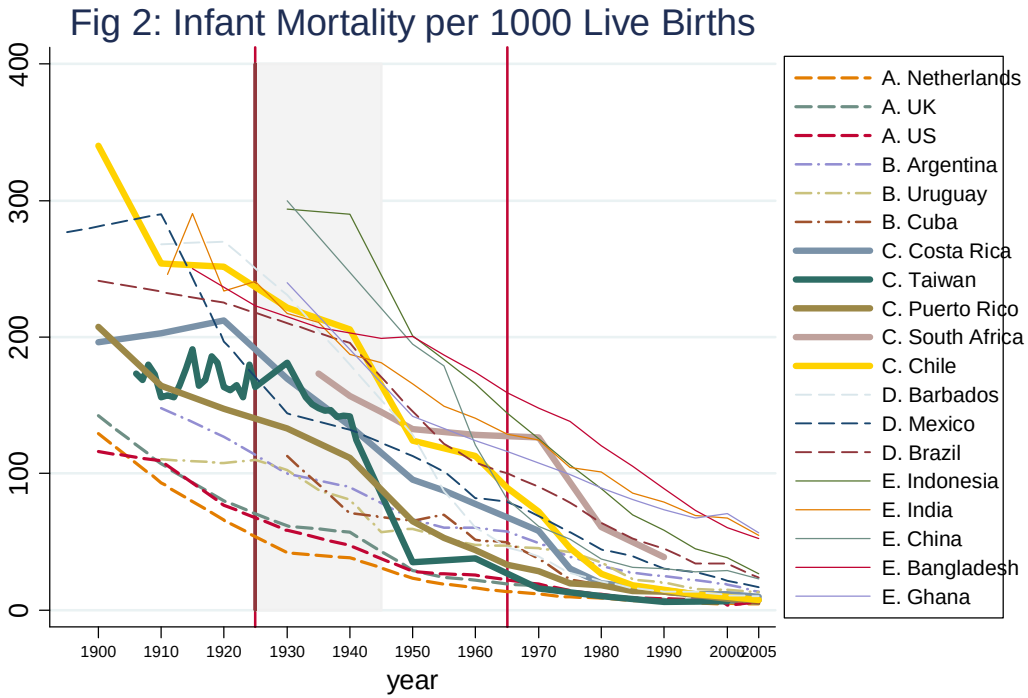
	GDP per capita (1990 international dollars)[a]			Income group	Health care rating[b]	Life expectancy at age 60 (M, F)	Human development ranking
Regime at birth	**1930**	**1940**	**1960**	**2000**	**2000**	**2000**	**2000**
Very early decline, graded (1800s)							
Netherlands	5603	4831	8287	High	17	18.9, 23.7	8
UK	5441	6856	8645	High	18	18.8, 22.7	13
US	6568	6573	11,028	High	37	19.6, 23.1	6
South Africa-whites	2247	2496	3041	Upper middle	175	14.5, 17.1	107
Early decline, graded (prior to 1920s)							
Argentina	4246	4127	5503	Upper middle	75	17.8, 22.8	34
Uruguay	4301	3661	4960	Upper middle	65	17.1, 22.2	40
Cuba	1505	1208	2052	Upper middle	39	19.3, 21.5	55
Early decline, mid-paced (1920s-1940s)							
Puerto Rico	815	896	3421	High	37	19.6, 23.1	---
Costa Rica	1626	1763	2715	Upper middle	36	19.3, 22.8	43
Taiwan	1099	1365	1354	High	---	---	---
South Africa-blacks	2247	2496	3041	Upper middle	175	14.5, 17.1	107
Chile	3143	4161	4320	Upper middle	33	18.3, 22.7	38
Early/later decline, rapid (1930s-1940s)							
Mexico	1478	1455	2700	Upper middle	61	19.7, 21.7	54
Brazil	1098	130	2222	Upper middle	125	16.2, 19.6	73
Barbados	1815	1698	4034	High	46	18.6, 22.6	31
Later decline, rapid (1950s)							
India	659	637	718	Lower middle	112	14.6, 17.7	124
Bangladesh	659	637	529	Low	88	14.7, 15.7	145
China	567		439	Lower middle	144	16.6, 20.4	96
Ghana	878	1000	1122	Low	135	14.5, 16.5	129
Indonesia	1164	1235	1019	Lower middle	92	15.5, 17.5	110

Sources: Maddison 2006, WHO (2000b, 2002), Word Bank; and the United Nations Development Program (2002).

