The Urban Mortality Transition and Poor Country Urbanization

Remi Jedwab and Dietrich Vollrath

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ONLINE APPENDIX

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1 Data

1.1 Characteristics of Cities, Urban Areas, and Rural Areas

Urbanization Rate Data. We use Bairoch (1988), Acemoglu et al. (2002), Malanima and Volckart (2007), United Nations (2014) and Jedwab & Moradi (2016) to obtain, when available, the urbanization rate (%) of 159 countries (which account for 99% of the world population in 2000) in 1700 (N = 18), 1900 (N = 70), 1950 (N = 159) and 2010 (N = 159).

National Income Data. We use Maddison (2008) and Bolt and Van Zanden (2014), who update Maddison (2008), to obtain log per capita GDP (PPP, constant 1990 dollars) for all the countries and decades for which we use data on urbanization rates. Developed (developing) countries are defined as countries whose GDP per capita (PPP, constant 2011 international $) is above (below) the income level of Slovakia, which is the latest country to have been reclassified as a "developed" country by the International Monetary Fund in 2013.[1]

City Population Data. For each urban agglomeration, we use Chandler (1987) and United Nations (2014) to obtain their population in 1700, 1900, 1950 and 2015, and their projected population in 2030. An urban agglomeration comprises the city proper and also the suburban fringe or thickly settled territory lying outside according to United Nations (2014). We also use the same sources to obtain the population of selected cities in selected years.

City Welfare Ratio Data. The sources used to obtain the welfare ratios for the pre-1910 period (estimated for a "bare bones" consumption basket) are Allen (2007), Allen et al. (2011), Allen, Murphy & Schneider (2012), Frankema & Waijenburg (2012), Francis Jr. (2013) and Bassino, Fukao & Takashima (2014). We obtain the size of each city for the same decade as the decade for which we have the welfare ratio from Chandler (1987).

Demographic Data for Megacities, Urban Areas and Rural Areas. We use various historical and contemporary sources – censuses, demographic surveys, sanitary reports, and historical studies (e.g., books, theses and articles) – to obtain for as many cities, countries and periods as possible the crude rate of natural increase, which is the difference between the crude birth

[1] Source: https://www.imf.org/external/pubs/ft/wp/2011/wp1131.pdf.

rate and the crude death rate. These sources are described for each city-year in the spreadsheet megacities_data_12182017.xlsx available on the website of the authors [Note that the data set is actually not available yet. It will be made available if the paper is accepted for publication, as it is standard in our discipline.]. There is a sheet tab for each country for which we have city-specific demographic data (Afghanistan, Angola, etc.).[2] The sheet tabs report the demographic rates for each city as well as the sources used to obtain these. There is also a sheet tab Summary_Cities that compiles the information from each country-specific tab.[3]

Ultimately, we have data for 38 city-year observations in the 1800s or before, 33 cities in the 1820s-1850s, 69 cities in the 1880s, 89 cities in the 1900s, 63 cities in the 1960s, and 100 cities in the 2000s, so 392 cities in total. The cities before 1900 and in the 1900s were selected because they were among the 100 largest cities in 1900 according to Chandler (1987). The cities in the 1960s and the 2000s were selected because they are among the 100 cities that will be the world's largest urban agglomerations in 2030 according to United Nations (2014). We also collect the same type of data for a number of cities that were among the richest cities of the past, but were not among the 100 largest cities in 1900 and will not be among the 100 largest cities by 2030.

For each city-period observation, we obtain from the similar sources the crude rates of birth, death and natural increase of the other cities, the rural areas and the whole area of their respective country and period.[4] The sources for these estimates are also described for each country-year in the spreadsheet megacities_data_12182017.xlsx available on the website of the authors. The sheet tab Summary_Cities compiles the information from each country-specific tab.

