Urbanization and Mortality Decline

Sanghamitra Bandyopadhyay
School of Business and Management
Queen Mary, University of London
Mile End, Bancroft Building
London E1 4NS
UK
+44-20-7882-2699 (phone)
+44-20-7882-3615 (fax)
s.bandyopadhyay@qmul.ac.uk

Elliott Green[1]
Department of International Development
London School of Economics
Houghton Street
London WC2A 2AE
UK
+44-20-7852-3632 (phone)
+44-20-3486-2626 (fax)
e.d.green@lse.ac.uk

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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 rigorously in a global context. Using cross-national panel data we find evidence of a robust negative correlation between crude death rates and urbanization. The use of instrumental variables suggest that this relationship is causal, while historical data from the early 20th century suggests that this relationship holds in earlier periods as well. Finally, we find robust evidence that mortality decline is correlated with urbanization through the creation of new cities rather than promoting urban growth in already-extant cities.

Keywords: Urbanization, Mortality Decline, Economic Development, Structural Change, Demographic Transition

JEL Codes: J11, N90, O18, R00

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 has been estimated that in 2010 a majority of humans lived in cities for the first time in world history (Storper, van Marrewijk & van Oort, 2012, p. 2).

These two indisputable facts about modern history have largely been discussed independently, particularly 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 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 four ways in which mortality decline could lead to urbanization, namely via definitional changes, 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 using OLS, fixed effects and first differences, alongside historical evidence from the early 20th century. In section 4 we address endogeneity concerns through the use of instrumental variables and copulas. In section 5 we focus on what mechanisms are driving the relationship between mortality decline and urbanization, and find strong evidence that the mechanism is via the creation of new cities over time rather than through urban growth in already extant cities. Finally, in section 6 we conclude.

2. Conceptual Framework

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 (2009 [1845])'s 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 (Boustan, Bunten, & Hearey, 2013; Michaels, Rauch, & Redding, 2012; Nunn & Qian, 2011; Voigtländer & Voth, 2013). Similarly some cross-national analyses have used pooled-OLS to find a robust relationship between GDP/capita, the sectoral composition of GDP and/or the labour force, and levels of urbanization (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 and 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" (cf. Henderson 2010). 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 Davis and Henderson (2003) and Moomaw and 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 and Shatter, 1996, p. 22, argue that this result is a consequence of a lack of sufficient time-series data, while Davis and 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, and Strobl (2006) and Henderson, Storeygard, and Deichmann (2017) suggest that decreasing levels of rainfall and climate change 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] Ebeke and Etoundi (2017), Gollin, Jedwab, and Vollrath (2015) and Jedwab (2012) also focus on explaining Africa's experience of urbanization without economic growth, which they argue has been driven by natural resource rents, exports and a sectoral shift from agriculture into non-tradable sectors. Finally, Poelhekke (2011) shows a correlation between agricultural risk (as measured by standard deviations of agricultural produce) and urban population growth, even in areas with little to no economic growth.[3]

Recent scholarship 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; Guest, 2011) – without, however, interrogating this relationship with global times-series data. 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. We first examine the effects of population growth in rural and then in urban areas, before focussing on “push” factor of rural mortality decline and the “pull” factor of urban mortality decline.

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.

One possible consequence of this mechanism is that population growth over time will, by definition, lead to higher levels of urbanization until countries either stabilize their populations or reach an urbanization level of 100%. But this tautology relies upon the assumption that this population growth must take place in a fixed number of human settlements, all of which will eventually grow above the urban threshold. In contrast, there is long-standing evidence dating back to prehistory of humans leaving larger settlements to start their own new settlements (Herbst 2000; Scott 2009), a pattern which has continued to the present day as city-dwellers move to new suburbs or the countryside in a phenomenon known as counter-urbanization. Thus countries like New Zealand, Sweden and Switzerland have stabilized their urbanization levels in recent years well below 90% despite growing populations, due in large part to the expansion in the number of peri-urban or rural suburbs surrounding their major cities.

2.2. Urban Mortality Decline and Urban Natural Increase

The second potential mechanism is through urban mortality decline and a subsequent increase in the rate of urban natural 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).[4] Thus modern mortality decline has changed urban population growth from negative to positive, with evidence from Jedwab, Christiaensen, and Gindelsky (2017) that urban natural increase is correlated with both urban growth rates and urbanization rates, both for historical European examples and 33 contemporary developing countries.

2.3. Rural Mortality Decline and Rural-Urban Migration

The third mechanism hypothesizes a causal link between rural mortality decline and urbanization 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 and 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) and Shaw (1974) showed a strong correlation between rural-population growth and out-migration across mid-20th century Latin America. More recently Davis and 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.

2.4. Urban Mortality Decline and Rural-Urban Migration

The fourth and final potential mechanism is declining urban mortality rates as a “pull” factor, inasmuch as they lead people to migrate to cities to take advantage of better public health facilities. While this mechanism is plausible at least theoretically (Boustan et al., 2013), 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, p. 571).

3. Empirical Evidence

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 2010, with descriptive statistics listed in Appendix A3.[5] In the former case we follow Barrios et al. (2006) and Fay and Opal (2000) and measure urbanization as the log of the percentage urban, to avoid the problem of being bounded at both 0 and 1 (cf. Benhabib, Corvalan, & Spiegel 2013). Nonetheless, due to the fact that urbanization is measured differently across countries and, depending on varying definitions, can often stabilize at levels below 100% (Davis & Henderson, 2003), we have used log of total urban population as an alternative dependent variable while also controlling for log of total population, as discussed below in section 3.1. We also use Papke and Wooldridge (1996)’s Generalized Linear Model (GLM) method to deal with the fact that the raw urbanization variable is bounded between 0 and 1. The GLM method is a flexible method of generalizing OLS models that use response variables with error distributions that are not normally distributed. It uses a link function (in our case a logit) to allow the linear model to be related to the response variable.

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 Denmark, Iceland, Norway and Sweden while in Japan and South Korea it is 50,000 people, a 250-fold difference. (The median value for countries with an urban threshold is 2500.)[6] Thus using urbanization levels as a dependent variable in cross-sectional cross-national regressions, as in Gollin et al. (2015), 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 92 countries whose threshold is listed in the most recent editions of the UN Demographic Yearbook and World Urbanization Prospects. While the relationship is negative, as expected, it is very weak, with an R^2 of only 0.0006, 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' estimation methods in our empirical testing 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 to make it comparable in scale to the urbanization data. 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 8.0, 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.[7] As discussed below in more detail, we also introduced other control variables such as log of population, manufacturing as a percentage of GDP,[8] democracy (as measured by Polity IV), rainfall,[9] continent dummies, total fertility rate and temperature, none of which were consistently statistically significant.[10]

3.1. Initial Results

We first estimate our basic model, presented in equation 1, and use pooled OLS to estimate it.

$$LogPercentUrban_{it} =$$

$$\alpha + \beta CrudeDeathRate_{it} + \gamma LogGDPpercapita_{it} + \delta AgricultureGDP_{it} + \lambda_t + \varepsilon_{it} \quad (1)$$

where $LogPercentUrban_{it}$ is the natural logarithm of the percentage of population urbanized in country *i* and year *t*, $CrudeDeathRate_{it}$ is the crude death rate of country *i* and year *t*, $LogGDPpercapita_{it}$ is the natural logarithm of GDP per capita of country *i* and year *t*, λ_t accounts for time varying factors across all countries and ε_{it} is an error term assumed to be normally distributed, N(0, $\sigma^2_{\varepsilon_{it}}$).

We present our first set of results in Table 1, starting with a regression of log urban percentage on crude death rate before introducing log GDP per capita and agriculture as a share of GDP in subsequent regressions. 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 1-2 we first present pooled OLS results while columns 3-4 regressions include country fixed effects in order to examine whether the results are driven by cross-country differences rather than within-country change. In columns 5-6 we used the GLM method devised by Papke and Wooldridge (1996) for situations where the dependent variable is bounded between 0 and 1. The model estimated is:

$$LogPercentUrban_{it} = \alpha + \beta CrudeDeathRate_{it} + \gamma LogGDPpercapita_{it} + \delta AgricultureGDP_{it} + \phi_i + \lambda_t + \varepsilon_{it} \qquad (2)$$

where ϕ_i represents a set of country fixed effects and λ_t accounts for time varying factors across all countries. Columns 1 and 3 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, mortality decline has a substantial effect on urbanization: taking the crude mortality rate coefficient from column #3, a one-standard deviation decrease in the crude death rate leads to an increase in the log of percentage urban of 0.195 (= -0.300*0.651), equivalent to 26% of its standard deviation.[11] Moreover, we confirm the findings of Davis and 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.[12] It is possible that, given our sample size, our results are being driven by post-demographic transition countries where there is plausibly a causal relationship between mortality decline and GDP per capita (Cervelatti & Sunde, 2011), but rerunning our results excluding countries with a crude birth rate of less than 30/1000 in 1950 led to no changes in our results (available from authors upon request). (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.)

