Urbanization and Mortality Decline

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Abstract

We investigate the relationship between mortality decline and urbanization, which has hitherto been proposed by demographers but has yet to be tested. Using pooled-OLS, fixed effects first differences and long differences we find evidence for a robust negative correlation between crude death rates and urbanization. The use of Granger causality tests and instrumental variables suggest that this relationship is causal. Our preliminary results suggest that mortality decline causes urbanization through the creation of new cities rather than promoting urban growth in already-extant cities.

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1 Introduction

The past century has been a period of massive demographic and economic change across the world. Two of the most important of these changes have been the rapid decline in mortality and the rise of urbanization. In the former case the advent of modern public health, the invention of penicillin and other new drugs, the creation of international organizations like the WHO and other interventions have reduced mortality across all parts of the world, especially those previously prone to dangerous communicable tropical diseases. In the latter case all regions have seen huge increases in the proportion of people who live in cities to the point where it was estimated in 2007 that majority of humans lived in cities for the first time in world history.

These two indisputable facts about modern history have largely been discussed independently in the economics literature, which has largely focussed on the economic rather than demographic reasons behind urbanization. Here for the first time we use cross-national panel data to examine the relationship between mortality decline and urbanization through the use of pooled-OLS, fixed effects, first differences, long differences, Granger causality tests and instrumental variables across a wide range of country samples and years. The evidence not only suggests that mortality decline is robustly associated with urbanization but that other variables previously thought to be correlated with urbanization such as GDP per capita and agriculture as a share of GDP are not robustly correlated with urbanization when employing country fixed effects and first differences, respectively.

Most of the literature in economics on urbanization has focussed solely on rural-urban migration as the mechanism by which countries become proportionally more urban. Thus much of the literature has neglected the other major pathway to urbanization, namely the redefinition of rural localities as urban areas once they cross a given population threshold. Here our preliminary results suggest that mortality decline causes urbanization not through promoting greater rural-urban migration but instead by causing rural population growth and thereby spurring the creation of new cities.

The rest of the paper is organized as such. First in Section 2 we outline the major hypothesized reasons behind urbanization, starting with the economic causes behind rural-urban migration. We then outline three ways in which mortality decline could lead to urbanization, namely via rural population growth leading to rural-urban migration, urban natural population growth, and urban mortality decline leading to rural-urban migration. In Section 3 we discuss our data and the results, first for OLS and fixed effects and then with instrumental variables. In Section 4 we conclude.

2 Theory

In recent decades urbanization has largely been explained through attention to the economic determinants of rural-urban migration, especially the rural-urban wage gap that arose out of urban industrial transformation. This argument goes all the way back to Friedrich Engels' emphasis on the role of manufacturing in pulling rural migrants into cities and more recently formed the basis for (Todaro, 1969)'s noted model whereby rural inhabitants migrated to urban areas despite notable levels of urban unemployment due to expected future wages (see (Kelley & Williamson, 1984) for an overview). For much of the 20th century the wage gap/structural transformation argument was seen as convincing (Brueckner, 1990), and still appears to be convincing in explaining urbanization in Europe and North America (Michaels, Rauch, & Redding, 2012; Nunn & Qian, 2011). Similarly some cross-national analyses have found a robust relationship in pooled-OLS results between GDP/capita, the sectoral composition of GDP and/or the labour force, and levels of urbanization (J. C. Davis & Henderson, 2003; Moomaw & Shatter, 1996).

However, recent urbanization in the developing world – and especially in Sub-Saharan Africa – has largely proceeded despite a small to non-existent wage gap and a lack of industrialization. Indeed, in their study of urbanization (Fay & Opal, 2000, p. 27) note that "the very fact that our results show a weak relationship between urbanization and traditionally accepted migration factors may indicate that, in Africa at least, we are omitting part of the urbanization story." Moreover, the cross-national econometric analyses that support the structural transformation theory rely upon pooled-OLS results with year fixed effects; however, upon introducing country fixed-effects both (J. C. Davis & Henderson, 2003; Moomaw & Shatter, 1996) find that GDP/capita is no longer correlated with urbanization, suggesting that this relationship is driven by cross-national differences in both GDP/capita and urbanization rather than within-country differences across time. ((Moomaw & Shatter, 1996, p. 22) argue that this result is a consequence of a lack of sufficient time-series data, while (J. C. Davis & Henderson, 2003) let this result pass without comment.)[1]

As a result various scholars have attempted to explain the urbanization process through other potential mechanisms. For instance, (Barrios, Bertinelli, & Strobl, 2006) suggest that decreasing levels of rainfall have led to urbanization in late 20th-century Africa as lower rainfall leads to lower agricultural employment, leading rural residents to migrate to urban areas.[2] (Gollin, Jedwab, & Vollrath, 2012; Jedwab, 2012) also focus on explaining African urbanization, which they argue has been in large part driven by natural resource exports and a sectoral shift from agriculture into non-tradable sectors. Finally, (Poelhekke, 2011) argues that agricultural risk (as measured by standard deviations of agricultural produce) drives rural-urban migration, even in areas with little to no economic growth.[3]

Recent evidence from demographers has, however, suggested that mortality decline as part of the demographic transition has played a major, if not the major, role in explaining modern urbanization (Dyson, 2011; Fox, 2012). The relationship between mortality decline and urbanization is not necessarily straight-forward, however, inasmuch as it consists of four potential mechanisms, each of which we examine in turn.

2.1 Rural Mortality Decline, Rural Population Growth and Definitional Change

The most obvious way in which mortality decline can contribute to urbanization is through an increase in rural population and subsequent population growth above urban threshold levels. Many countries define urbanization levels with a threshold for population centres below which the centre is considered rural and above which it is urban. Thus mortality decline in rural localities below the threshold can, ceteris paribus, push these localities above the threshold and make them officially urban, thereby increasing the percentage urban in the country overall.

2.2 Rural Mortality Decline and Rural-Urban Migration

The second mechanism hypothesizes a causal link between rural mortality decline as high rural population growth creates rural unemployment and thus spurs rural-urban migration. In other words, this is a "push" mechanism whereby people want to leave rural areas, in contrast to the "pull" story told by (Todaro, 1969) in which people want to move to cities. Despite the fact that economists have historically preferred "pull" stories about urbanization (Kelley & Williamson, 1984, p. 420), there is nonetheless a substantial literature linking rural-urban migration to rural population growth. The link between mortality decline and population growth is well established, most recently and notably by (Acemoglu & Johnson, 2007), who show that increasing life expectancy is positively correlated with population and number of births in a cross-section of countries. As for the link between population growth and rural-urban migration, (Hoselitz, 1957) argued for a causal link between rural population growth, youth unemployment and rural-urban migration in Asia, while both (Schultz, 1971; Shaw, 1974) showed a strong correlation between rural-population growth and out-migration across mid-20th century Latin America. More recently (J. C. Davis & Henderson, 2003, p. 115) have shown a robust positive association between population growth and urbanization, which they claim as a result of rural population growth and subsequent rural-urban migration.

2.3 Urban Mortality Decline and Urban Natural Increase

The third potential mechanism is through urban mortality decline and a subsequent increase in the rate of urban natural population growth to the point where it is higher than the rural natural rate of population growth. Here there is no doubt that urban mortality decline is essential for modern urbanization to take place, inasmuch as pre-modern cities had higher mortality rates than fertility rates and thus rural-urban migration only helped to maintain city populations rather than increase them (Dyson, 2011; Haines, 2001; Lees & Hohenberg, 1989; Lynch, 2003; Wrigley, 1985). However, the result of declining urban mortality is almost always to bring rural and urban natural rates of increase synchronous to each other rather than to push urban natural growth rates higher than rural growth rates (Dyson, 2011, p. 36), with exceptions to the rule both rare and fleeting, as discussed below with regards to modern Africa. Thus urban mortality decline by itself cannot drive urbanization.

2.4 Urban Mortality Decline and Rural-Urban Migration

The fourth and final potential mechanism is that declining urban mortality rates lead to higher rural-urban migration as people migrate to cities to take advantage of better public health facilities. While this mechanism is plausible at least theoretically, few if any surveys of rural-urban migrants have ever suggested that health concerns are a major consideration in their decision. For instance, one survey from Ecuador suggested that the most popular motives for migrating included not enough work, attending school, being with friends/relatives and not enough income (Bilsborrow, McDevitt, Kossoudji, & Fuller, 1987). Similarly, strong evidence from one study of eight countries in Africa suggests that rural women who have had one or more child die are actually less likely to migrate to cities than they are to migrate to other rural areas, leading the authors to clearly state that 'women in sub-Saharan Africa do not move to cities to escape the much higher mortality conditions facing their children in rural areas' (Brockerhoff & Eu, 1993).

2.5 Empirical Evidence

Thus from these four potential mechanisms only the first two are plausible, namely definitional change and rural-urban migration. Here we explain the data we use for our analysis. The cross-national panel data on urbanization and mortality both come from the United Nations Population Division in five-year increments from 1950 to 2005. In the former case we measure urbanization as the log of the percentage urban, to avoid the problem of being bounded at both 0 and 1. Nonetheless, due to the fact that urbanization is measured differently across countries and, depending on varying definitions, can often stabilize at levels below 100% (J. C. Davis & Henderson, 2003), we have also used log of total urban population as an alternative dependent variable while also controlling for log of total population, with near-identical results (results available from authors). We also used the GLM method devised by (Papke & Wooldridge, 1996) for situations where the dependent variable is bounded between 0 and 1 with very similar results, again available from the authors upon request.