Notes: a. Bangladesh was part of India until 1947; Puerto Rico and Barbados GDP per capita numbers are estimated through linear extrapolation.
b. lower numbers are better;

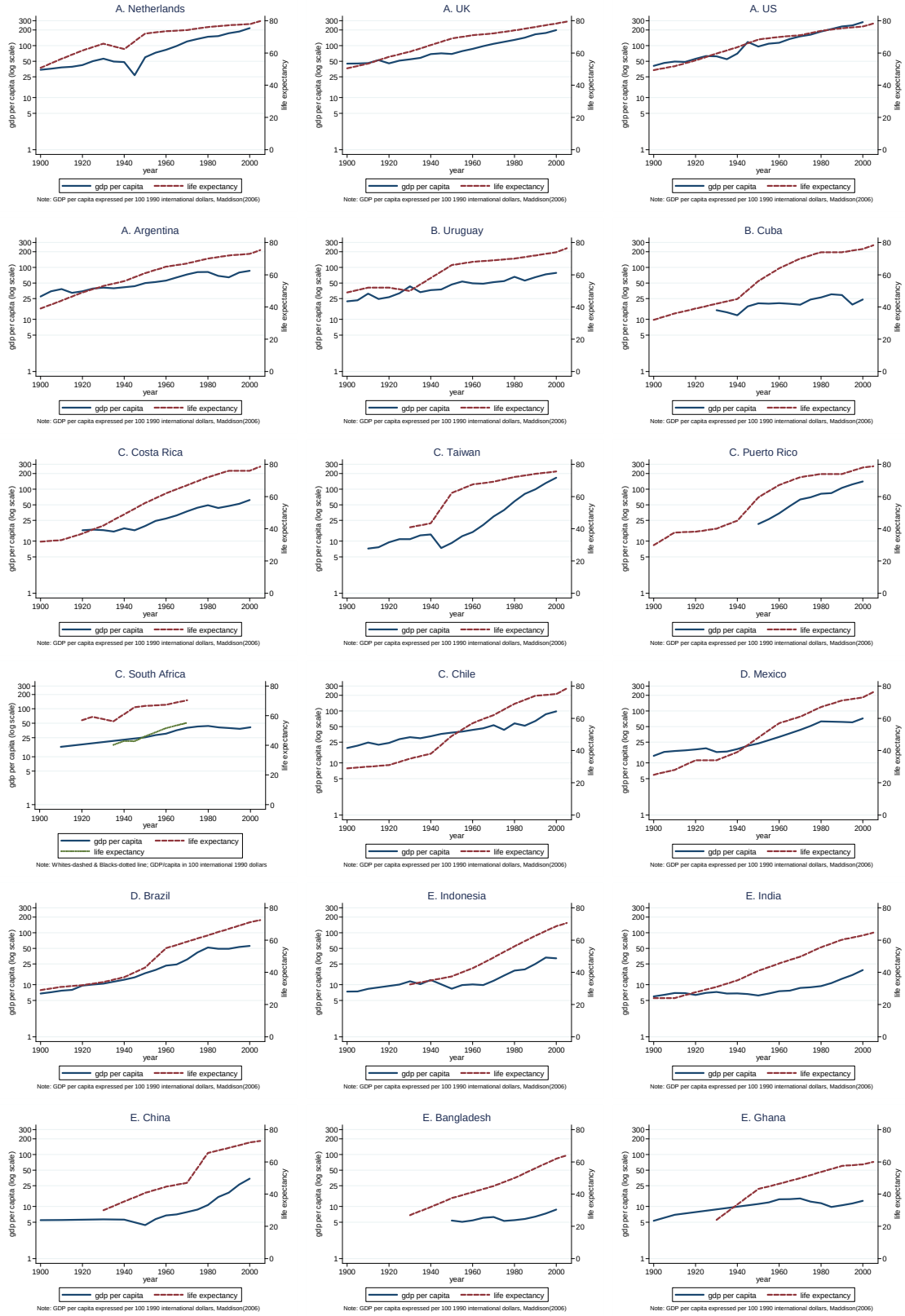


Note: Countries listed from highest to lowest life expectancy in 1930; See appendix for sources.