Demographic Data for Slums vs. Non-Slum Areas. We use various historical sources to obtain the crude rates of birth, death and natural increase of the slum areas and the non-slum areas for 4 cities of the developed world in the 19th century: London in 1886, Manchester in 1894, New York in 1890-1895 and Paris in 1864.[5] We also have the same type of data for the slum areas and the non-slum areas of 7 cities of the developing world in the 20th century: Cairo, Dhaka, Karachi, Manila, Mexico, Mumbai, and Nairobi. The sources for these estimates are described in the related country-specific sheet tabs in the spreadsheet megacities_data_12182017.xlsx available on the website of the authors.[6] The sheet tab Summary_Slums compiles the information from each country-specific tab, and reports the average demographic rates in each group of cities.

City Development Index Data. We do have a city development index for 118 cities of at least 500,000 inhabitants circa 2010 (UN-Habitat 1998, 2012). The city development index combines information on each city's per capita GDP in purchasing power parity terms, thus accounting for

[2]For example, for the city of Paris (see tab France), the demographic rates are available for the 17th century, the 1700s, the 1750s, the 1800s, the 1820s, the 1850s, the 1880s, the 1900s, the 1960s, and the 2000s.

[3]Note that the crude birth rates and the crude death rates are directly reported in the sources for most city-periods in our sample. Fortunately, most sources use consistent definitions of these rates. For the oldest city-periods in our sample, we use the work of anthropometrists who studied graves and skeletons to obtain data on average fertility (i.e. birth rates) and life expectancy (i.e. death rates). For a few more recent city-periods in our sample, and only when necessary, we use total fertility rates to obtain crude birth rates, and child mortality rates or life expectancy to obtain crude death rates. These cases are indicated in the spreadsheet megacities_data_12182017.xlsx.

[4]For all the "mega-cities" of a same country, we use their percentage share in the total urban population, their crude rates of birth and their crude rates of death, and the urban crude rates of birth and the urban crude rates of death, to obtain the mean crude rates of birth and crude rates of death of the remaining urban areas (the "other cities").

[5]For London (1886), we use data for 7 *Sanitary Districts* of the East End. For Manchester (1894), we use data for *Township* areas. For New York (1890-1895), we use data for 8 *Great Tenement House Districts*. For Paris (1865), we use data for 7 *Arrondissements pauvres*.

[6]For example, for the city of Paris (see tab France), we obtain from various sources the crude birth rates and crude death rates for each of the 20 *arrondissements*, and then estimate the population-weighted average crude birth rates and crude death rates for the 7 *arrondissements* classified as *pauvres* (poor) in these same sources.

costs of living, and information on infrastructure, waste, health and education (details available in the UN reports). More precisely, we use the city prosperity index of UN-Habitat (2012) as the main source of city income information for the 2000s, and complement our data using the city development index of UN-Habitat (1998) when the information for the year 2012 is missing (using Stockholm for which we have information in both years to link the two data sets).[7]

Urban and Rural Population Growth Data. We know from United Nations (2014) the respective growth rates of the urban and rural population of each country between 1950 and 2015.

City Population Density and Slum Data. We use Demographia (2014) to obtain the population density (number of inhabitants per sq km) for each urban agglomeration for the most recent year in the 2000s-2010s. An urban agglomeration comprises the city proper and also the suburban fringe or thickly settled territory lying outside according to United Nations (2014). Therefore, the population density is estimated also including the suburbs of the city, and not just the core area. We then use UN-Habitat (2003) and United Nations (2012) to obtain the slum share (%) for the country of each city for the most recent year in the 2000s-2010s. The slum share is the share of the urban slum population in the total urban population (%) of each country. From World Bank (2015), we know the share of the urban population with access to improved sanitation facilities and the share of the urban population with access to an improved water source.

City Infrastructure Data. The city infrastructure index combines information on access to water, sanitation, electricity, roads, and housing. Full details are available in the UN-Habitat (1998, 2012) reports. We use the 2012 index as the main source of city infrastructure information for the 2000s, and complement our data using the 1998 index when the information for the year 1998 is missing (using Stockholm for which we have information in both years to link the two data sets).

City Dependency Ratio Data. Data on the child dependency ratio (%) was recreated using the DHS (2013), for each city.[8] and IPUMS (2013)[9] The child dependency ratio is the ratio of the number of residents aged 0-14 over the number of residents aged 15-64 x 100.