The UN urbanization data is based on data from individual countries and thus relies upon country-specific definitions of urbanization. These definitions, however, vary widely in their threshold for the difference between rural and urban areas: at the extremes the current threshold is 200 people in Iceland and Norway while in Japan and South Korea it is 50,000 people, a 250-fold difference. (Both the median and modal value for countries with an urban threshold is 2000.) Thus using urbanization levels as a dependent variable in cross-national regressions, as in (Gollin, et al., 2012), could lead to inaccurate results as countries with higher thresholds should, ceteris paribus, have lower levels of urbanization.

To see if there is a relationship between urban thresholds and urbanization levels we plot urbanization levels in 2010 against urban thresholds in 2010 in Figure 1 for the 55 countries whose threshold is listed in the two most recent UN Demographic Yearbooks. While the relationship is negative, as expected, it is very weak, with an R2 of only 0.03, which suggests that varying levels of urban thresholds do not play a role in determining urbanization levels. Nonetheless, we employ fixed effects, first differences and long differences in order to eliminate these cross-country differences from our analysis.

[Insert Figure 1 here]

We employ data from the UN Population Prospects database on crude death rate, which is given in the total number of deaths per country over a five year period divided by the total number of person-years per country over the same period. Mortality is normally defined as the ratio of deaths per 1000 inhabitants but here we normalize it to deaths per 10,000 inhabitants. We list the mortality data under the most recent of the five-year period; thus the mortality data for 1950-1955 is listed under 1955. We also use mortality data from the World Bank as a robustness check; it correlates with the UN data at r=0.972 and yields the same results as below.

We add two control variables found to be consistently correlated with urbanization in previous research into urbanization (J. C. Davis & Henderson, 2003; Fay & Opal, 2000; Fox, 2012; Poelhekke, 2011), namely real GDP per capita (from the Penn World Tables, in constant 2005 US dollars) and agriculture as a percentage of GDP (from the World Bank). The link between GDP per capita and urbanization has a long theoretical pedigree, most notably in (Lewis, 1954)'s two-sector model by which economic growth in cities prompts rural-urban migration. Agriculture as a percentage of GDP is a more problematic variable for the simple reason that many countries currently define urban areas in part by a minimum threshold of the percentage of people or economic activity outside the agricultural sector, including Botswana (with a minimum of 75% of the economy outside agriculture), Chile (50% of employees involved in non-agricultural work), Japan (60% of the population engaged in non-agricultural work) and Lithuania (2/3 of employees involved in non-agricultural work), among others. Thus we introduce each of these variables separately in our regressions, not only due to missing observations but also due to concerns about multicollinearity. We also introduced other control variables such as log of population, manufacturing as a percentage of GDP,[4] democracy (as measured by Polity IV), rainfall,[5] continent dummies, total fertility rate and temperature, none of which were consistently statistically significant (results available from authors).

2.6 Basic Results

We present our first set of results in Table 1, starting with a regression of log urban percentage on lagged crude death rate before introducing log GDP per capita and agriculture as a share of GDP in subsequent regressions. The model estimated is given by:

$$\ln UrbPerc_{it} = \alpha + \beta \ln CrudeDeath_{it} + \gamma \ln GDPpc_{it} + \delta AgriGDP_{it} + \epsilon_{it} \tag{1}$$

where, $\ln UrbPerc_{it}$ is log of percentage of population that is urban for country i and time t, $\ln CrudeDeath_{it}$ is the log of crude death rate of country i and time t, $\ln GDPpc_{it}$ is log GDP per capita of country i and time t, $AgriGDPpc_{it}$ is the share of agriculture in total GDP for country i and time t, and ϵ_{it} is an error term assumed to be normally distributed with $N(0, \sigma^2_{\epsilon_{it}})$. Despite our stated need to use fixed effects to account for different definitions of urbanization we nonetheless begin by comparing pooled OLS and fixed effects results to see if the control variables vary in their relationship with urbanization. Thus in Columns 1-3 we first show pooled OLS results while columns 4-6 use fixed effects in order to examine whether the results are driven by cross-country differences rather than within-country change. Columns 1 and 4 are perfectly balanced samples, while the other columns are unbalanced. In all specifications we introduce year dummies (not reported here) and cluster the standard errors at the country-level.

[Insert Table 1 here]

As expected, we find a consistently negative and statistically significant relationship between mortality and urbanization, as well as with agriculture as a share of GDP. Moreover, we confirm the findings of (J. C. Davis & Henderson, 2003) that GDP per capita is correlated with urbanization using pooled OLS but not when using fixed effects, albeit with a much larger sample size.[6] In itself this is a substantial finding which adds to previous research indicating a lack of a fixed-effects relationship between income and civil wars (Djankov & Reynal-Querol, 2010) and income and democracy (Acemoglu, Johnson, Robinson, & Yared, 2008).[7] The loss of nearly half of our observations by controlling for GDP per capita and agriculture as a share of GDP slightly reduces the size of the coefficient on the mortality variable as well as its statistical significance but it remains at all times significant at the 1% level. Figure 2 plots the simple cross-national times-series relationship between crude mortality and log of urbanization between 1955 and 2005.

[Insert Figure 2 here]

We next first difference (by 5 and 10 years) both the urbanization variable and the crude death rate variable of our basic equation 1 to examine whether changes in mortality are associated with changes in urbanization, as presented in Table 2 in five-year differences for panel A and ten-year differences for panel B. The basic model estimated is given by:

$$\ln UrbPerc_{it} - \ln UrbPerc_{i,t-k} = \vartheta + \mu(\ln CrudeDeath_{it} - \ln CrudeDeath_{i,t-k}) + \rho \ln GDPpc_{it} + \phi AgriGDP_{it} + \varepsilon \tag{2}$$

where, $\ln UrbPerc_{it-k}$ is the log of percentage of population that is urban for country i and time $t-k$, where $k = 5, 10$, $\ln CrudeDeath_{i,t-k}$ is the crude death rate of country i and time $t-k$, $k = 5, 10$, $\ln GDPpc_{it}$ is log GDP per capita of country i and time t, $AgriGDP_{it}$ is the share of agriculture in total GDP for country i and time t, and ε_{it} is an error term assumed to be normally distributed with $N(0, \sigma^2_{\varepsilon_{it}})$. Here again for the sake of completeness we present OLS estimates in columns 1-3 and fixed effects in columns 4-6. In panel A for all regressions but two the mortality variable is significant at the 5% level, including the basic fixed effects regression in column 4, while in column 5 the mortality variable is significant at the 8% level and in column 6 it is significant at the 10.1% level. The weak statistical relationship in these final two columns could, of course, be driven by the fact that both urbanization and mortality decline are slow-moving variables: in many countries such as Argentina, Belgium, Canada and Switzerland, for instance, the crude death rate declined by less than 2 persons per 1000 over the entire 50-year period. As such we turn to the ten-year differences in panel B, where the mortality coefficient is instead always significant at the 5% level. In Panel A Log GDP and Agriculture as a Share of GDP are not consistently associated with urbanization, and in Panel B neither variable is ever correlated with urbanization.

[Insert Table 2 here]

Another alternative with slow-moving variables is to use only the first and last years of our sample in a balanced long difference regression. Thus in Table 3 we present our estimates of our basic regression, equation 2, in column 1 and a regression including GDP per capita as a control in column 2 using the years 1955 and 2005. Data on agriculture as a percentage of GDP is only available from 1960, however, and only for an unrepresentative sample of 32 countries for the start and end dates of 1960 and 2005. As a result we follow previous studies of urbanization (Fay & Opal, 2000; Poelhekke, 2011) and use 1970 as a starting point for column 3, which yields 83 countries with observations for both years. Our results, as reported in in Table 3, show that change in mortality remains correlated with change in urbanization at the 1% level in all three regressions. Change in log GDP is not correlated in column 2 but, oddly, is negatively correlated with change in urbanization in column 3, as is change in agriculture as a percentage of GDP. We plot the relationship between mortality and urbanization from column 1 in figure 3.

[Insert Table 3 and Figure 3 here]

We also conducted various other robustness checks which we do not have space to report here. First, there exists some evidence for region-specific causes of urbanization. For instance, (Barrios, et al., 2006) show that rainfall is negatively correlated with urbanization in Sub-Saharan Africa but not elsewhere, while other evidence from suggests that modern Africa has never had higher urban mortality than rural mortality. As such we ran all of our regressions from Tables 1-3 in samples which separately excluded Africa, the Americas, Europe and Asia, with no changes in our results. We also followed (Fay & Opal, 2000) to see if the effect of mortality change differed across democracies and non-democracies by separately examining each group as a sub-sample (as defined by Polity UV). Finally, for all regressions we excluded countries with small populations in 1950, with thresholds of either 100,000 (thereby dropping seven countries) or 500,000 people (dropping 25 countries). In none of these cases do our results change.

2.7 Testing for Reverse Causality

Our results so far clearly suggest that mortality decline is correlated with urbanization, and the Granger causality tests undertaken indicate that mortality decline precedes urbanization rather than vice-versa (results for Granger causality are tabulated in Appendix 2). We now turn to concerns about reverse causality, whereby urbanization could be driving mortality decline rather than vice-versa. More specifically, in countries where urban mortality rates are lower than rural mortality rates, exogenous increases in urbanization could thereby drive down the overall mortality rate (Li & Wen, 2005, p. 478).