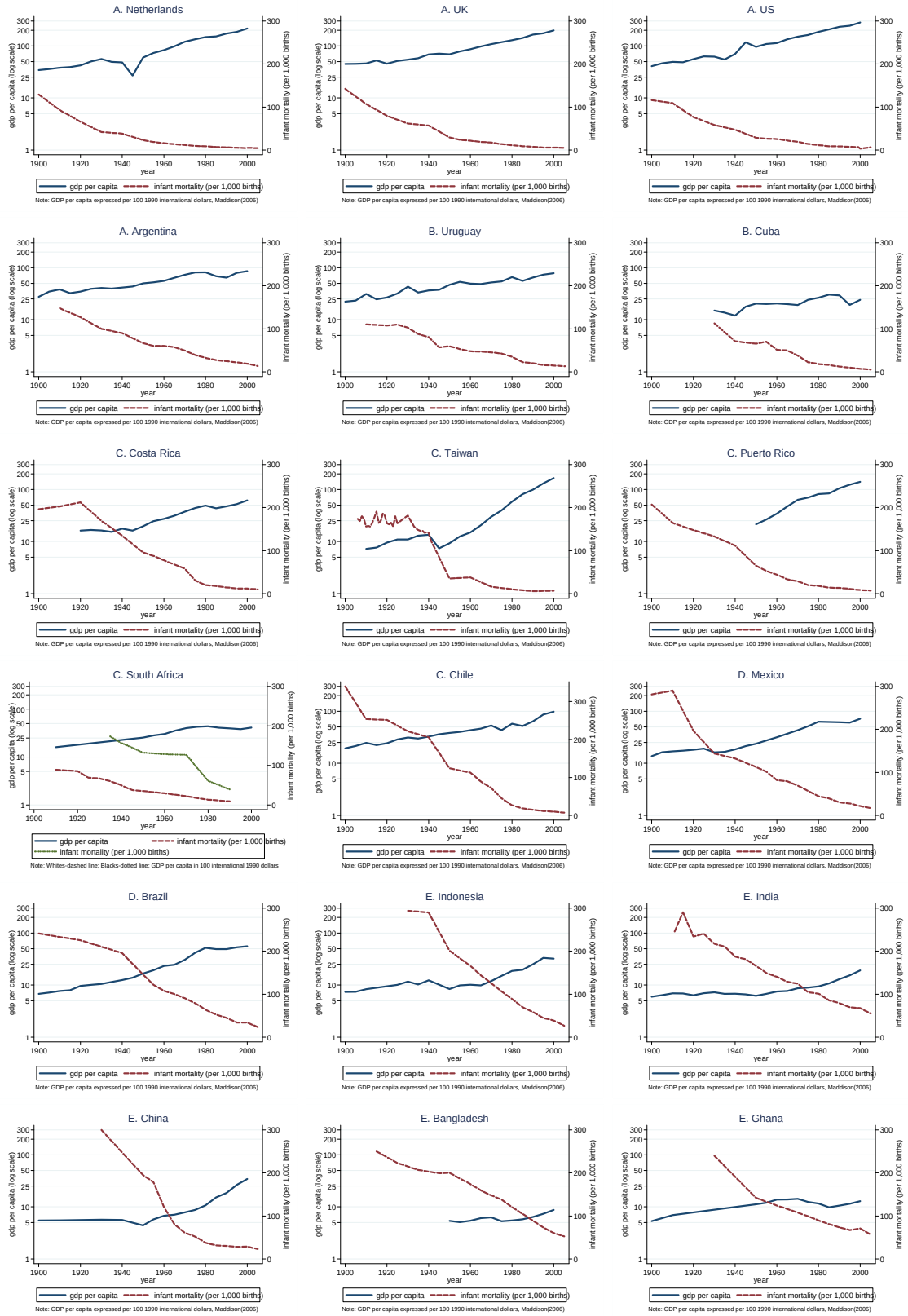
Note: Countries listed from highest to lowest life expectancy in 1930; See appendix for sources.