City Educational Attainment and Employment Data. We use *IPUMS* census microdata to recreate the share of people aged 25 and over that have completed tertiary education, for the most recent year in the 2000s.[10]

Consumption Shares. The consumption shares for 35 countries among the 43 poor countries of our main analysis come from the *Global Consumption Database* of the World Bank.[11] The consumption shares for 29 OECD countries then come from the *Statistical Database* of the OECD.[12]

1.2 Samples and Data for the Calibration

Sample of 43 Poor Countries. We focus our calibration analysis on 43 "poor" countries in 1950-2005. We selected countries with (a) at least 1 million inhabitants in 1950, (b) an urbanization rate below 20% in 1950, so countries unurbanized initially, and (c) data available on the slum share in 2005. The choice of 2005 was dictated by the availability of widespread slum data in this year (UN-Habitat 2003, 2012). The 43 countries include 29 countries from Africa, 11 from Asia, 2 from Latin America and 1 from the Middle East: Angola, Bangladesh, Benin, Burkina-Faso, Burundi, Cambodia, Cameroon, Central African Republic, Chad, China, the D.R.C., Ethiopia,

[7] The city prosperity index of UN-Habitat (2012) is based on city-level measures of productivity, infrastructure, waste, health and education. The city development index of UN-Habitat (1998) is based on measures of productivity, quality of life, infrastructure development and environmental sustainability.

[8] Source: http://www.statcompiler.com/

[9] Source: https://international.ipums.org/international/

[10] Source: https://international.ipums.org/international/

[11] Source: http://datatopics.worldbank.org/consumption/

[12] Source: http://stats.oecd.org/

Ghana, Guinea, Haiti, Honduras, India, Indonesia, Ivory Coast. Kenya, Laos, Madagascar, Malawi, Mali, Mozambique, Myanmar, Nepal, Niger, Nigeria, Pakistan, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Thailand, Togo, Uganda, Tanzania, Vietnam, Yemen, Zambia and Zimbabwe.

Sample of 20 Historical Countries. We also calibrate our model for 20 "historical" countries in 1800-1900 and 1800-1950. The 20 countries includes 19 Western European countries and the United States, as one example of a Neo-European country: Austria, Belgium, Denmark, England, Finland, France, Germany, Hungary, Ireland, Italy, the Netherlands, Northern Ireland, Norway, Portugal, Scotland, Spain, Sweden, Switzerland, the United States and Wales. Note that we know their total population and their total urban population in 1800, 1900 and 1950.

2 Decomposition of the Location Elasticities

In this section we show how location elasticities can be decomposed into location-specific wage elasticities, agglomeration effects, house price elasticities, and amenity elasticities.

General decomposition: Let individual utility be described by the following

$$V_j = \omega_c \ln c_j + \omega_h \ln h_j + \omega_q \ln Q_j + \omega_d \ln(1/CDR_j). \tag{1}$$

where c_j is consumption of non-housing goods and services, and h_j is consumption of housing services. The preference weights ω_c and ω_h fulfill, without loss of generality, $\omega_c + \omega_h = 1$.

The amenity value Q_j and the crude death rate CDR_j are taken as given by an individual in location j. They choose, however, the amounts of c_j and h_j to purchase. The budget constraint facing an individual in location j is

$$w_j = c_j + p_j h_j \tag{2}$$

where p_j is the price of housing (relative to consumption goods), and w_j is the wage. Optimizing over consumption and housing, we get that $c_j = \omega_c w_j$ and $h_j = \omega_h w_j / p_j$. This results in utility of

$$V_j = \ln w_j - \omega_h \ln p_j + \omega_q \ln Q_j + \omega_d \ln(1/CDR_j) + \Omega, \tag{3}$$

where $\Omega = \omega_c \ln \omega_c + \omega_h \ln \omega_h$.

For our purposes, we care about the growth rate of utility in each location, which is given by

$$\hat{V}_j = \hat{w}_j - \omega_h \hat{p}_j + \omega_q \hat{Q}_j - \omega_d C\hat{D}R_j. \tag{4}$$

We can evaluate each of these separate terms to find the effect of population growth on utility growth.