For this thesis to be true it would require increasing levels of urbanization unrelated to mortality decline, which by definition must come from either excessive urban fertility rates or rural-urban migration. The first possibility can easily be ruled out as all empirical scholarship on the topic has found a general trend of initial higher fertility rates in rural than urban areas converging towards relatively equal urban and rural fertility rates across time, whether historically in Europe or in 20th-century Bangladesh, Egypt, Sri Lanka and China (even prior to the one-child policy) (Abu-Lughod, 1964; Dyson, 2011; Khan & Raeside, 1997; Lavely & Freedman, 1990).

The second potential cause of urbanization, namely rural-urban migration, is certainly a more plausible cause of reverse causality. For instance, modern Sub-Saharan Africa has always seen lower mortality rates in urban than rural areas due to better public health facilities (Gould, 1998, pp. 172-173); thus rural-urban migration could at least theoretically have increased urbanization levels while also decreasing the overall mortality rate. However, the reason why this gap between rural and urban areas existed in the first place was because African rural-urban migrants were highly restricted in their movements under colonial rule, when cities were built for European residence and Africans were kept away from city centres precisely for health reasons (Freund, 2007, pp. 76-82). Indeed, as independence brought an end to restrictions on rural-urban migration, the mortality gap between urban and rural areas declined rapidly as the public services which had been built for much smaller urban populations were unable to cope with higher numbers of city dwellers, leading to increasing mortality rates for all urban residents (Gould, 1998, pp. 173-175).[8] Moreover, demographic and health survey data from Africa suggests that lower urban mortality rates are driven not by differences in adult mortality rates, which are actually higher in urban than rural areas, but instead by differences in child mortality rates (Günther & Harttgen, 2012). Those most likely to benefit from lower child mortality rates in cities would be permanent urban residents rather than rural-urban migrants, who are disproportionately single and have fewer children than both rural and permanent urban residents across a variety of contexts (Brockerhoff & Eu, 1993; Hare, 1999; Zhao, 1999). In such situations higher urbanization levels as a result of rural-urban migration are thus unlikely to push national mortality rates down.

In fact, even if urban public services could cope with a rapid increase in population as a result of rural-urban migration, there remains the assumption that rural-urban migrants would enjoy the same levels of mortality as the rest of the permanent urban population. Yet here evidence is again clear, with numerous studies showing that mortality rates among recent rural-urban migrants are higher than among those born in cities. For instance, in early modern Europe rural-urban migrants were unable to cope with urban outbreaks of diseases they had heretofore never encountered, in contrast to the non-migrant urban residents who were less disease prone at least in part due to immunities they had developed (Finlay, 1981, p. 174). More recently evidence suggests that 20th-century rural-urban migrants across the developing world had poorer diets than both permanent urban residents and rural residents, in large part because migrants are not accustomed to cooking for themselves or purchasing food (Johnson, 1964, pp. 307-308). Finally, evidence from both India and Senegal suggests that migrants with children have higher infant and child mortality rates than permanent urban residents, in the latter case even after living for a decade or more in urban areas (Brockerhoff, 1990; Stephenson, Matthews, & McDonald, 2003). It is thus no accident that previous research has found a relationship between urbanization and the loss of disability-adjusted life years (Ghobarah, Huth, & Russett, 2003).

Despite this substantial evidence it is still possible that we have neglected an alternative avenue and thus we utilize the instrumental variable created by (Acemoglu & Johnson, 2007), who develop an instrument that predicts future changes in life expectancy based on new innovations and technologies designed to address diseases. They use their instrument to capture the effects of increases in life expectancy on economic growth and other variables in a 47-country study for the period 1940 to 1980, finding that increases in life expectancy have an effect on GDP, fertility and population growth but not on GDP per capita. Their dataset includes populous countries from the Americas, Asia, Europe and Oceania but not Africa. To check to see if the sample is representative of our wider sample we used our basic regression from column 1 of Table 1 only with the 47-country sample and then again only with the 122 countries not included in the AJ analysis. We found almost identical coefficients on the lagged mortality variable (-0.737 for the 47-country sample and -0.733 for the 122-country sample), both of which are highly statistically significant, which suggests that the AJ sample is representative of the wider sample. (The results are similar with fixed effects and the control variables.)

Here we would like to use their instrument to account for the effects of mortality on urbanization. However, the complete data on mortality collected by the United Nations begins only in 1950 with a small 42-country sample available for the years before 1950 from the 1950 Demographic Yearbook. We have two solutions to this problem. In the first instance we use the 42-country sample despite the fact that it does not include such countries as Brazil, China and Ecuador. In general the data is given by country; in the case of New Zealand, however, it was given by race (Maori and non-Maori), which we then altered to reflect the whole country by weighting the data according to population figures for the 1930s. Due to the fact that mortality rates in 1940 are sharply higher than in 1939 for many European countries due to the onset of World War II, we take the mean of each country's observed mortality between 1935 and 1939 to calculate the 1940 mortality variable. We then follow AJ and subtract our mortality variable for 1940 from the UN-defined mortality rate for 1975-1980 for our right-hand side variable.

Our second solution is to interpolate mortality data for 1935-39 from the rate of mortality change between 1950-55 and 1965-70 in a similar fashion to the way (Acemoglu & Johnson, 2007) construct their life expectancy data.[9] (Our results do not change if we extrapolate from the 1950-55 to 1955-60 rate, or replace the linear interpolation with a log). This solution, while not ideal, nonetheless gives us the data on mortality for the full 47-country sample. We also used League of Nations data from the pre-war period, which is available for 40 countries in the sample; whether used alone or averaged with the UN data the results concord with the ones presented below.

We do not, however, have reliable data on urbanization in 1940 as neither the League of Nations nor any other international source calculated such data at the time. While the UN did list data on urbanization in its initial Demographic Yearbook in 1950, this data ranged in origin from 1930 in Belgium and El Salvador to 1948 in Japan, Romania and others, with no clear way of knowing whether the definitions of urbanization are comparable to the 1980 data. We could collect urbanization levels from various individual country censuses, as other demographers have done (K. Davis & Casis, 1946), but doing so would not only bias our results towards those countries with censuses but would again make the comparison faulty due to unadjusted changes in definitions of urbanization. As a result we again use the UN data to interpolate urbanization levels in 1940 based on the rate of urbanization between 1950 and 1960. We plot the basic relationship between change in urbanization and change in the two measures of mortality in Figures 4a and 4b, both of which exhibit a clear downward sloping relationship.

[Insert Figures 4a and 4b here]

We report our results in Table 4, with first-stage results in Panel A and second-stage results in Panel B. In columns 1 and 2 we use the League of Nations data on mortality and a 45-country dataset, while in columns 3 and 4 we use the interpolated data from the United Nations and a 47-country dataset. We add a control for change in GDP per capita over the time span in columns 2 and 4. As seen in Panel A, AJ's predicted mortality instrument is highly correlated with change in actual mortality, and in Panel B change in crude death rate remains negative and statistically significantly correlated with change in urbanization, albeit weakly in column 4 (p=0.054). Controlling for change in GDP makes no difference to our results in columns 2 and 4, and using the interpolated data on mortality in columns 3 and 4 also fails to alter our results.

[Insert Table 4 here]

As a final robustness check we complete our empirical analysis with one more set of instrumental variable results. In this case we use the malaria ecology index computed by (Kiszewski et al., 2004), which is a measure of the degree to which the non-human environment is conducive to the spread of malaria. Because it does not consider modern health interventions it is a good measure of malarial conditions prior to modern health interventions, and has been used as an instrument for mortality and life expectancy in other recent scholarship (Cervellati & Sunde, 2011; Lorentzen, McMillan, & Wacziarg, 2008). Here, however, we use the malaria ecology index not as an instrument for mortality itself but rather for future mortality decline, since those areas with the highest initial levels of malaria were also those most likely to benefit from DDT, bed-nets, indoor residual spraying and modern health education. Indeed, the evidence for adult mortality and life expectancy convergence more generally across the late 20th century is compelling, even considering debates about to what degree convergence holds for infant mortality (Acemoglu & Johnson, 2007; R. Clark, 2011; Neumayer, 2003; Wilson, 2001).

In Table 5 we present our results with malaria ecology as an instrument for change in CDR between 1955 and 2005 while retaining the dependent variable of change in urbanization over the same time period. (While our results do not differ if we use a starting date of 1940 as in Table 5, we prefer to use the unadultered United Nations data here.) In Panels A and B we present first- and second-stage results, respectively, with F-statistics listed in Panel A to indicate the strength of the instrument(s). In column 1 we just use malaria ecology as an instrument without controls, and introduce change in GDP as a control in column 2. In columns 3 and 4 we repeat the exercise, but this time introduce a second instrument to capture the pre-modern disease environment, namely log of mean elevation.[10] We focus on elevation here merely because it is uncorrelated with the malaria ecology index (r=-0.096), but other geographic variables such as mean temperature and absolute latitude yield identical results whether used alone or in combination with each other.

[Insert Table 5 here]

The results are as expected, with malaria ecology performing strongly as an instrument, whether alone or in combination with mean elevation. Change in GDP is negative and significant but does not alter the relationship between mortality change and urbanization, and the use of two instruments rather than one pass overidentification tests in columns 3 and 4.