We next first difference both the left and right-hand sides of our basic models in equations 1 and 2 to examine whether changes in mortality are associated with changes in urbanization. Since urbanization and mortality decline are slow-moving variables, we use both ten-year and forty-year differences, starting in 1970 and ending in 2010. We estimate the following model:

$$\Delta LogPercentUrban_i = \theta \Delta CrudeDeathRate_i + \rho \Delta LogGDPpercapita_i + \mu \Delta AgricultureGDP_i + \mu_t + \varepsilon_i \qquad (3)$$

where $\Delta LogPercentUrban_i = LogPercentUrban_{it} - LogPercentUrban_{it-2}$ is the first difference in the natural logarithm of the percentage of population urbanized of country *i* and between years *t* and *t-2,* with the other variables defined similarly. We also introduce year dummies μ_t to account for time-varying factors across countries.

We present our results in Table 2. Here again for the sake of completeness we present pooled OLS estimates in columns 1-2 and add country fixed effects in columns 3-4. In columns 5 and 6 we only used the first and last years of our sample in a balanced long difference regression, thereby re-estimating equation 2, albeit with a perfectly balanced sample with observations only from 1970 and 2010.[13] As reported in Table 2 the coefficients on crude death rate is always negative and statistically significant, except when using fixed effects in column 4, where it retains the correct sign; in contrast, the coefficient on log GDP per capita is never statistically significant.

[Insert Table 2 here]

3.2. Additional Results

Our results thus far demonstrate a robust negative association between crude mortality and urbanization. However, there are various additional robustness tests which we can perform here. First, as noted above it is possible that using the log of percentage urban would give greater weight to urbanization in highly rural countries than in more urbanized countries. As such we used log of the urban population as an alternative dependent variable, while controlling for log of total population, a strategy employed by Davis and Henderson (2003). As reported in Table A6 in the appendix, our results continue to hold across the main specifications employed in columns 1 and 3 of Tables 1 and 2 above.

Second, it is possible that the relationship between mortality decline and urbanization is an artefact of population growth, inasmuch as crude mortality is measured as deaths per 1000 (or 10,000) inhabitants. Thus it is hypothetically possible for a crude mortality rate to decline purely via population growth rather than actual declines in mortality, which would lead our results to be suspect. As such we again reran the main specifications from Tables 1 and 2, this time using log of percentage urban as the dependent variable but controlling for log of population. The results are reported in Table A7 in the appendix; the coefficient on crude mortality remains negative and statistically significant while the coefficient on log of population is never statistically significant except in column 4 (where it is not robust to dropping crude death rate as a covariate).[14]

Third, for close to half of the countries in our dataset there is no clear definition of urban areas, which means that we are not sure if the urbanization data is consistent across time. Thus we examined historical UN demographic yearbooks to document country-level urban thresholds across time, and compiled a list of countries with consistent thresholds between 1970 and 2010 (29 countries) and 1980 and 2010 (41 countries). In Table A8 we report the results for both subsets across the same four specifications used in Table A6; despite the very low number of countries included our results continue to be robust.[15]

We also conducted various other robustness checks which we do not have space to report here. First, it is possible that changes in age structure might have an effect on both mortality decline and urbanization, especially via working-age rural-urban migration. Thus we reran all of our specifications while controlling for median age, with no changes in our results. Second, 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 Freund (2007) suggests that modern Africa has never had higher urban mortality than rural mortality. As such we ran all of our regressions from Tables 1-2 in samples which separately excluded Africa, the Americas, Europe and Asia, with no changes in our results. Third, we also followed Fay and 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 IV). Finally, for all regressions we dropped all country-years for countries with small populations, with thresholds of either 100,000 or 500,000 people, to account for measurement error. In none of these cases do our results change.

3.3. 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 as above we use equation 2 to 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 labour force in agriculture it drops to 13. (The list of countries is given in Table A5.)

Our results are given in Table 3, first without controls, and then controlling for both GDP and labour force in agriculture. In all six columns change in crude death rate is negative and statistically significant despite a very small sample size.[16] Change in GDP/capita is also significant in column 4 but not columns 5 or 6, and change in labour force in agriculture is negative and statistically significant in columns 4-6.

[Insert Table 3 here]

4. Dealing with Endogeneity Concerns

Our results so far clearly suggest that mortality decline is robustly correlated with urbanization. We now turn to concerns about reverse causality and omitted variables, whereby urbanization could be driving mortality decline rather than vice-versa, and where both phenomena could be an outcome of a third variable. We tackle each of these issues in order.

4.1. Sources of Reverse Causality

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 residents 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).[17] 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). Evidence also 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 were 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).

4.2. Omitted Variables

It is also possible that both urbanization and mortality decline are outcomes of a third variable, heretofore omitted from our analysis. As mentioned in section 3 above, we already controlled for a variety of additional variables such as population size, temperature, rainfall and levels of fertility and democracy which could have an effect on both urbanization and mortality. Another solution here is to find an instrumental variable that is correlated with mortality decline but not with urbanization except via mortality decline. In an earlier version of this paper we used an instrumental variable capturing predicted mortality decline in the late 20th century from Acemoglu and Johnson (2007), which performs well with high F-statistics and the correct sign and level of statistical significance for the crude death rate coefficient. However, here there is a concern that the instrument does not satisfies the exclusion restriction for two reasons: first, the general decline in mortality captured by the index was driven by broad modern public health interventions that might have affected rural and urban areas differently, such that mortality decline was faster in urban than rural areas; and second, the index captures non-childhood diseases like tuberculosis that have a direct effect on human capital. As such we do not include the results here (but are available upon request).

Instead we focus on an alternative instrument here, namely the Malaria Ecology Index (MEI) computed by Kiszewski et al. (2004), which is a measure of the degree to which the non-human ecological 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 on economic development (Cervellati & Sunde, 2011; Lorentzen, McMillan, & Wacziarg, 2008). Here, however, we use the MEI 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 and indoor residual spraying. There is strong evidence that the MEI satisfies the exclusion restriction inasmuch as it is difficult to see how the aforementioned public health innovations that led to the decline in malaria, which were limited in scope to malarial areas and were focussed on the aforementioned malaria-specific technologies like spraying and bed-nets, could have had an independent effect on urbanization that was not via mortality decline. Indeed, as spelled out clearly by Packard (2009), efforts to combat malaria have actually had little to no effect on GDP levels and industrialization inasmuch as they have increased population size via lower infant and child mortality but not economic growth.[18] This evidence is consistent with other recent population-wide studies that show a positive effect of mortality decline from infectious diseases of childhood on population growth but a more ambiguous relationship with economic outcomes (Acemoglu & Johnson, 2007; Hansen & Lønstrup, 2015; Kazianga, Masters & McMillan, 2014).[19]

In Table 4 we present our results with the MEI as an instrument for change in CDR between 1960 and 2010 while retaining the dependent variable of change in urbanization over the same time period. 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.

[Insert Table 4 here]

The results are as expected, with the MEI performing strongly as an instrument, whether alone or in combination with mean elevation as evinced by the F-statistic. Change in GDP is negative and significant but does not alter the relationship between mortality change and urbanization.

In addition to the traditional method of using IVs, for robustness we also used the novel tool of copulas for establishing the causal relationship from mortality decline to urbanization. This method uses the joint likelihood function of the endogenous and exogenous regressors, which are separated (as marginal distributions) using copulas, and then generates a new regressor which is now free from endogeneity. The generated regressor is then used in the regression model. This method is gaining increasing popularity in the applied and development economics realm (cf. Blauw and Franses 2016). A technical description of this method is described in Appendix 1. Estimates using the copula method are presented in Tables A1 and A2, which replicate Tables 1 and 2, respectively. The results are in full agreement with the results obtained using IVs.[20]

5. Investigating Mechanisms

Having established that there is a robust, causal relationship between crude mortality and urbanization via the use of instrumental variables and copulas, we now attempt to establish the operative mechanism by which mortality decline causes urbanization. From section 2 we recall three potential mechanisms that could link mortality decline and urbanization, namely definitional changes, rural-urban migration and urban natural increase. We use four ways in which to distinguish between these mechanisms: first we examine the relationship between both adult and infant mortality and urbanization; second, we control for the causes of rural-urban migration; third, we disaggregate urbanization in a stable number of cities and urbanization in general; and fourth, we focus on urbanization in primate cities.