Table 3: Life expectancy vs ln GDP per capita (1990 international dollars) from 1900-2000

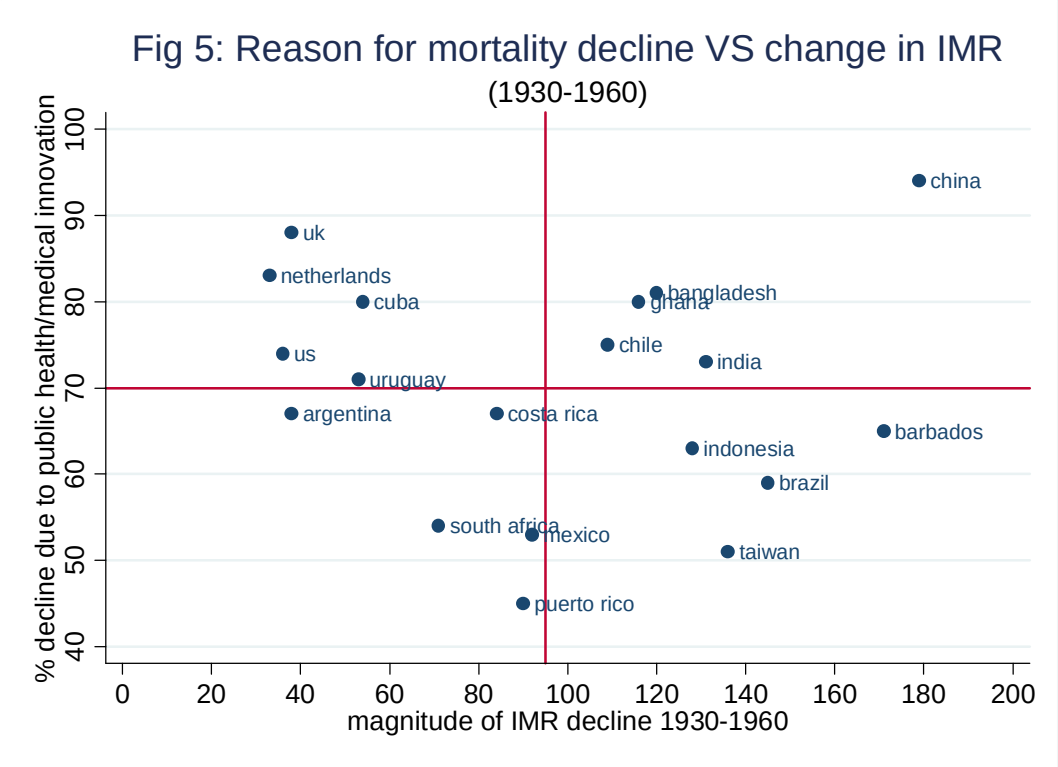


Notes: A: Very early regimes; B: Early regimes; C: Mid-paced regimes; D: Later regimes; E: Very late regimes. Barbados (pattern D) not shown due to incomplete information on GDP per capita.

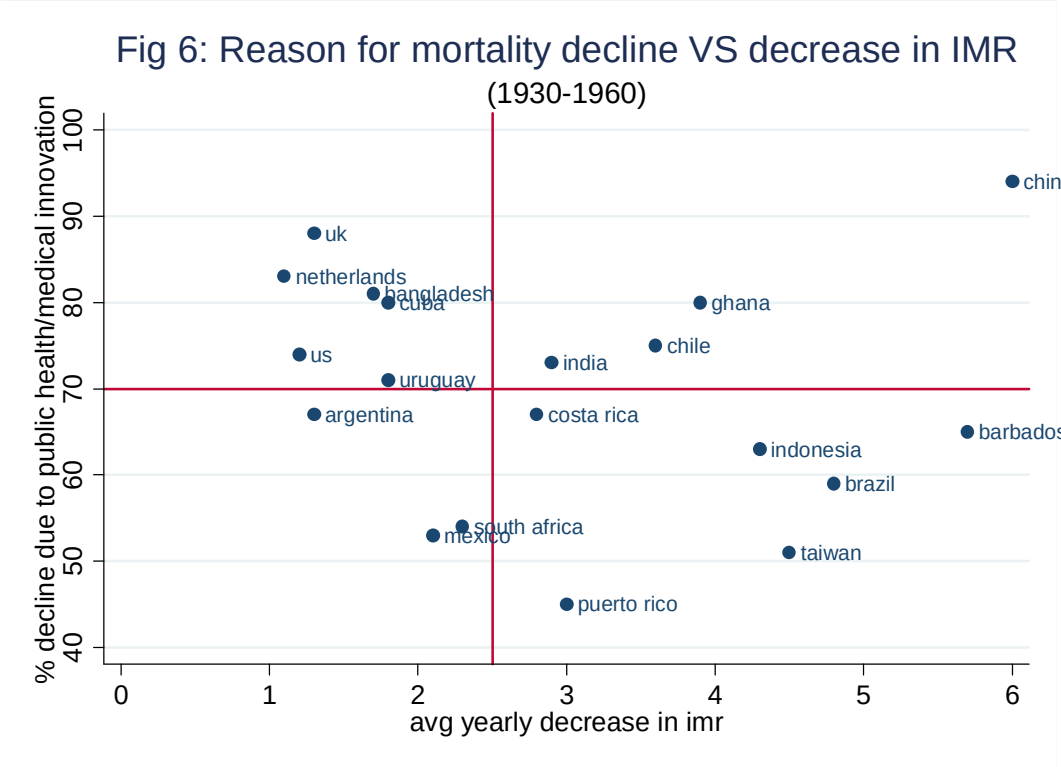
Table 4: IMR vs ln GDP per capita (1990 international dollars) from 1900-2000