3 Historical Evidence

As noted above there is significant qualitative evidence suggesting that the spur for modern urbanization was the advent of modern public health in the late 19th century. As such we should see a relationship between mortality decline and urbanization using pre-1950 data as well, with or without controls for sectoral change. However, unlike with the post-1950 data, which yields a perfectly balanced dataset, the historical data is extremely unbalanced, with data on mortality from (Mitchell, 2007a, 2007b, 2007c) going back to 1815 in Denmark, France, Norway and Sweden but only the 1920s in parts of the Americas and Eastern Europe. Thus we only examine long differences between 1900 and 1950, using data on urbanization and the percentage of the labour force in agriculture from the Cross-National Times-Series Data Archive (CNTSDA; http://www.databanksinternational.com/) where it is measured using thresholds of 20,000 (the same as in contemporary Syria), 25,000 and 50,000 (the same as in Japan and South Korea) people. We also use GDP/capita data from Maddison when it is available, and data from the CNTSDA on the percentage of the labour force employed in agriculture. In all cases we take the average value for the years 1900-04 and 1950-54 (except for the case of Japan, where urbanization data is available from 1952-54), with similar results if we use 1890-94 instead as a starting date (albeit with a diminished dataset). Without controls we have a dataset of 26 countries across Europe, North and South America, Oceania and Asia; when controlling for GDP the number of countries drops to 21 and when controlling for labour force in agriculture it again drops to 13. (The list of countries is given in Appendix 4.)

Our results are given in Table 6, first without controls, then controlling for GDP and then controlling for both GDP and labour force. In all nine columns change in crude death rate is negative and statistically significant despite a very small sample size. Change in GDP/capita is also significant in columns 3-7 but not 8 or 9, and change in labour force in agriculture is negative and statistically significant in columns 7-9.

[Insert Table 6 here]

4 Investigating Mechanisms

Having established that there is a causal relationship between mortality decline and urbanization, we now attempt to establish the operative mechanism at play. From section 2 we recall two potential mechanisms that could link mortality decline and urbanization, namely definitional change and rural-urban migration. The first way we attempt to distinguish between these two mechanisms is to distinguish between infant mortality and adult mortality, inasmuch as we would expect the former to be correlated with urbanization if it were definitional changes that was the operative mechanism (as brought about through population growth), while we would instead expect declines in the latter to be correlated with urbanization if it was rural adult population growth leading to job scarcity and rural-urban migration that was the operative mechanism. Here we rely upon data from the UN Population Prospects on infant mortality (as calculated by the number of deaths under the age of one per 1000 births) and data on adult mortality from (De Walque & Filmer, 2011). The latter data uses sibling mortality reports as collected in Demographic and Health Survey data to calculate adult mortality in five-year increments between 1975-79 and 2000-04 for 46 countries.

In Table 7 we rerun our estimations of equation 1 from columns 4-6 in Table 1; here, however, we substitute crude death rate with infant mortality and adult mortality separately and then together. In columns 1-3 we see that infant mortality is always negatively and significantly associated with urbanization, while in columns 4-6 adult mortality is never associated with urbanization. In columns 7-9 we include both infant and adult mortality variables and, despite a greatly reduced dataset from the first three columns, again observe a consistent negative relationship between infant mortality and urbanization but no relationship between adult mortality and urbanization.

[Insert Table 7 here]

The strong relationship between infant mortality and urbanization in Table 7 is not particularly surprising given the high correlation between infant mortality and the crude death rate (r = 87.5) compared to the correlation between adult mortality and the crude death rate (r = 51.8). However, what is surprising is the total lack of any correlation between adult mortality and urbanization, which suggests that rural-urban migration as caused by adult population growth and rural job scarcity is not a major mechanism in the process of urbanization. Of course this is not a definitive finding, inasmuch as declines in infant mortality might possibly spur rural-urban migration directly as parents migrate to urban areas for jobs that will feed their larger families. Moreover, it is possible that infant mortality decline merely has a lagged effect on rural unemployment rather than an immediate one.

A second way to assess the relative importance of rural-urban migration vs. definitional changes is to examine actual city data across a long time period and examine the relationship between mortality decline and urban growth rates in a stable number of cities vs. all cities above a certain threshold. To complete this exercise we use two sets of data on all cities in the world over the threshold of 100,000 people in 1960 and 2010, as compiled in the 1962 and 2011 UN Demographic Yearbooks, respectively. (The threshold is admittedly high but it is the only such comprehensive source for city populations for 1960, and it is only twice the size of the current highest urban thresholds in the world used in Japan and South Korea.) We compiled three observations per country. First, we tabulated the population of all cities that had 100,000 or more residents in 1960 and calculated the percentage of the total population that lived in these cities. Second, we calculated the population of these same exact cities in 2010 and recalculated the percentage of the population that lives in the same cities in 2010. Third, we tabulated the total population of all cities that had 100,000 or more residents in 2010 and calculated the percentage of the population that lived in these cities in 2010.

This exercise allowed us to use two different dependent variables measuring change in urbanization between 1960 and 2010. The first such measure used the first two observations, which calculates the change in the percentage of the population that lives in the same cities in 1960 and 2010. The second measure used the first and the third observations, or the change in the total population that lives in all cities with 100,000 or more residents between 1960 and 2010. To take one example, Estonia had one city with more than 100,000 residents in 1960, namely Tallin (with a population of 288,000 people, or 23.7% of the total population). In 2010 the population of Tallinn had grown to 399,816, or 30.8% of the total population. However, in the intervening years another city had grown above the 100,000 threshold, namely Tartu (population 103,512), which, using this threshold, gave a total urban population of 503,328 in 2010 for an urbanization level of 38.8%. In other words, the urbanization level in Estonia between 1960 and 2010 increased from 23.7% to 38.8%, for an absolute increase of 15.1%, of which 8% was due to the inclusion of the population of the city of Tartu under the total sum of urban residents and 7.1% was due to an increasing percentage of people living in Tallinn. In our analysis we continue to measure urbanization using logs, such that change in log percentage urban in the first case comes to 0.262 and 0.493 in the second case.

We can thus regress changes in these two different variables onto change in crude death rate, while adding change in log GDP per capita as well as a control variable.

$$\Delta UrbPerccity10K_i = \zeta + \theta\Delta\ln CrudeDeath_i + \lambda\Delta\ln GDPpc_i + \eta_i \tag{3}$$

where, $\Delta UrbPerccity10K_i$ is the change in log of percentage of population living in cities with population greater than 10,000 residents, of country i for time period 1960-2010, for columns 1-4, and for all cities for columns 5-8. $\Delta\ln CrudeDeath_i$ is the change in the log of crude death rate of country i over 1960-2010, $\Delta\ln GDPpc_i$ is the change in log GDP per capita of country i,for 1960-2010 and η_i is an error term assumed to be normally distributed with $N(0,\sigma^2_{\eta_i})$.(Adding change in agriculture as a percentage of GDP as well yields a maximum of 14 observations, with results that match those recorded here.) In fifteen cases the UN demographic yearbook for 1960 noted a lack of congruence between its data and country census data, with another 37 cases for 2010; in all 52 cases we eliminate the countries from our analysis due to concerns about accuracy,[11] but the results hold if these cases are included. Since the data in all cases is taken directly from country censuses, in several cases the data is not from 1960 or 2010 and thus we estimate the data given the urban population growth rates between the two dates that are given. However, in some cases the initial observation was zero (i.e., the largest city had less than 100,000 residents) while the second was above 100,000. In such cases estimating the 2010 city population based on growth rates from the first observation would obviously yield an overestimate for the 2010 population, and thus instead we use the average annual urban population growth rate from the entire sample of 2.21%. In all 35 cases with an initial urbanization level of zero we are also confronted with the question of how to compute change in log of percentage urban, whereby we assume an urbanization level of 1% for the purposes of the exercise. Nonetheless, due to concerns about data accuracy we re-do our analysis using only countries which had at least one city with a population higher than 100,000 in 1960.

In Figures 5a and 5b we present visual estimates of the relationship between growth in cities that existed in 1960 against mortality decline and then using growth in urbanization instead, respectively.

[Insert Figures 5a and 5b here]

We tabulate our results in Table 8, first only counting the same cities in 2010 that existed in 1960 in columns 1-4, and then using all cities with 100,000 or more residents in columns 5-8. In columns 1-2 and 5-6 include all countries in the dataset while in columns 3-4 and 7-8 we only include countries which had an urbanization level above zero in 1960. Finally, in the even-numbered columns we control for change in log GDP per capita.

[Insert Table 8 here]

Our results are striking. In columns 1-4, where change in urbanization does not include the addition of new cities, change in mortality is not correlated with change in urbanization; however, when including new cities that grew over the 100,000 threshold in columns 5-8, mortality decline is negatively and robustly correlated with change in urbanization.

5 Conclusion

In this paper we have shown that mortality decline is correlated with urbanization between 1955 and 2005 across a wide range of specifications and with numerous control variables. Moreover, our use of various instrumental variables suggests that this relationship is causal. We also show that this relationship holds for historical early-20th century data as well. Finally, we suggest that mortality decline causes urbanization through the creation of new cities rather than by promoting rural-urban migration.

Our results have at least two broader ramifications. First, previous scholarship like (Acemoglu & Johnson, 2007; Young, 2005) has claimed that mortality decline does not necessarily contribute to broader development. However, we add to a different set of literature that suggests that mortality decline might not necessarily lead directly to economic growth but that the link might instead be indirect. Indeed, some evidence suggests that the effects of urbanization on economic growth are positive for developing countries (Bertinelli & Black, 2004; Brülhart & Sbergami, 2009; Henderson, 2003). Moreover, other evidence suggests that urbanization encourages ethnic homogenization and could thereby help to alleviate the noted downsides of ethnic diversity (Green, 2013).