Our first such exercise is to disaggregate mortality into infant mortality (with data from the UN Population Prospects) and adult mortality (with data from developing countries from De Walque and Filmer (2011)), inasmuch as we would expect the infant mortality to be negatively correlated with urbanization if it were either definitional changes or urban natural increase that was the operative mechanism (as brought about through population growth), while we would instead expect declines in the adult mortality 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. Our results, which are reported in the appendix in Table A9, indicate that infant mortality is robustly correlated with urbanization while adult mortality is not. This strong relationship between infant mortality and urbanization is not particularly surprising given the high correlation between infant mortality and the crude death rate (r = 0.875) compared to the correlation between adult mortality and the crude death rate (r = 0.518). The lack of any consistent correlation between adult mortality and urbanization suggests that rural-urban migration as caused by adult population growth and rural job scarcity might not be 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.

Our second exercise is to use proxies for rural-urban migration from the literature on urbanization as control variables to see if mortality decline has an effect on urbanization independent of the factors that explain rural-urban migration, inasmuch as we do not have cross-national panel data on rural-urban migration by country. We use three such proxies. First we take data on annual precipitation (1950-2005) from Dell, Jones and Olken (2012) to control for the effects of declining rainfall on rural-urban migration, as proposed by Barrios, Bertinelli, and Strobl (2006). Second we use the annual standard deviation of temperature (1955-2000) from the Climatic Research Unit at the University of East Anglia to control for the effects of agricultural volatility, as suggested by Poelhekke (2011). Third and finally, we control for the share of natural resource exports in GDP (with decadal data from 1960-2010), to control for the effects of migration to “consumption cities” as suggested by Gollin, Jedwab and Vollrath (2016) (who also provided the data). The results, which are listed in Table A10, show that, while the coefficients for the other control variables generally have the right sign and are often statistically significant, the coefficient for crude death rate is consistently negative and statistically significant across all four specifications.[21] This evidence does indeed suggest that mortality decline appears to have an effect on urbanization independent of rural-uban migration.

A third way to assess the relative importance of the three potential mechanisms is to examine actual city data across a long time period and examine the relationship between mortality decline and urbanization levels in a stable number of cities vs. all cities above a certain threshold. In the former case higher levels of urbanization must result from some combination of rural-urban migration and urban natural increase, while only in the latter case could definitional changes play a role. 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.[22] Inasmuch as these data are originally taken from country-level censuses we did not use 1970 as our starting date as historical data on city populations is actually more extensive for 1960 than 1970, due to the fact that many developing countries saw a decline in the quality and frequency of their censuses over the course of the 1960s.[23]

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 those 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 explain this difference in more detail, it is perhaps best to take an example from one country. For instance, 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 of 103,512 in 2010), which, using this threshold, gave a total urban population of 503,328 in 2010 for an total 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 increase in the percentage of people living in Tallinn. (In our analysis we continue to measure urbanization using log of percentage urban, such that change in log percentage urban in the first case comes to 0.262 and 0.493 in the second case.)

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 eliminated the countries from our analysis due to concerns about accuracy,[24] 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 exactly 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 initial 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 2a and 2b 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 2a and 2b here]

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, using equation #2. (Adding change in agriculture as a percentage of GDP as well yields a maximum of 14 observations, with results that match those recorded here.) We tabulate our results in Table 5, 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 5 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 correlated with change in urbanization. These results clearly suggest a strong role for definitional changes as the operating mechanism by which mortality decline contributes to urbanization.

As a fourth and final test for the mechanism at work, we examine the relationship between mortality decline and the change in the population of individual cities. We focus on primate cities, i.e., the largest city in each country, in order to not have an unbalanced sample, and distinguish between the percentage of each country's population in the statistically defined city vs. the percentage in the greater urban agglomeration, such that the size of the former is fixed across time but the latter takes into account new cities forming on the outskirts of the metropolitan area. Along the same lines as above, if mortality decline leads to urbanization only via the creation of new cities and not urban population growth or rural-urban migration in already-existing cities, then we should observe a correlation between mortality decline and the percentage in the urban agglomeration but not between mortality decline and the percentage in the city itself.

To test this hypothesis we need data on the population of the city proper as well as the urban agglomeration for all primate cities in the world. We draw from UN data for both urban agglomerations (from the 2014 World Urbanization Prospects) and on city populations (from the UN Statistics Division). The former data is much more extensive and dates back to 1950 for urban agglomerations with more than 300,000 inhabitants in 2014; the latter is sparser as it draws directly from country-level census data and only includes significant numbers of cities from the late 1990s onwards. As such we can only use data from 2000 and 2010 inasmuch as there are only eleven countries with data for 1990 and 2010. This exercise yields data from 54 countries across six continents, including large countries like Japan and the US and smaller ones such as Iceland and Vanuatu. In two cases, Australia and Serbia, the boundaries of the primate cities in question changed during the period, leading us to remove them from the dataset.

In Table 6 we thus list four specifications, two using OLS with year fixed effects and two including country and year fixed effects. In columns 1 and 3 the dependent variable is the log of the percentage of the primate city urban agglomeration, and in columns 2 and 4 it is the log of the percentage of the primate city proper population. The results are quite clear and match our previous findings: crude death rate is not correlated with urbanization in proper primate cities but is correlated with urbanization in primate city urban agglomerations in both columns 1 and 3 (albeit only at the 10% level, which we attribute to the large amount of noise for a relatively small number of observations and the very short time series of the data). Moreover, both the coefficient on crude death rate and the R2 are far higher in columns 1 and 3 than in columns 2 and 4, indicating a better fit with the data (although the values of the dependent are slightly different in the two sets of columns).

[Insert Table 6 here]

6. Conclusion

In this paper we have shown that mortality decline is correlated with urbanization between 1955 and 2010 across a wide range of model specifications with numerous controls as well as historical data from the early 20th century. We then used an instrumental variable approach and the method of copulas to show that this relationship is causal. Finally, using a variety of data we suggested that mortality decline causes urbanization through the creation of new cities rather than via rural-urban migration or urban natural increase.

Our results have at least two broader ramifications. First, previous scholarship like Acemoglu and Johnson (2007) and 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 urbanization has an independent positive effect on economic growth in developing countries (Bertinelli & Black, 2004; Brülhart & Sbergami, 2009; Henderson, 2003).

Second, our research allows for further insight into the relationship between mortality decline, urbanization and economic growth. For instance, Nunn and Qian (2011) show that the introduction of the potato was responsible for higher population growth and urbanization in early modern Europe. Nunn and 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 and 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.

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, more cross-national data on rural-urban migration, perhaps from demographic and health surveys, could be useful in testing the mechanism in more detail. Third, 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 as established by Acemoglu and Johnson (2007).

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[1] Moomaw and Shatter (1996) use data covering the period 1960 to 1980 only; for Davis and Henderson (2003) the data covers 1960 to 1995. In this regard also see Liddle and Messinis (2015), whose Granger causality tests do not yield strong evidence for a general causal relationship between economic growth and urbanization.

[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 and Opal (2000) find no relationship between deviations in crop yields and subsequent urbanization.

[4] Mortality rates that were higher in urban areas than in rural areas in the pre-modern world were mostly but not entirely universal, with China as a major exception (Voigtländer & Voth, 2013, p. 780).

[5] Annual data on urbanization tabulated by the World Bank is interpolated for the vast majority of countries and thus not of interest to us here. Other alternative sources such as Vernon Henderson's World Cities data or Africopolis are either incomplete or cover very few countries.

[6] Some countries also use population density as part of their definition of urbanization. In the most recent UN Demographic Yearbook, however, of the 11 which used density thresholds 9 also had population thresholds; in contrast, 39 countries had population thresholds without any density thresholds.

[7] See Appendix Table A4 for bivariate correlations for the main variables of interest as well as log of population. There is a degree of correlation between log GDP per capita and agriculture as a percentage of GDP; however, our results do not change if we include either variable one at a time instead of together.

[8] 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.

[9] 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.

[10] We were unable to control for the various factors behind rural-urban migration discussed in section 2.4 due to their lack of availability at the cross-national level.

[11] This 1.22% increase occurs over a five-year period because the urbanization variable is given in 5-year periods. Using the coefficients from column #4 of Table #1, the effect of a one-standard deviation increase in agriculture's share of GDP in column 4 is 0.13, while for crude mortality it is 0.16.

[12] Davis and Henderson (2003) use a sample of a maximum of 129 countries whereas ours has a maximum of 180 countries with GDP data. Fay and 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.

[13] We follow previous studies of urbanization by Fay and Opal (2000) and Poelhekke (2011) and used 1970 as a start date as data on agriculture as a percentage of GDP is only available from 1960, and only for an unrepresentative sample of 32 countries for the start and end dates of 1960 and 2010.