Wage elasticities and agglomeration effects: To determine the wage in a given location, we assume a production function of the form

$$Y_j = A_j K_j^{\alpha_j} X_j^{\beta_j} N_j^{1-\alpha_j-\beta_j} \tag{5}$$

where A_j is productivity, K_j is capital, and X_j is land. Note that the shares α_j and β_j are unique to a given location. Assuming that labor earns its marginal product, the wage in location j is given by

$$w_j = (1 - \alpha_j - \beta_j) A_j K_j^{\alpha_j} X_j^{\beta_j} N_j^{-\alpha_j-\beta_j}. \tag{6}$$

We can allow explicitly for agglomeration effects by letting productivity be a function of the labor force, as in

$$A_j = B_j N_j^{\gamma_j} \tag{7}$$

where B_j is the inherent productivity in location j, and $\gamma_j > 0$ captures the agglomeration effect in location j.

With this specification for productivity, and the expression for the wage, the growth rate of the wage is given by

$$\hat{w}_j = \hat{a}_j^w + (\gamma_j - \alpha_j - \beta_j)\hat{N}_j, \tag{8}$$

where $\hat{a}_j^w = \hat{B}_j + \alpha_j \hat{K}_j$ is the growth of productivity and capital that is independent of the growth rate in the labor force. The effect of growth in the labor force may be positive or negative, depending on how big the agglomeration effects (γ_j) are relative to the importance of capital and land in production ($\alpha_j + \beta_j$).

In terms of our baseline model, we can write the above as

$$\hat{w}_j = \hat{a}_j^w + \epsilon_j^w \hat{N}_j, \tag{9}$$

where $\epsilon_j^w = \gamma_j - \alpha_j - \beta_j$ is the elasticity of the wage with respect to population size.

House price elasticities: The second term in utility growth involves the price of housing. Given some limitations on housing due to land constraints and/or regulations, then it should be the case that prices are rising with N_j. We could write this in a reduced form as

$$\hat{p}_j = \hat{a}_j^h + \epsilon_j^h \hat{N}_j \tag{10}$$

where ϵ_j^h is the elasticity of the housing price with respect to population size. The value $\hat{a}_j^h$ is exogenous growth in the housing price in location j for any reason unrelated to population size.

Amenity elasticities: The third term in utility growth involves amenties. Assuming some effect of population size on the quantity (or implicit value) of amenities available, then we could write, again in reduced form,

$$\hat{Q}_j = \hat{a}_j^q + \epsilon_j^q \hat{N}_j. \tag{11}$$

Here, $\hat{a}_j^q$ is exogenous growth in the value of amenities, and ϵ_j^g is the elasticity of amenities with respect to population size.

Crude death rate: As stated in the main paper, we are taking the growth of crude death rates to be exogenous, and unrelated to population size.

Reduced form welfare growth: Combining the information about the different components of utility growth, we can write

$$\hat{V}_j = G_j - \epsilon_j \hat{N}_j - \omega_d C\hat{D}R_j \tag{12}$$

where

$$G_j = \hat{a}_j^w - \omega_h \hat{a}_j^h + \omega_q \hat{a}_j^q \tag{13}$$

is the exogenous growth in wages, housing prices, and amenities, where each are weighted as in the utility function. Similarly, the combined elasticity term, ϵ_j is

$$\epsilon_j = \epsilon_j^w - \omega_h \epsilon_j^h + \omega_q \epsilon_j^q \tag{14}$$

$$= \gamma_j - \alpha_j - \beta_j - \omega_h \epsilon_j^h + \omega_q \epsilon_j^q \tag{15}$$

where the second line shows the explicit role of agglomeration effects (γ_j) and the production function parameters (α_j and β_j) on the elasticity. While the value of γ_j is expected to be positive, note that the rest of these terms would act to make ϵ_j negative. The values of α_j and β_j indicate how quickly wages decline with the number of workers. The relationship of housing prices to population size is presumably positive, so the term $\omega_h \epsilon_j^h$ is positive, and so acts to make the overall elasticity negative as well.