Second, our research allows for further insight into the relationship between mortality decline, urbanization and economic growth. For instance, (Nunn & Qian, 2011) show that the introduction of the potato was responsible for higher population growth and urbanization in early modern Europe. (Nunn & Qian, 2011) argue that the relationship between the introduction of the potato and higher urbanization can be explained either via an increase in agricultural productivity or an increase in per capita income, which they claim in both cases would lead to rural-urban migration. However, (Nunn & Qian, 2011) do not consider a third potential mechanism tying the potato to higher rates of urbanization, which is that the higher levels of nutrition brought about by the introduction of the potato led to mortality decline, higher population growth rates and subsequent urbanization through the creation of new cities.[12]

There are several avenues for further research. First, it is important to disaggregate the contribution of mortality decline to definitional changes, rural-urban migration and urban population growth, especially at the sub-national level where panel data on rural-urban migration exists. Second, researchers could disaggregate mortality decline itself, in particular by focussing on mortality decline at different age ranges. Current UN data on mortality grouped by 5-year age sets only extends back to 1995 but sub-national data may prove more useful in this regard. Finally, it may be possible to put an economic value on mortality decline by calculating the added value it brings to society by promoting urbanization and subtracting its negative direct effects on GDP per capita established by (Acemoglu & Johnson, 2007).

Notes

[1](Moomaw & Shatter, 1996) use data covering the period 1960 to 1980 only; for (J. C. Davis & Henderson, 2003) the data covers 1960 to 1995.

[2](Brückner, 2012) presents instrumental variable evidence which suggests that declining rainfall leads to lower levels of agricultural value added as a share of GDP in Africa, which is then negatively correlated with urbanization levels.

[3]However, note that (Fay & Opal, 2000) find no relationship between deviations in crop yields and subsequent urbanization.

[4]We confirm (Jedwab, 2012)'s finding that manufacturing as a percentage of GDP is statistically significantly correlated with urbanization in a sample excluding Africa but not in an only-Africa sample; in both cases mortality decline remains negative and statistically significant.

[5]We confirm (Barrios, et al., 2006)'s finding that rainfall is negatively correlated with urbanization using time- and country-fixed effects but that this result is entirely driven by African countries.

[6](J. C. Davis & Henderson, 2003) use a sample of a maximum of 129 countries whereas ours has a maximum of 166 countries with GDP data. (Fay & Opal, 2000, p. 20) find a positive association between income and urbanization using fixed effects but their sample only includes a maximum of 100 countries.

[7](Nunn & Qian, 2011, p. 615) find a positive and significant relationship between GDP per capita and urbanization using either year or country fixed effects, but do not report results using both year and country fixed effects. Moreover, by starting their analysis in 1500, when data on income is only available for 22 countries, their sample is severely unbalanced.

[8]To take one example, poor housing for migrants led to outbreaks of infectious diseases like tuberculosis, which then spread easily to permanent urban residents as well (Johnson, 1964, p. 308).

[9]The extrapolated mortality data for 1940 is correlated with the UN data at r=0.78.

[10]The relationship between mortality decline and elevation is negative, such that areas which were more mountainous like China, Morocco, Papua New Guinea and Yemen saw large declines in mortality over the period.

[11]To give one such example, the most recent Syrian census recorded a total urban population of 19.6 million people, or considerably larger than the total country population of 11.7 million people!

[12]Alternatively, it is possible that the introduction of the potato was equivalent to a change in the Malthusian technology schedule, whereby technological change results in population growth but not necessarily economic growth (G. Clark, 2007, pp. 28-29), and it is the former rather than the latter that contributes to urbanization.

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Table 1: Urbanization and Mortality Decline
(Dependent Variable: Log of Percentage Urban)

Regression	OLS	OLS	OLS	FE	FE	FE
	(1)	(2)	(3)	(4)	(5)	(6)
Crude Death Rate	-0.783***	-0.319***	-0.211***	-0.282***	-0.287***	-0.218***
	(0.060)	(0.055)	(0.063)	(0.042)	(0.051)	(0.070)
Log GDP per capita		0.359***	0.200***		0.008	-0.091
		(0.029)	(0.042)		(0.051)	(0.060)
Agriculture share of GDP			-1.468***			-0.944***
			(0.042)			(0.166)
Constant	4.608***	1.094***	2.377***	3.658***	3.728***	5.0173
	(0.104)	(0.277)	(0.475)	(0.078)	(0.385)	(0.527)
N	1859	1505	1091	1859	1505	1091
Country Clusters	169	166	162	169	166	162
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	no	no	no	yes	yes	yes
R^2	0.464	0.633	0.655	0.362	0.362	0.383

* p ≤ 0.10, ** p ≤ 0.05; *** p ≤ 0.01; robust standard errors clustered at the country level are in parentheses.

Table 2: Urbanization and Mortality Decline, First Differences
(Dependent Variable: Log of Percentage Urban)

Regression	OLS	OLS	OLS	FE	FE	FE
Panel A: Five-year differences						
	(1)	(2)	(3)	(4)	(5)	(6)
Crude Death Rate	-0.079***	-0.093***	-0.097**	-0.021**	-0.025*	-0.031†
	(0.025)	(0.034)	(0.045)	(0.010)	(0.014)	(0.019)
Log GDP per capita		0.013	-0.012		0.035**	0.020
		(0.018)	(0.017)		(0.016)	(0.015)
Agriculture share of GDP			-0.228***			-0.051
			(0.067)			(0.053)
Constant	0.078***	0.062***	0.112***	0.110***	0.101***	0.116***
	(0.010)	(0.009)	(0.018)	(0.005)	(0.008)	(0.014)
N	1690	1339	927	1690	1339	927
Country Clusters	169	166	155	169	166	155
Time Dummies	yes	yes	yes	yes	yes	yes
R^2	0.111	0.098	0.184	0.100	0.079	0.159
Panel B: Ten-year differences						
	(1)	(2)	(3)	(4)	(5)	(6)
Crude Death Rate	-0.184***	-0.169***	-0.133***	-0.095**	-0.073***	-0.064**
	(0.040)	(0.043)	(0.042)	(0.034)	(0.027)	(0.028)
Log GDP per capita		-0.002	0.004		0.006	-0.002
		(0.028)	(0.033)		(0.020)	(0.030)
Agriculture share of GDP			0.001			-0.013
			(0.022)			(0.021)
Constant	0.068***	0.166***	0.220***	0.075***	0.173***	0.218***
	(0.008)	(0.022)	(0.033)	(0.008)	(0.014)	(0.023)
N	845	628	411	845	628	411
Country Clusters	169	166	154	169	166	154
Time Dummies	yes	yes	yes	yes	yes	yes
R^2	0.172	0.159	0.193	0.158	0.127	0.183

* $p \le 0.10$, ** $p \le 0.05$; *** $p \le 0.01$; robust standard errors clustered at the country level are in parentheses. † $p = 0.101$.

Table 3: Urbanization and Mortality Decline, Long Differences
(Dependent Variable: Δ in Log of Percentage Urban)

Time Period	1955-2005	1955-2005	1970-2005
	(1)	(2)	(3)
Δ in Crude Death Rate	-0.345***	-0.246***	-0.276***
	(0.049)	(0.058)	(0.078)
Δ in Log of GDP per capita		-0.032	-0.264***
		(0.039)	(0.090)
Δ in Agriculture % of GDP			-1.720***
			(0.354)
Constant	4.215***	4.527***	6.724***
	(0.052)	(0.617)	(0.793)
N	338	136	166
Country Clusters	169	68	83
Time Dummies	yes	yes	yes
Country Dummies	yes	yes	yes
R^2 (overall)	0.445	0.309	0.193

* p ≤ 0.10, ** p ≤ 0.05; *** p ≤ 0.01; robust standard errors clustered at the country level are in parentheses.

Table 4: Urbanization and Mortality Decline, Instrumental Variable Results

	(1)	(2)	(3)	(4)
CDR 1940 Data	1935-39 average	1935-39 average	1950-65 UN data	1950-65 UN data
Panel A: First-Stage Results (Dependent Variable: Δ in Crude Death Rate, 1940-1980)				
Δ in Predicted Mortality	0.987***	1.002***	2.092***	1.345***
	(0.223)	(0.262)	(0.338)	(0.392)
Δ in GDP per capita		-0.023		1.276***
		(0.213)		(0.318)
R^2	0.307	0.307	0.339	0.346
Panel B: 2SLS Results (Dependent Variable: Change in Log of Percentage Urban)				
Δ in Crude Death Rate	-0.238**	-0.264**	-0.142***	-0.191*
	(0.120)	(0.121)	(0.055)	(0.099)
Δ in GDP per capita		0.041		0.175
		(0.096)		(0.245)
N	42	42	47	47
R^2	0.244	0.254	0.272	0.337

* p ≤ 0.10, ** p ≤ 0.05; *** p ≤ 0.01; robust standard errors are clustered to take into account the same unit of observation for Bangladesh, India and Pakistan in 1940.

Table 5: Urbanization and Mortality Decline, Instrumental Variable Results

	(1)	(2)	(3)	(4)
	Panel A: First-Stage Results (Dependent Variable: Δ in Crude Death Rate, 1955-2005)			
Malaria Ecology	-0.302***	-0.420***	-0.337***	-0.425***
	(0.064)	(0.110)	(0.067)	(0.108)
Elevation (log)			-2.065***	-1.970**
			(0.486)	(0.951)
Δ in GDP, 1955-2005		-2.652**		-3.202**
		(1.262)		(1.343)
Constant	-8.253***	-5.784***	4.395	6.929
	(0.669)	(1.660)	(3.008)	(6.295)
F-statistic	22.34	9.36	20.88	7.71
R^2	0.075	0.140	0.154	0.163
	Panel B: 2SLS Results (Dependent Variable: Change in Log of Percentage Urban, 1955-2005)			
Δ in Crude Death Rate	-0.122***	-0.132***	-0.100***	-0.109***
	(0.021)	(0.033)	(0.017)	(0.029)
Δ in GDP		-0.360**		-0.302**
		(0.172)		(0.287)
Constant	-0.374	-0.254	-0.155	-0.086
	(0.228)	(0.328)	(0.170)	(0.287)
N	164	66	156	63
χ2 (p-value)			0.130	0.139

* p ≤ 0.10, ** p ≤ 0.05; *** p ≤ 0.01; robust standard errors are clustered to take into account the same unit of observation for Bangladesh, India and Pakistan in 1940.