[14] At the suggestion of one of our referees, we also include a fifth column in Table A6 where we add additional controls to our main specification, such as total fertility rate, the Polity2 democracy score, and a dummy for sovereign states; as with other specifications, our results remain the same.

[15] The countries in the two subsamples are located in Asia, the Americas, Europe, Africa and Oceania, and vary in the size of their threshold from 200 in Denmark to 10,000 in Greece and Switzerland. Countries which changed their urban thresholds over time include Austria (5000 up to 2005, 2000 from 2010), Honduras (1000 up to 1975, 2000 from 1980) and Japan (30,000 up to 1975, 50,000 from 1980).

[16] This small sample size raises issues about the accuracy of the results inasmuch as the standard errors are clustered (Cameron and Miller 2015); as such the results should be considered a robustness test only. In this light we estimated the same specifications using the wild bootstrap for the standard errors following Cameron, Gelbach and Miller (2008); in all cases the confidence intervals decreased in size due to smaller standard errors.

[17] 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).

[18] In contrast, diseases like HIV/AIDS and tuberculosis affect adult mortality and thus have a more obvious direct effect on human capital and urbanization levels; cf. Ashraf, Lester & Weil, 2008.

[19] Another set of literature focussed on micro-level evidence finds a positive effect of mortality decline from disease on incomes and education (cf. Bleakley, 2010 for an overview), but do not examine any macro-economic effects on urbanization or economic growth. As both Packard (2009) and Hansen and Lønstrup (2015) have noted, these micro- and macro-economic effects are not contradictory.

[20] We also generated GMM estimates of equations 1-3, which in all cases were in full agreement with our main results in Tables 1-2 and A1-A2 (results available from authors).

[21] These results do not differ if we follow Gollin et al. (2016) and lag the control variables.

[22] The threshold is admittedly high but it is the only such comprehensive source for city populations for 1960. It was the urban threshold in China up until 1990, and it is only twice the size of the current highest urban thresholds in the world used in Japan and South Korea. It has also been used historically as a standard threshold in the literature on urbanization (cf. Davis (1955)).

[23] For example, the most recent urbanization data listed in the 1976 Demographic Yearbook was from 1960 for Cape Verde, Equatorial Guinea, Namibia and Oman and 1964 for Cote d'Ivoire, Libya and Surinam.

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[24] 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!

Bibliography

Abu-Lughod, J. (1964). Urban-Rural Differences as a Function of the Demographic Transition: Egyptian Data and an Analytical Model. *American Journal of Sociology, 69*(5), 476-490.

Acemoglu, D., & Johnson, S. (2007). Disease and Development: The Effect of Life Expectancy on Economic Growth. *Journal of Political Economy, 115*(6), 925-985.

Ashraf, Q. H., Lester, A., & Weil, D. N. (2008). When Does Improving Health Raise GDP? NBER Working Paper #14449.

Barrios, S., Bertinelli, L., & Strobl, E. (2006). Climatic Change and Rural–Urban Migration: The Case of Sub-Saharan Africa. *Journal of Urban Economics, 60*(3), 357-371.

Benhabib, J., Corvalan, A., & Spiegel, M. M. (2013). Income and democracy: Evidence from nonlinear estimations. *Economics Letters, 118*(3), 489-492.

Bertinelli, L., & Black, D. (2004). Urbanization and Growth. *Journal of Urban Economics, 56*(1), 80-96.

Bilsborrow, R. E., McDevitt, T. M., Kossoudji, S., & Fuller, R. (1987). The Impact of Origin Community Characteristics on Rural-Urban Out-Migration in a Developing Country. *Demography, 24*(2), 191-210.

Blauw, S., & Franses, P. H. (2016). Off the Hook: Measuring the Impact of Mobile Telephone Use on Economic Development of Households in Uganda using Copulas. *Journal of Development Studies, 52*(3), 315-330.

Bleakley, H. (2010). Health, Human Capital and Development. *Annual Review of Economics, 2*, 283-310.

Blundell, R., & Bond, S. (1998). Initial Conditions and Moment Restrictions in Dynamic Panel Data Models. *Journal of Econometrics, 87*(1), 115-143.

Boustan, L. P., Bunten, D., & Hearey, O. (2013). Urbanization in the United States, 1800-2000. NBER Working Paper #19041, National Bureau of Economic Research.

Brockerhoff, M. (1990). Rural-to-Urban Migration and Child Survival in Senegal. *Demography, 27*(4), 601-616.

Brockerhoff, M., & Eu, H. (1993). Demographic and Socioeconomic Determinants of Female Rural to Urban Migration in Sub-Saharan Africa. *International Migration Review, 27*(3), 557-577.

Brückner, M. (2012). Economic growth, size of the agricultural sector, and urbanization in Africa. *Journal of Urban Econonomics, 71*(1), 26-36.

Brueckner, J. K. (1990). Analyzing Third World Urbanization: A Model with Empirical Evidence. *Economics Development and Cultural Change, 38*(3), 587-610.

Brülhart, M., & Sbergami, F. (2009). Agglomeration and Growth: Cross-Country Evidence. *Journal of Urban Economics, 65*(1), 48-63.

Cameron, A. C., Gelbach, J. B., & Miller, D. L. (2008). Bootstrap-Based Improvements for Inference with Clustered Errors. *Review of Economics and Statistics, 90*(3), 414-427.

Cameron, A. C., & Miller, D. L. (2015). A Practitioner's Guide to Cluster-Robust Inference. *Journal of Human Resources, 50*(2), 317-372.

Cervellati, M., & Sunde, U. (2011). Life Expectancy and Economic Growth: The Role of the Demographic Transition. *Journal of Economic Growth, 16*(2), 99-133.

Davis, J. C., & Henderson, J. V. (2003). Evidence on the Political Economy of the Urbanization Process. *Journal of Urban Economics, 53*(1), 98-125.

Davis, K. (1955). The Origin and Growth of Urbanization in the World. *American Journal of Sociology, 60*(5), 429-437.

Davis, K., & Casis, A. (1946). Urbanization in Latin America. *Milbank Memorial Fund Quarterly, 24*(2), 186-207.

De Walque, D., & Filmer, D. (2011). Trends and Socioeconomic Gradients in Adult Mortality around the Developing World. Policy Research Working Paper #5716, Development Research Group, World Bank.

Dell, M., Jones, B. F., & Olken, B. A. (2012). Temperature Shocks and Economic Growth: Evidence from the Last Half Century. *American Economic Journal: Macroeconomics, 4*(3), 66-95.

Dyson, T. (2011). The Role of the Demographic Transition in the Process of Urbanization. *Population and Development Review, 37*(Supplement), 35-54.

Ebeke, C. H., & Etoundi, S. M. N. (2017). The Effects of Natural Resources on Urbanization, Concentration and Living Standards in Africa. *World Development, 96*, 408-417.

Engels, F. (2009 [1845]). *The Condition of the Working Class in England*. Oxford: Oxford University Press.

Fay, M., & Opal, C. (2000). Urbanization Without Growth: A Not So Uncommon Phenomenon. World Bank Policy Research Working Paper #2412, Urban Development and Transportation Division, World Bank.

Finlay, R. (1981). Natural Decrease in Early Modern Cities. *Past and Present, 92*, 169-174.

Fox, S., (2012). Urbanization as a Global Historical Process: Theory and Evidence from Sub-Saharan Africa. *Population and Development Review, 38*(2), 285-310.

Freund, B. (2007). *The African City: A History*. Cambridge: Cambridge University Press.

Gollin, D., Jedwab, R., & Vollrath, D. (2016). Urbanization with and without Industrialization. *Journal of Economic Growth, 21*(1), 35-70.

Gould, W. T. S. (1998). African Mortality and the New "Urban Penalty". *Health & Place, 4*(2), 171-181.

Guest, A. (2011). World Urbanization: Destiny and Reconceptualization. In L. J. Kulcsár & L. K. Curtis (Eds), *International Handbook of Rural Demography* (pp. 49-65). New York: Springer.

Günther, I., & Harttgen, K. (2012). Deadly Cities? Spatial Inequalities in Mortality in sub-Saharan Africa. *Population and Development Review, 38*(3), 469-486.

Haines, M. R. (2000). The population of the United States, 1790–1920. In S. L. Engerman & R. E. Gallman (Eds), *The Cambridge Economic History of the United States. Volume 2: The Long Nineteenth Century* (pp. 143-205). Cambridge: Cambridge University Press.

Haines, M. R. (2001). The Urban Mortality Transition in the United States, 1800-1940. NBER Historical Working Paper #134.

Hansen, C. W. & Lønstrup, L. (2015). The Rise in Life Expectancy and Economic Growth in the 20th Century. *Economic Journal, 125*(584), 838-852.