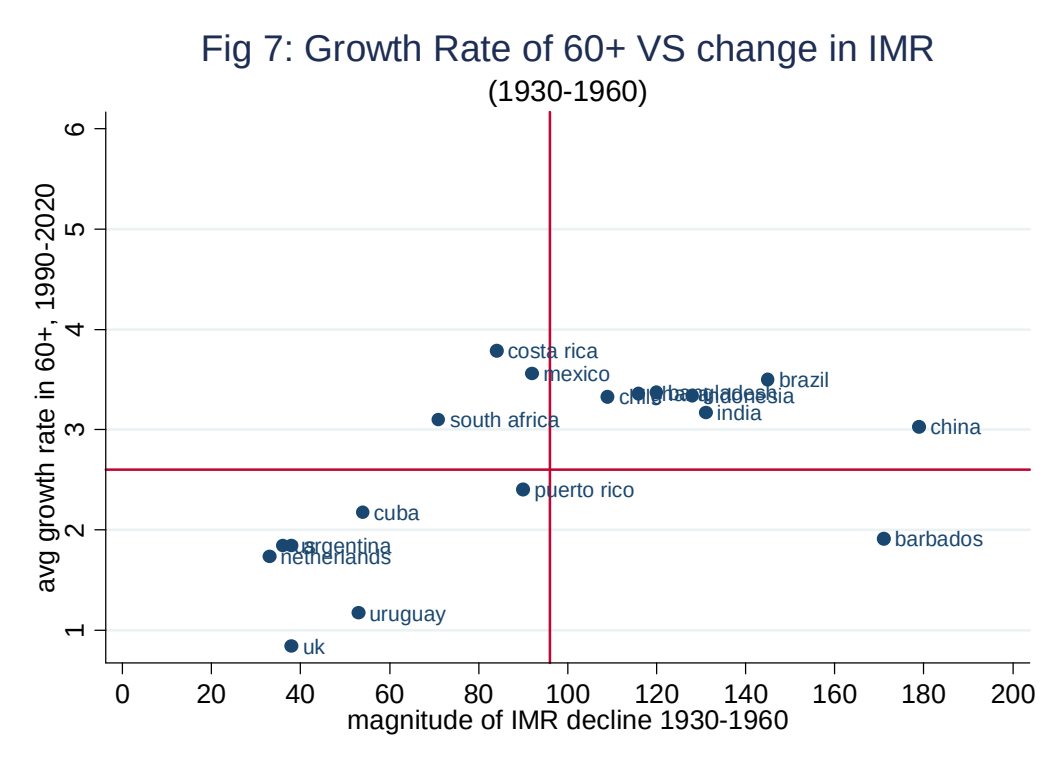
Notes: A: Very early regimes; B: Early regimes; C: Mid-paced regimes; D: Later regimes; E: Very late regimes. Barbados (pattern D) not shown due to incomplete information on GDP per capita.



Note: lines are plotted at average values.



Note: lines are plotted at average values.



Note: lines are plotted at average values.

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