Table 6: Urbanization and Mortality Decline, 1900-1950
(Dependent Variable: Δ in Log of Percentage Urban)

Urban Threshold	50,000	25,000	20,000	50,000	25,000	20,000	50,000	25,000	20,000
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Δ in Crude Death Rate	-0.058**	-0.048*	-0.057**	-0.059**	-0.054*	-0.060**	-0.131***	-0.108***	-0.122***
	(0.023)	(0.025)	(0.026)	(0.024)	(0.027)	(0.028)	(0.019)	(0.023)	(0.026)
Δ in Log of GDP per capita				0.049**	0.043*	0.054*	0.088**	0.051	0.068
				(0.021)	(0.024)	(0.028)	(0.039)	(0.048)	(0.056)
Δ in % Labour Force in Agriculture							-0.291***	-0.338***	-0.368***
							(0.050)	(0.083)	(0.100)
Constant	0.256***	0.273***	0.324***	-0.095	-0.028	-0.066	-0.148	0.154	0.100
	(0.050)	(0.054)	(0.056)	(0.173)	(0.214)	(0.238)	(0.300)	(0.385)	(0.447)
N	52	52	52	42	42	42	26	26	26
Country Clusters	26	26	26	21	21	21	13	13	13
Time Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
R^2 (overall)	0.459	0.458	0.418	0.536	0.532	0.510	0.477	0.474	0.440

* p ≤ 0.10, ** p ≤ 0.05; *** p ≤ 0.01; robust standard errors clustered at the country level are in parentheses.

Table 7: Urbanization and Mortality Decline (Fixed Effects)
(Dependent Variable: Log of Percentage Urban)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Infant Mortality Rate	-0.041***	-0.043***	-0.031***				-0.022**	-0.019**	-0.028*
	(0.007)	(0.007)	(0.009)				(0.009)	(0.009)	(0.015)
Adult Mortality Rate				-0.775	-0.573	0.012	0.706	0.592	0.944
				(1.268)	(1.216)	(1.430)	(0.920)	(0.959)	(0.902)
Log GDP per capita		-0.022	-0.100		0.072	-0.007		0.047	-0.048
		(0.051)	(061)		(0.053)	(0.060)		(0.050)	(0.059)
Agriculture Share of GDP			-0.930***			-0.449**			-0.479**
			(0.169)			(0.210)			(0.191)
Constant	3.667***	3.967***	5.016***	3.499***	2.958***	3.306***	3.363***	2.968***	3.931***
	(0.089)	(0.397)	(0.532)	(0.027)	(0.405)	(0.488)	(0.106)	(0.413)	(0.571)
N	1848	1505	1091	248	243	216	248	243	216
Country Clusters	168	166	162	46	46	44	46	46	44
Time Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
R^2 (overall)	0.433	0.396	0.440	0.045	0.153	0.139	0.120	0.180	0.176

* p ≤ 0.10, ** p ≤ 0.05; *** p ≤ 0.01; robust standard errors clustered at the country level are in parentheses.

Table 8: Urbanization and Mortality Decline 1960-2010, with 100,000 as a threshold
(Dependent Variable: Log of Percentage Urban)

Dependent variable	Δ in % living in cities with 100,000+ residents in 1960				Δ in % living in all cities with 100,000+ residents			
	All countries in dataset		Countries > 0% urban in 1960		All countries in dataset		Countries > 0% urban in 1960	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ in Crude Death Rate	0.002	-0.006	-0.006	-0.012	-0.066***	-0.074***	-0.032***	-0.038***
	(0.005)	(0.009)	(0.010)	(0.013)	(0.012)	(0.023)	(0.008)	(0.011)
Δ in Log GDP per capita		-0.003		-0.078		0.140		-0.328
		(0.123)		(0.275)		(0.377)		(0.249)
Constant	0.170***	0.037	0.199***	0.121	0.754***	0.393	0.539***	0.808
	(0.048)	(0.199)	(0.058)	(0.361)	(0.116)	(0.435)	(0.061)	(0.328)
N	190	108	132	76	190	108	132	76
Country Clusters	95	54	66	38	95	54	66	38
Time Dummies	yes	yes	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes	yes	yes
R^2 (overall)	0.002	0.011	0.009	0.043	0.192	0.223	0.178	0.349

* p ≤ 0.10, ** p ≤ 0.05; *** p ≤ 0.01; robust standard errors clustered at the country level are in parentheses.