Hare, D. 1999. "Push" versus "pull" factors in migration outflows and returns: Determinants of migration status and spell duration among China's rural population. *Journal of Development Studies, 35*(3), 45-72.

Henderson, J. V., Storeygard, A., & Deichmann, U. (2017). Has Climate Change Driven Urbanization in Africa? *Journal of Development Economics, 124*, 60-82.

Henderson, J. V. (2003). The Urbanization Process and Economic Growth: The So-What Question. *Journal of Economic Growth, 8*(1), 47-71.

Henderson, J. V. (2010). Cities and Development. *Journal of Regional Science, 50*(1), 515-540.

Herbst, J. (2000). *States and Power in Africa: Comparative Lessons in Authority and Control*. Princeton: Princeton University Press.

Hoselitz, B. F. (1957). Urbanization and Economic Growth in Asia. *Economic Development and Cultural Change, 6*(1), 42-54.

Jedwab, R. (2012). Why is African Urbanization Different? Evidence from Resource Exports in Ghana and Ivory Coast. Mimeo, Department of Economics, George Washington University.

Jedwab, R., Christiaensen, L., & Gindelsky, M., (2017). Demography, Urbanization and Development. *Journal of Urban Economics, 98*, 6-16.

Johnson, G. Z. (1964). Health Conditions in Rural and Urban Areas of Developing Countries. *Population Studies, 17*(3), 293-309.

Kazianga, H., Masters, W. A., & McMillan, M. S. (2014). Disease control, demographic change and institutional development in Africa. *Journal of Development Economics, 110*, 313-326.

Kelley, A. C., & Williamson, J. G. (1984). Population Growth, Industrial Revolutions, and the Urban Transition. *Population and Development Review, 10*(3), 419-441.

Khan, H. T. A., & Raeside, R. (1997). Factors affecting the most recent fertility rates in urban-rural Bangladesh. *Social Science and Medicine, 44*(3), 279-289.

Kiszewski, A., Mellinger, A., Spielman, A., Malaney, P., Sachs, J. D., & Sachs, S. E. (2004). A Global Index of the Stability of Malaria Transmission. *American Journal of Tropical Medicine and Hygiene, 70*(5), 486-498.

Lavely, W., & Freedman, R. (1990). The Origins of the Chinese Fertility Decline. *Demography, 27*(3), 357-367.

Lees, L. H., & Hohenberg, P. M. (1989). Urban Decline and Regional Economies: Brabant, Castile, and Lombardy, 1550-1750. *Comparative Studies in Society and History, 31*(3), 439-461.

Lewis, W. A. (1954). Economic Development with Unlimited Supplies of Labour. *The Manchester School, 22*(2), 139-191.

Li, Q., & Wen, M. (2005). The Immediate and Lingering Effects of Armed Conflict on Adult Mortality: A Time-Series Cross-National Analysis. *Journal of Peace Research, 42*(4), 471-492.

Liddle, B., & Messinis, G. (2015). Which Comes First - Urbanization or Economic Growth? Evidence from Heterogeneous Panel Causality Tests. *Applied Economics Letters, 22*(5), 349-355.

Lorentzen, P., McMillan, J., & Wacziarg, R. (2008). Death and Development. *Journal of Economic Growth, 13*(2), 81-124.

Lynch, K. A. (2003). *Individuals, Families and Communities in Europe, 1200-1800*. Cambridge: Cambridge University Press.

Michaels, G., Rauch, F., & Redding, S. J. (2012). Urbanization and Structural Transformation. *Quarterly Journal of Economics, 127*(2), 535-586.

Mitchell, B. (2007a). *International Historical Statistics: Africa, Asia and Oceania 1750-2005* (6 ed.). Houndmills, UK: Palgrave Macmillan.

Mitchell, B. (2007b). *International Historical Statistics: Europe 1750-2005* (6 ed.). Houndmills, UK: Palgrave Macmillan.

Mitchell, B. (2007c). *International Historical Statistics: The Americas 1750-2005* (6 ed.). Houndmills, UK: Palgrave Macmillan.

Moomaw, R. L., & Shatter, A. M. (1996). Urbanization and Economic Development: A Bias toward Large Cities? *Journal of Urban Economics, 40*(1), 13-37.

Nunn, N., & Qian, N. (2011). The Potato's Contribution to Population and Urbanization: Evidence from a Historical Experiment. *Quarterly Journal of Economics, 126*(2), 593-650.

Packard, R. M. (2009). “Roll Back Malaria, Roll in Development”? Reassessing the Economic Burden of Malaria. *Population and Development Review, 35*(1), 53-87.

Papke, L. E., & Wooldridge, J. M. (1996). Econometric Methods for Fractional Response Variables with an Application to 401(k) Plan Participation Rates. *Journal of Applied Econometrics, 11*(6), 619-632.

Poelhekke, S. (2011). Urban growth and uninsured rural risk: Booming towns in bust times. *Journal of Development Economics, 96*(2), 461-475.

Schultz, T. P. 1971. Rural-Urban Migration in Colombia. *Review of Economics and Statistics, 53*(2), 157-163.

Scott, J. (2009). *The Art of Not Being Governed: An Anarchist History of Upland Southeast Asia*. New Haven: Yale University Press.

Shaw, R. P. (1974). Land Tenure and the Rural Exodus in Latin America. *Economic Development and Cultural Change, 23*(1), 123-132.

Stephenson, R., Matthews, Z., & McDonald, J. W. (2003). The Impact of Rural-Urban Migration on Under-Two Mortality in India. *Journal of Biosocial Science, 35*(1), 15-31.

Storper, M., van Marrewijk, C., & van Oort, F. G. (2012). Processes of Change in Urban Systems. *Journal of Regional Science, 52*(1), 1-9.

Todaro, M. P. (1969). A Model of Labor Migration and Urban Unemployment in Less Developed Countries. *American Economic Review, 59*(1), 138-148.

United Nations. (2014). *World Urbanization Prospects, the 2014 Revision*. Department of Economic and Social Affairs/Population Division.

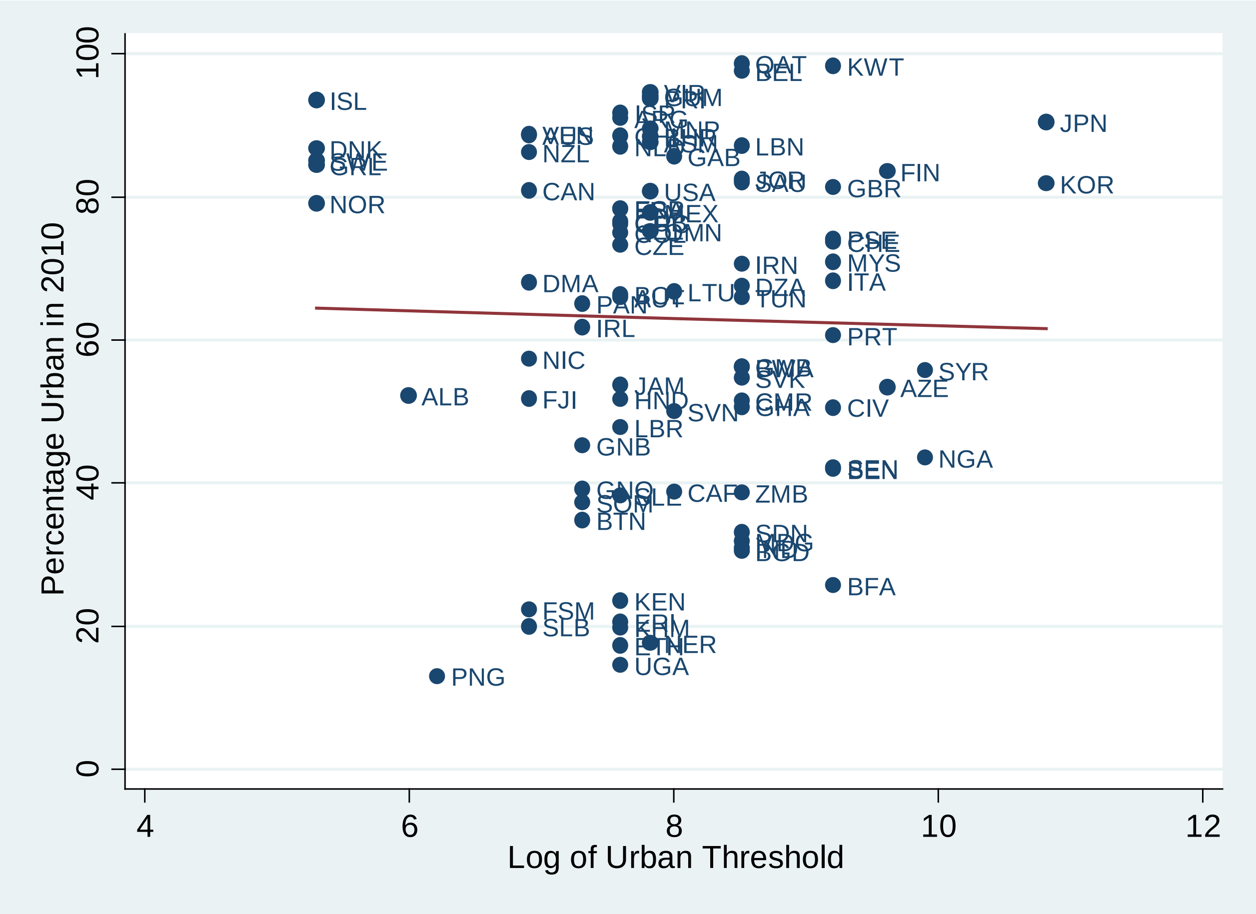
Voigtländer, N., & Voth, H.-J. (2013). The Three Horsemen of Riches: Plague, War, and Urbanization in Early Modern Europe. *Review of Economic Studies, 80*(2), 774-811.