Figure 1: Urbanization Levels and Urban Thresholds in 2010

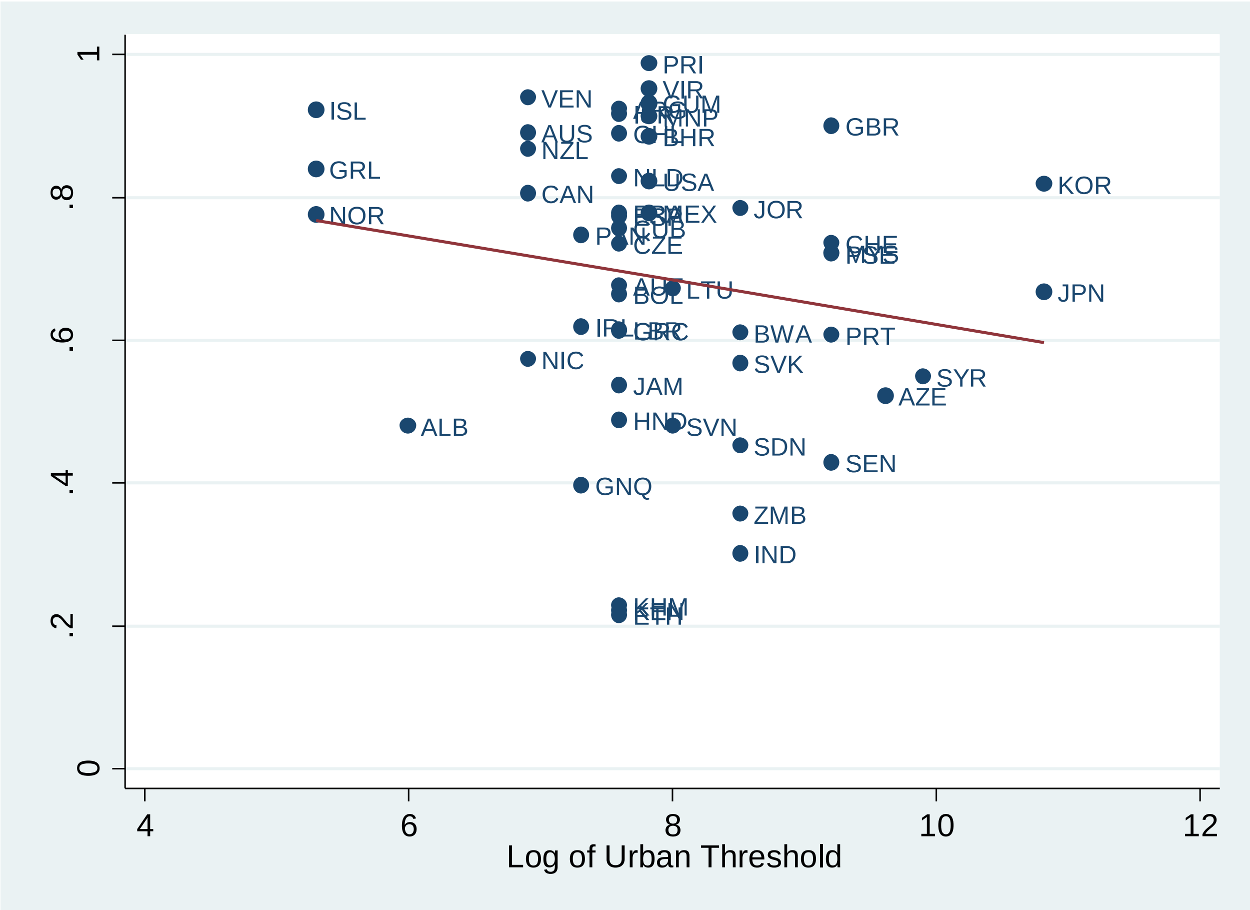


Figure 2: Urbanization and Crude Death Rate, 1955-2005

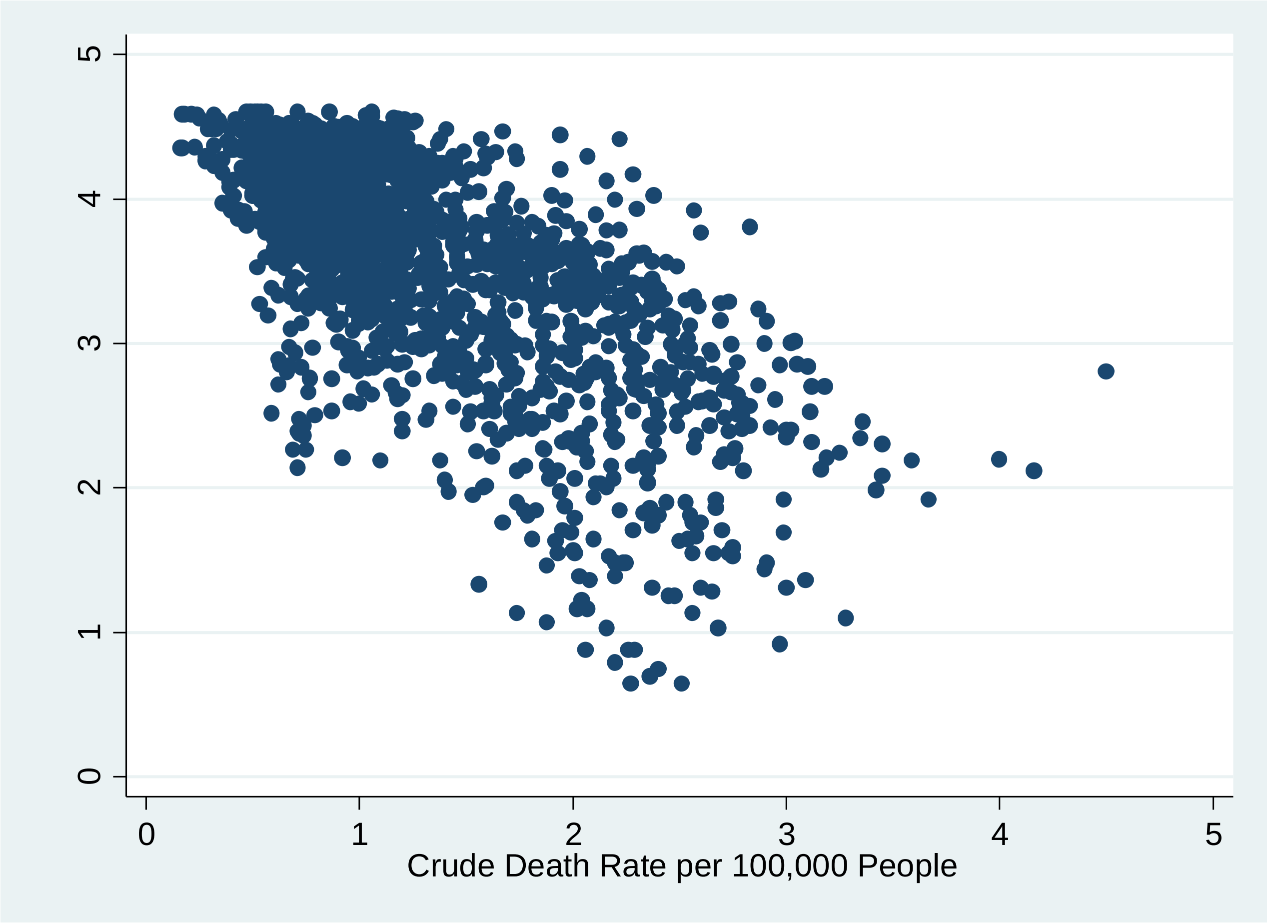
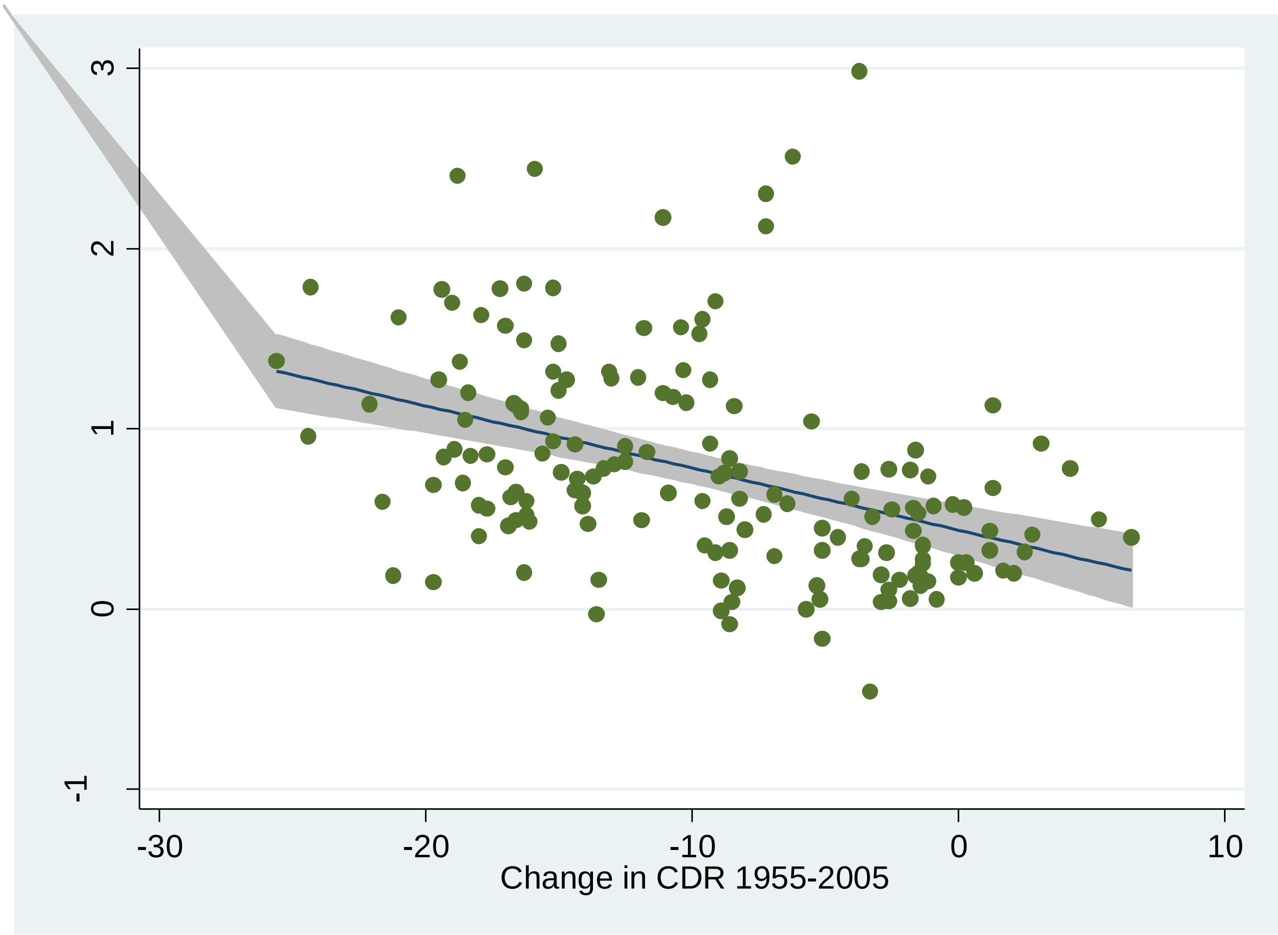
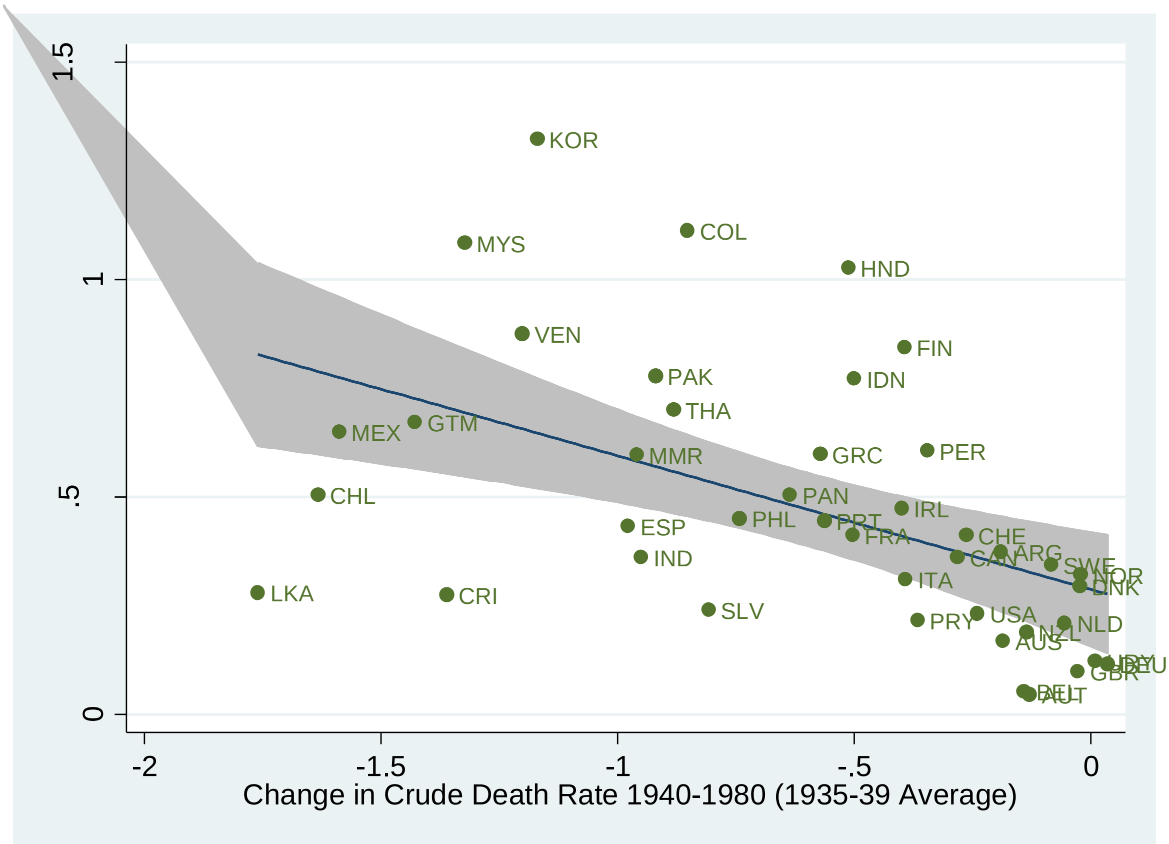
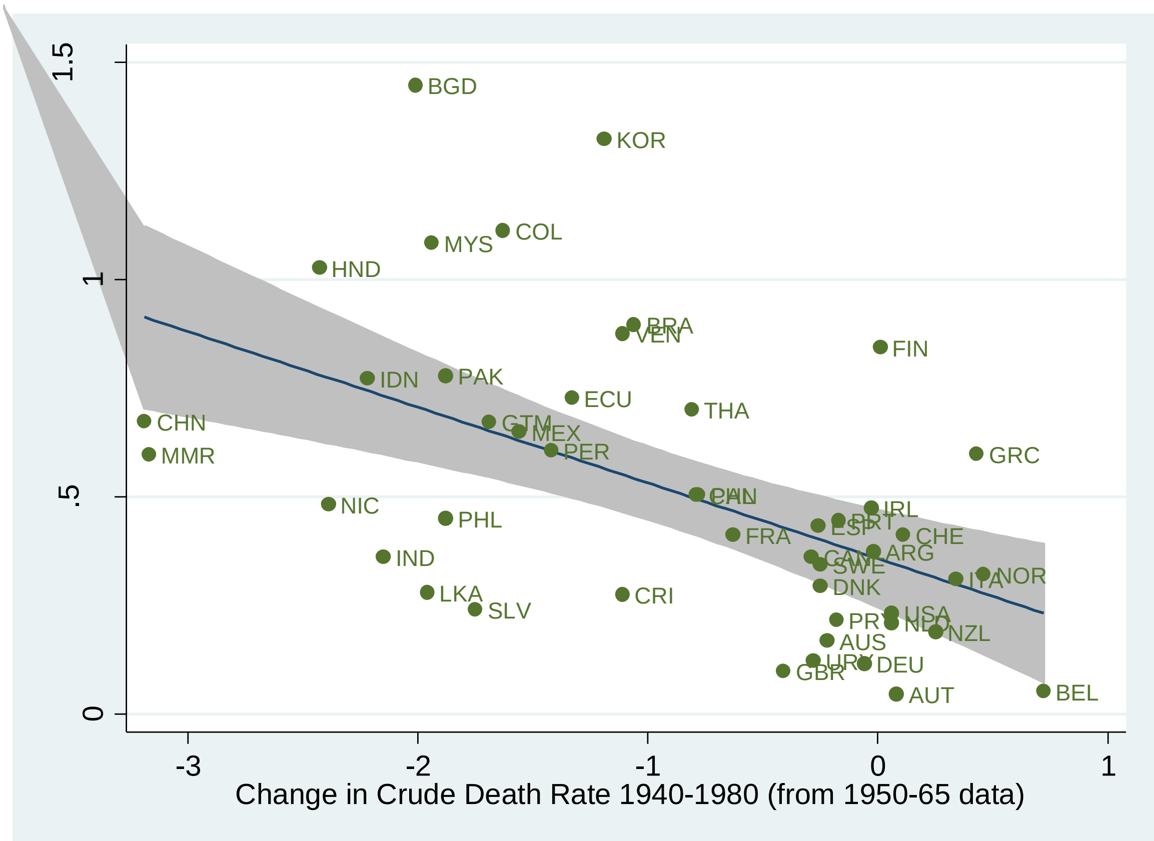