Wrigley, E. A. (1985). Urban Growth and Agricultural Change: England and the Continent in the Early Modern Period. *Journal of Interdisciplinary History, 15*(4), 683-728.

Young, A. (2005). The Gift of the Dying: The Tragedy of AIDS and the Welfare of Future African Generations. *Quarterly Journal of Economics, 120*(2), 423-466.

Zhao, Y. (1999). Leaving the Countryside: Rural-To-Urban Migration Decisions in China. *American Economic Review, 89*(2), 281-286.

Figure 1: Urbanization Levels and Urban Thresholds in 2010



Figures 2a-2b: Log Urbanization and Crude Death Rate, 1960-2010

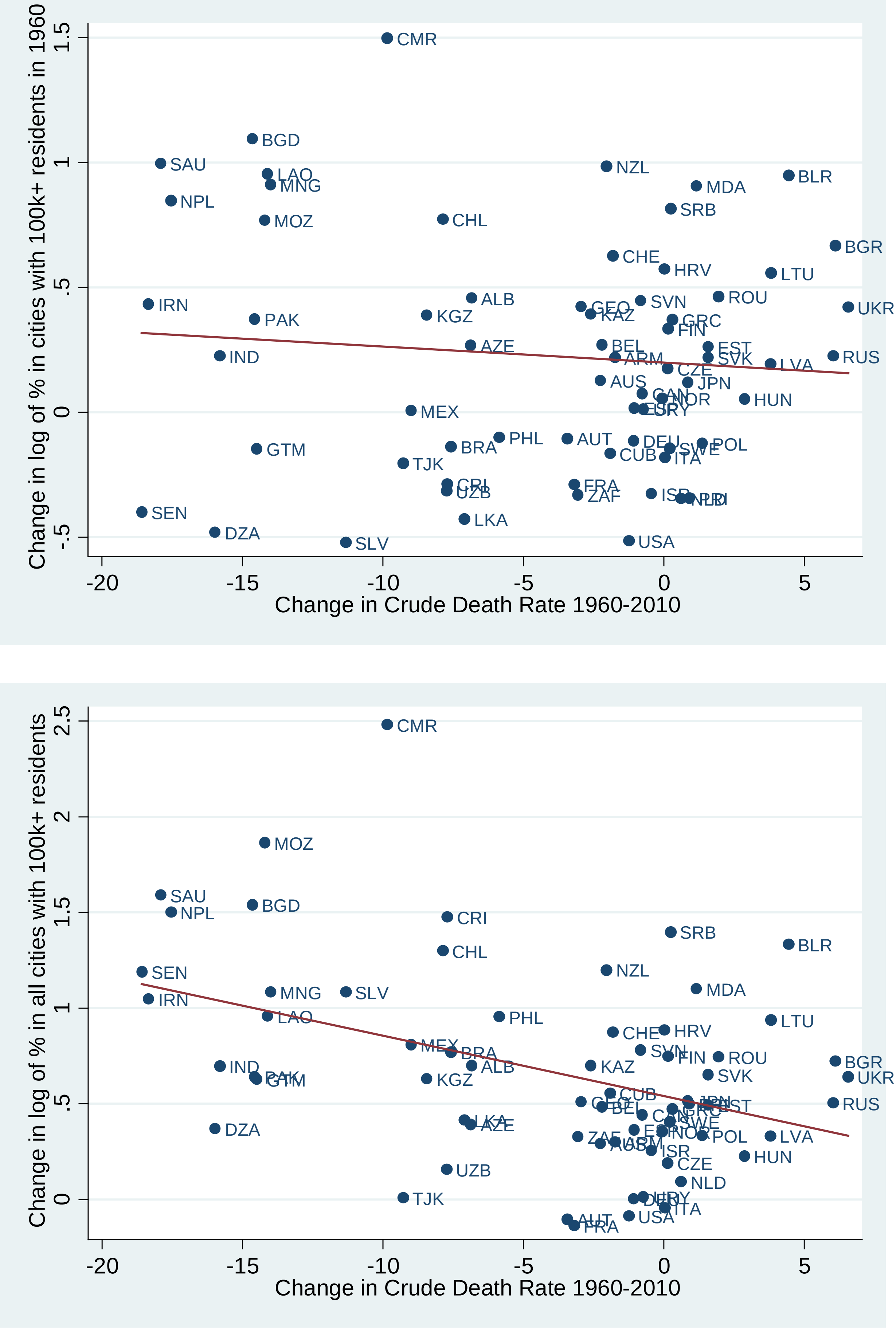


Table 1: Urbanization and Mortality Decline, 1955-2010

Dependent Variable	Log of % Urban	Log of % Urban	Log of % Urban	Log of % Urban	% Urban	% Urban
Regression	OLS	OLS	FE	FE	GLM	GLM
	(1)	(2)	(3)	(4)	(5)	(6)
Crude Death Rate	-0.720***	-0.151***	-0.302***	-0.241***	-0.277***	-0.306***
	(0.057)	(0.062)	(0.039)	(0.065)	(0.054)	(0.088)
Log GDP per capita		0.188***		-0.058		0.041
		(0.031)		(0.069)		(0.073)
Agriculture share of GDP		-1.444***		-0.804***		-0.411**
		(0.372)		(0.174)		(0.185)
Constant	4.525***	2.572***	4.162***	4.729***	-0.723***	-0.965*
	(0.059)	(0.313)	(0.038)	(0.611)	(0.093)	(0.552)
N	2196	1288	2196	1288	2208	1288
Country Clusters	183	175	183	175	184	175
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	no	no	yes	yes	yes	yes
R^2	0.434	0.627				
R^2 (within)			0.649	0.657		

* $p \leq 0.10$, ** $p \leq 0.05$; *** $p \leq 0.01$; robust standard errors clustered at the country level are in parentheses. The data is measured in 5-year increments.

Table 2: Urbanization and Mortality Decline, Ten- and Forty-Year First Differences (1970-2010)

(Dependent Variable: Log of Percentage Urban)

Regression	OLS 10-year	OLS 10-year	FE 10-year	FE 10-year	FE 40-year	FE 40-year
	(1)	(2)	(3)	(4)	(5)	(6)
Crude Death Rate	-0.179***	-0.255***	-0.110***	-0.087	-0.586***	-0.580***
	(0.040)	(0.045)	(0.014)	(0.058)	(0.038)	(0.065)
Log GDP per capita		0.046		0.049		-0.013
		(0.031)		(0.043)		(0.064)
Agriculture share of GDP		-0.534***		-0.223		-1.507***
		(0.154)		(0.171)		(0.395)
Constant	0.055***	0.048***	0.061***	0.052***	4.343***	4.770***
	(0.008)	(0.011)	(0.007)	(0.015)	(0.043)	(0.595)
N	915	511	915	511	366	144
Country Clusters	183	165	183	165	183	72
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	no	no	yes	yes	yes	yes
R^2	0.222	0.278				
R^2 (within)			0.280	0.227	0.566	0.764

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

Table 3: Urbanization and Mortality Decline, 1900-1950
(Dependent Variable: Log of Percentage Urban)

Urban Threshold	50,000	25,000	20,000	50,000	25,000	20,000
	(1)	(2)	(3)	(4)	(5)	(6)
Crude Death Rate	-0.058**	-0.048*	-0.057**	-0.131***	-0.108***	-0.122***
	(0.023)	(0.025)	(0.026)	(0.019)	(0.023)	(0.026)
Log of GDP per capita				0.088**	0.051	0.068
				(0.039)	(0.048)	(0.056)
Share of Labour Force in Agriculture				-0.291***	-0.338***	-0.368***
				(0.050)	(0.083)	(0.100)
Constant	0.256***	0.273***	0.324***	-0.148	0.154	0.100
	(0.050)	(0.054)	(0.056)	(0.300)	(0.385)	(0.447)
N	52	52	52	26	26	26
Country Clusters	26	26	26	13	13	13
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes
R^2 (overall)	0.459	0.458	0.418	0.477	0.474	0.440