Figure 3: Log Urbanization and Crude Death Rate, 1955-2005

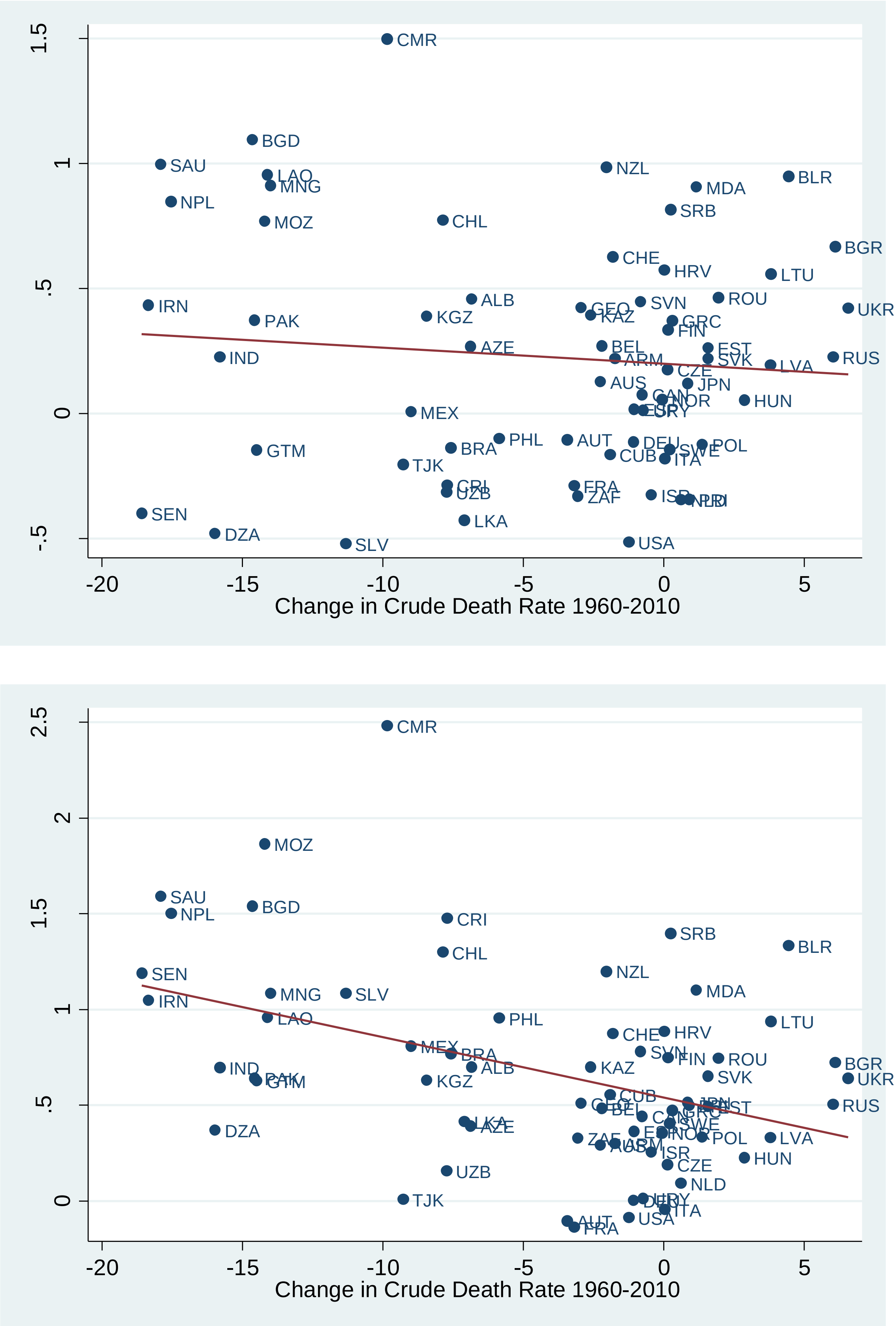


Figures 4a-4b: Log of Percentage Urban and Crude Death Rate, 1940-1980





Figures 5a-5b: Log Urbanization and Crude Death Rate, 1960-2010



Appendix 1: Summary Statistics

	Obs.	Mean	St.Dev.	Min.	Max.
Crude Death Rate (per 10,000)	1859	1.302	0.650	0.160	4.500
Log of Percentage Urban	1859	3.578	0.752	0.642	4.605
Log of GDP per capita	1516	8.409	1.167	5.033	11.490
Agriculture, Percentage of GDP	1133	0.210	0.169	0.001	0.931

Appendix 2: Lag and Lead Coefficients, Dependent variable: log of percentage population urban

	Coefficients		
Lead CDR			
3			-0.145* (0.080)
2		-0.078 (0.115)	-0.005 (0.075)
1	-0.174 (0.143)	-0.122 (0.098)	-0.153* (0.085)
Lag CDR			
1	-0.626*** (0.127)	-0.091 (0.072)	0.028 (0.060)
2		-0.511*** (0.121)	0.012 (0.121)
3			-0.509*** (0.130)
N	1859	1521	1183
R^2	0.465	0.462	0.462

Note: Figures in parentheses are white heteroskedasticity consistent standard errors.

Appendix 3: Countries included in Table 6

Country	Columns 1-3	Columns 4-6	Columns 7-9
Argentina	X	X	
Australia	X	X	
Belgium	X	X	X
Bulgaria	X	X	
Canada	X	X	X
Chile	X	X	
Costa Rica	X		
Cuba	X		
Denmark	X	X	X
El Salvador	X		
France	X	X	X
Italy	X	X	X
Japan	X	X	
Luxembourg	X		
Mexico	X	X	X
Netherlands	X	X	X
Norway	X	X	X
Panama	X		
Portugal	X	X	X
Romania	X	X	
Spain	X	X	X
Sweden	X	X	X
Switzerland	X	X	X
United States	X	X	X
Uruguay	X	X	
Venezuela	X	X	

All data is from (Mitchell, 2007a, 2007b, 2007c) with the exception of the United States, which is from (Haines, 2000, p. 153).