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

Table 4: Urbanization and Mortality Decline, Instrumental Variable Results

	(1)	(2)
Panel A: First-Stage Results		
(Dependent Variable: Δ in Crude Death Rate, 1960-2010)		
Malaria Ecology	-0.042***	-0.033***
	(0.006)	(0.007)
Δ in GDP, 1960-2010		0.163*
		(0.089)
Constant	-0.692***	-0.879***
	(0.065)	(0.116)
F-statistic	48.75	21.49
R^2	0.143	0.231
Panel B: 2SLS Results		
(Dependent Variable: Change in Log of Percentage Urban, 1960-2010)		
Δ in Crude Death Rate	-0.796***	-0.967***
	(0.118)	(0.251)
Δ in GDP		0.144
		(0.160)
Constant	0.009	-0.240
	(0.115)	(0.344)
N	163	105

* $p \leq 0.10$, ** $p \leq 0.05$; *** $p \leq 0.01$; robust standard errors in parentheses.

Table 5: 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	-0.005	-0.025	-0.079	-0.075	-0.499***	-0.408**	-0.294***	-0.307***
	(0.053)	(0.075)	(0.085)	(0.106)	(0.124)	(0.190)	(0.076)	(0.083)
Δ in Log GDP per capita		-0.088		-0.214		-0.080		-0.364**
		(0.082)		(0.180)		(0.259)		(0.180)
Constant	-2.248***	-1.756**	-1.590***	0.292	-1.216***	-0.611	0.974***	2.398
	(0.055)	(0.723)	(0.087)	(1.663)	(0.131)	(2.252)	(0.078	(1.669)
N	208	132	150	94	208	132	150	94
Country Clusters	104	66	75	47	104	66	75	47
Time Dummies	yes	yes	yes	yes	yes	yes	yes	yes
Country Dummies	yes	yes	yes	yes	yes	yes	yes	yes
R^2 (overall)	0.004	0.154	0.049	0.235	0.233	0.211	0.267	0.003

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

Table 6: Urbanization and Mortality Decline in Cities vs. Urban Agglomerations, 2000-2010
(Dependent Variable: Log of Percentage of Primate City Population)

Dataset	Urban Agglomeration	City Proper	Urban Agglomeration	City Proper
Regression Type	OLS	OLS	FE	FE
	(1)	(2)	(3)	(4)
Crude Death Rate	-0.052*	0.018	-0.047*	-0.009
	(0.028)	(0.019)	(0.027)	(0.017)
Constant	-0.173***	-0.170	-0.175***	-0.144***
	(0.029)	(0.020)	(0.025)	(0.016)
N	104	104	104	104
Country Clusters	52	52	52	52
Time Dummies	yes	yes	yes	yes
Country Dummies	no	no	yes	yes
R^2	0.045	0.013		
R^2 (within)			0.099	0.007

* $p \leq 0.10$, ** $p \leq 0.05$; *** $p \leq 0.01$; robust standard errors in parentheses.

Appendices

Appendix 1: Description of Copula Method and Results

One additional solution to deal with problems of endogeneity is to undertake the same estimations as Tables 1 and 2 using copulas. We consider the following model:

$$\mathrm{Y} = \mathrm{X}\beta + \mathrm{e} \tag{4}$$

where Y is the measure of urbanisation and X is an *n x k* matrix including an intercept, mortality decline and control variables. β is a *k x 1* vector of coefficients and *e* is an *n x 1* vector of errors. The copula method of estimation deals with endogeneity by using copulas to estimate the joint density of the structural error, *e*, and the endogenous regressor.

We can now describe the method. Sklar (1973)'s theorem states that every joint distribution can be expressed as a function of its marginals and vice versa. The copula is the mapping of the cumulative distribution functions to their joint cumulative distribution function (CDF). For our purposes we will use the Gaussian copula, which is the most widely used copula and assumes that the variables involved have a joint normal distribution.

To fix ideas, let X be composed of x_1 as an endogenous regressor and X_2 as a vector of exogenous regressors. Let the CDF of e, (F_e) be normally distributed $N(0,\sigma_e^2)$. The Gaussian copula G obtains the joint CDF of x_1 and e:

$$\mathrm{G}(\mathrm{x}_1, \mathrm{e}) = \mathrm{N}(x_1^*, e^*) \tag{5}$$

where $x_1^* = \Phi^{-1}\left(\mathrm{F}_\mathrm{x}(\mathrm{x}_1)\right)$, $e^* = \Phi^{-1}\left(\mathrm{F}_\mathrm{e}(\mathrm{e}^*)\right)$, F_x is the cdf of x_1, Φ is the standard normal CDF and N is the bivariate standard normal distribution with the correlation coefficient ρ. Differentiating equation #5 we obtain the joint probability density function:

$$\mathrm{g}(\mathrm{x}_1, \mathrm{e}) = \frac{(\delta\delta\mathrm{G}(\mathrm{x}_1,\mathrm{e}))}{(\delta\mathrm{x}_1\delta\mathrm{e})} f_x f_e \tag{6}$$

where f_x and f_e are marginal densities of x_1 and e, respectively. Traditionally, this density can be used to now obtain the likelihood function and we can then consistently estimate the coefficient of the endogenous regressor using maximum likelihood estimation. Recent studies have however been using a more simpler method, as proposed by Park and Gupta (2012) by including x_1^* in equation #4 as a regressor and estimating by OLS, yielding identical estimates.

The following elaborates how this procedure yields identical estimates. We can express:

$$\begin{pmatrix} x_1^* \\ e^* \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ \rho & \sqrt{(1-\rho^2)} \end{pmatrix} \begin{pmatrix} v_1 \\ v_2 \end{pmatrix} \tag{7}$$

where v_1 and v_2 are independent random variables drawn from a standard normal distribution. The above holds if we assume the joint distribution of x_1^* and e^* to be bivariate standard normal, as is the case for a Gaussian copula.

With the structural error in Equation #4 given by:

$$e = F_e^{-1}(\Phi(e^*)) = \Phi_{\sigma_{e^2}}^{-1}(\Phi(e^*)) = \sigma_e^2 e^* \tag{8}$$

we can therefore use equation #8 to rewrite equation #4, and with breaking up X into endogenous and exogenous parts we obtain:

$$y = x_1\beta_1 + X_2\beta_2 + \sigma_e(\rho_1 x_1^* + \sqrt{}((1-\rho^2))v_2) \tag{9}$$

Thus by splitting the structural error from equation #4 into two parts a) $\sigma_e \rho^1 x_1^*$, which is uncorrelated with x_1 but can be estimated by including x_1^* as a regressor, and b) $\sigma_e(1-\rho^2)$, which is uncorrelated with x_1, we consistently estimate β_1.[1]

The results from the copula method are given below in Tables A1 and A2, which replicate the specifications used in Tables 1 and 2. As can be seen, in all cases the results using copulas do not differ notably from those without copulas. The coefficients for the copula estimates for the endogenous variable (CDR) are larger than the standard panel

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[1] The copula method can only be used when we assume normality of the structural error, and a bivariate normal distribution of this error and the endogenous regressor. This procedure is akin to the Heckman error correction method as it also uses a generated regressor to handle endogeneity (Heckman 1978). The copula method cannot be used with endogenous regressors that are binary or normally distributed as this would imply that the endogenous regressor and its generated regressor would be highly correlated resulting in large standard errors.

or OLS regression estimates. This is in line with other applications in the field (Blauw and Frances 2016) where the OLS estimates are observed to underestimate the estimated relationship compared with that of using the copula. Following Pagan (1984), the generated regressor does not generate accurate standard errors, thus the reported standard errors are bootstrapped standard errors, with 1000 replications.

Bibliography

Pagan, A. 1984. Econometric Issues in the Analysis of Regressions with Generated Regressors. Int. Econ. Rev. 25 (1), 221-247.

Park, S., Gupta, S., 2012. Handling Endogenous Regressors by Joint Estimation Using Copulas. Marketing Science 31 (4), 567-586.

Sklar, A., 1973. Random Variables, Joint Distribution Functions, and Copulas. Kybernetika 9 (6), 449-460.

Table A1: Urbanization and Mortality Decline, 1955-2010, Copula Results

(Dependent Variable: Log of Percentage Urban)

Regression	OLS	OLS	FE	FE
	(1)	(2)	(3)	(4)
Crude Death Rate	-0.888***	-0.261*	-0.649***	-0.457***
	(0.114)	(0.144)	(0.064)	(0.103)
Log GDP per capita		0.190***		-0.031
		(0.031)		(0.072)
Agriculture share of GDP		-1.422***		-0.774***
		(0.371)		(0.166)
Generated regressor	0.103	0.066	0.249***	0.161***
	(0.067)	(0.066)	(0.035)	(0.050)
Constant	0.130	-1.912***	0.017	0.173
	(0.149)	(0.336)	(0.078)	(0.588)
N	2196	1288	2196	1288
Country Clusters	183	175	183	175
Time Dummies	yes	yes	yes	yes
Country Dummies	no	no	yes	yes
R^2	0.446	0.628		
R^2 (within)			0.686	0.669

* $p \leq 0.10$, ** $p \leq 0.05$; *** $p \leq 0.01$; robust standard errors clustered at the country level are in parentheses. The data is measured in 5-year increments.

Table A2: Urbanization and Mortality Decline, Ten- and Forty-Year First Differences (1970-2010), Copula Results

(Dependent Variable: Log of Percentage Urban)

Regression	OLS 10-year (1)	OLS 10-year (2)	FE 10-year (3)	FE 10-year (4)	FE 40-year (5)	FE 40-year (6)
Crude Death Rate	-0.069***	-0.165*	-0.127***	-0.292	-0.732***	-1.035***
	(0.018)	(0.089)	(0.015)	(0.274)	(0.096)	(0.129)
Log GDP per capita		-0.035		0.047		0.070
		(0.032)		(0.042)		(0.061)
Agriculture share of GDP		-0.513***		-0.220		-1.590***
		(0.155)		(0.167)		(0.341)
Generated regressor	-0.079***	-0.176***	0.017	0.089	0.092*	0.332***
	(0.017)	(0.040)	(0.017)	(0.104)	(0.048)	(0.076)
Constant	0.008	-0.045*	0.072***	0.099*	0.080	0.043
	(0.013)	(0.026)	(0.014)	(0.052)	(0.117)	(0.534)
N	915	511	915	511	366	144
Country Clusters	183	165	183	165	183	72
Time Dummies	yes	yes	yes	yes	yes	yes
Country Dummies	no	no	yes	yes	yes	yes
R^2	0.243	0.299				
R^2 (within)			0.274	0.235	0.572	0.800

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

Appendix 2: Additional Tables

Table A3: Summary Statistics

	Obs.	Mean	St.Dev.	Min.	Max.
Log of Percentage Urban	2444	3.559	0.753	0.531	4.605
Crude Death Rate (per 10,000)	2196	1.242	0.651	0.123	6.138
Log of GDP per capita	1888	8.285	1.285	5.080	11.823
Agriculture, Percentage of GDP	1363	0.196	0.164	0.0003	0.931
Log of Population	2431	8.196	2.077	1.981	14.101

Table A4: Bivariate Correlations

	Log % Urb	CDR	Log GDP/c	Ag. %GDP	Log Population
Log of % Urban	1.000				
CDR	-0.658	1.000			
Log GDP/capita	0.744	-0.605	1.000		
Ag. % of GDP	-0.736	0.598	-0.813	1.000	
Log of Population	0.098	-0.034	-0.124	0.046	1.000

Table A5: Countries included in Table 3

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

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

Table A6: Urbanization and Mortality Decline, 1955-2010
(Dependent Variable: Log of Urban Population)

Regression	OLS	FE	OLS 10-year differences	FE 10-year differences
	(1)	(2)	(3)	(4)
Crude Death Rate	-0.732***	-0.269***	-0.159***	-0.129***
	(0.059)	(0.055)	(0.039)	(0.019)
Log Population	1.033***	1.093***	1.107***	0.730***
	(0.019)	(0.094)	(0.060)	(0.098)
Constant	-0.342*	-1.273***	0.058***	0.113***
	(0.185)	(0.864)	(0.014)	(0.016)
N	2160	2160	900	900
Country Clusters	180	180	180	180
Time Dummies	yes	yes	yes	yes
Country Dummies	no	yes	no	yes
R^2	0.935		0.618	
R^2 (within)		0.914		0.497

* $p \leq 0.10$, ** $p \leq 0.05$; *** $p \leq 0.01$; robust standard errors clustered at the country level are in parentheses. The data is measured in 5-year increments.

Table A7: Urbanization and Mortality Decline, 1955-2010

(Dependent Variable: Log of Percentage Urban)

Regression	OLS	FE	OLS 10-year differences	FE 10-year differences	FE
	(1)	(2)	(3)	(4)	(5)
Crude Death Rate	-0.727***	-0.276***	-0.162***	-0.121***	-0.333***
	(0.058)	(0.057)	(0.039)	(0.016)	(0.049)
Log Population	0.034*	0.071	0.092	-0.141**	
	(0.019)	(0.104)	(0.073)	(0.062)	
Total Fertility Rate					0.036**
					(0.014)
Polity2 Score					0.002
					(0.002)
Independent Country					0.069
					(0.103)
Constant	4.236***	3.515***	0.044***	0.080	-0.563***
	(0.181)	(0.948)	(0.011)	(0.010)	(0.119)
N	2160	2160	900	900	1097
Country Clusters	180	180	180	180	150
Time Dummies	yes	yes	yes	yes	yes
Country Dummies	no	yes	no	yes	yes
R^2	0.442		0.227		
R^2 (within)		0.654		0.288	0.699

* $p \leq 0.10$, ** $p \leq 0.05$; *** $p \leq 0.01$; robust standard errors clustered at the country level are in parentheses. The data is measured in 5-year increments.

Table A8: Urbanization and Mortality Decline, Countries with Consistent Urban Thresholds

(Dependent Variable: Log of Percentage Urban)

Regression	OLS	FE	OLS 10-year differences	FE 10-year differences
	(1)	(2)	(3)	(4)
		Panel 1: 1970-2010		
Crude Death Rate	-0.791***	-0.315***	-0.372***	-0.292*
	(0.147)	(0.081)	(0.094)	(0.157)
Constant	4.772***	4.360***	0.032**	0.038
	(0.121)	(0.075)	(0.016)	(0.024)
N	261	261	145	145
Country Clusters	29	29	29	29
Time Dummies	yes	yes	yes	yes
Country Dummies	no	yes	no	yes
R^2	0.346		0.345	
R^2 (within)		0.681		0.302
		Panel 2: 1980-2010		
Crude Death Rate	-0.724***	-0.223***	-0.262***	-0.150*
	(0.134)	(0.058)	(0.052)	(0.080)
Constant	4.671***	4.229***	0.038***	0.051***
	(0.128)	(0.057)	(0.012)	(0.015)
N	287	287	164	164
Country Clusters	41	41	41	41
Time Dummies	yes	yes	yes	yes
Country Dummies	no	yes	no	yes
R^2	0.489		0.273	
R^2 (within)		0.592		0.245

* $p \leq 0.10$, ** $p \leq 0.05$; *** $p \leq 0.01$; robust standard errors clustered at the country level are in parentheses. The data is measured in 5-year increments.

Table A9: Urbanization and Adult vs. Infant 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

* $p \leq 0.10$, ** $p \leq 0.05$; *** $p \leq 0.01$; robust standard errors clustered at the country level are in parentheses. The data is measured in 5-year increments.

Table A10: Urbanization and Mortality Decline, Controlling for Causes of Rural-Urban Migration

(Dependent Variable: Log of Percentage Urban)

Regression	OLS	FE	OLS 10-year differences	FE 10-year differences
	(1)	(2)	(3)	(4)
Crude Death Rate	-0.612***	-0.200***	-0.135***	-0.113***
	(0.085)	(0.063)	(0.027)	(0.013)
Log of Precipitation	-0.079	-0.033	-0.058***	-0.055**
	(0.057)	(0.050)	(0.020)	(0.024)
Temperature (Standard Deviation)	0.025	-0.108	-0.023	0.005
	0.020	(0.054)	(0.020)	(0.018)
Natural Resource Exports (% of GDP)	0.634**	0.361*	0.249***	0.179**
	(0.249)	(0.200)	(0.088)	(0.074)
Constant	4.256***	0.176***	0.161***	0.104***
	(0.198)	(0.022)	(0.017)	(0.013)
N	533	533	425	425
Country Clusters	108	108	108	108
Time Dummies	yes	yes	yes	yes
Country Dummies	no	yes	no	yes
R^2	0.471		0.187	
R^2 (within)		0.695		0.269

* $p \leq 0.10$, ** $p \leq 0.05$; *** $p \leq 0.01$; robust standard errors clustered at the country level are in parentheses. The data is measured in 5-year increments.