3 Extension with Endogenous Fertility

To incorporate endogenous fertility into the model, we modify the utility function to be as follows

$$V_j = \ln w_j + \ln Q_j + \beta \ln(1/CDR_j) + \gamma \ln n(w_j, CDR_j, \tau_j) \tag{16}$$

where $n(w_j, CDR_j, \tau_j)$ is the number of births as a function of the wage, w_j, and the crude death rate, CDR_j. τ_j is a location-specific cost of having children. This function is the optimal outcome of a choice problem facing individuals who take the wage and crude death rate in a location as given, deciding how many children to have.

Putting this in terms of growth rates, we have the following

$$\hat{V}_j = \hat{w}_j - \beta C\hat{D}R_j + \gamma\phi_w^n \hat{w}_j + \gamma\phi_{CDR}^n C\hat{D}R_j. \tag{17}$$

The term ϕ_w^n is the elasticity of fertility with respect to wages, and ϕ_{CDR}^n is the elasticity of fertility with respect to the death rate. There are several assumptions located in this expression. First, we assume that $\hat{Q}_j = 0$, or that amenities do not grow. We do this because the fertility decision is directly related to wages, and we have no way of separately tracking amenity from wage growth in the model. Hence, to solve the model we need a way of pinning down wage growth, and assuming that amenities do not grow is the most direct way of doing this. Second, we have assumed that τ_j does not change over time, although it drives level differences between locations in crude birth rates.

Re-arranging this expression for the growth rate of welfare, we have

$$\hat{V}_j = (1 + \gamma\phi_w^n)\hat{w}_j - (\beta - \gamma\phi_{CDR}^n)C\hat{D}R_j, \tag{18}$$

which shows that welfare growth is a combination of wage growth and changes in mortality, similar to the baseline model. Here, the effect of wage growth is modified by the effect that it has on optimal fertility behavior (the $\gamma\phi_w^n$ term) and the effect of mortality is modified by the effect it has on fertility (the $\gamma\phi_{CDR}^n$ term).

Based on parameter values from the literature noted below, $\phi_w^n < 0$, meaning that fertility is negatively related to wages. Thus the effect of wage growth on welfare growth is *smaller* with endogenous fertility. An increase in wages raises welfare, but also lowers optimal fertility, and as people value fertility ($\gamma > 0$), this lowers welfare.

For mortality, the literature also indicates that $\phi_{CDR}^n < 0$, or lower mortality raises net fertility. Combined with the assumptions that $\gamma > 0$, this implies that endogenous fertility makes the effect of changes in mortality even larger in absolute size. A decline in mortality directly raises welfare, but through its effect of raising fertility has an additional positive effect on welfare. Endogenous fertility thus tends to put greater weight on mortality rates and less on wage growth in determining welfare.

With wage growth determined by $\hat{w}_j = \hat{a}_j^w - \epsilon_j^w \hat{N}_j$, as in the original model, we have that

$$\hat{V}_j = G_j - \epsilon_j \hat{N}_j - \theta_j C\hat{D}R_j \tag{19}$$

In terms of our prior notation, this implies that now

$$\begin{aligned} G_j &= (1 + \gamma\phi_w^n)\hat{a}_j^w \\ \epsilon_j &= (1 + \gamma\phi_w^n)\epsilon_j^w \\ \theta_j &= (\beta - \gamma\phi_{CDR}^n) \end{aligned} \tag{20}$$

Note that the structure of utility growth is identical to what we have in the baseline model, as it depends on welfare growth not related to population, G_j, population growth, $\hat{N}_j$, and changes in the crude death rate, $C\hat{D}R_j$. The interpretation of G_j, ϵ_j, and the term θ_j are now different, as they incorporate terms involving fertility, but solving the model from here is identical to our baseline model.

What does change is the exact specification for growth in population. Rather than our set-up from before, now we have that

$$\hat{N} = \sum_{j=1}^{J} s_j \left(n(w_j, CDR_j, \tau_j) - CDR_j \right). \tag{21}$$

Aggregate population growth will change over time both because of changes in the allocation of individuals across locations, the s_j terms, but also because of changes in fertility due to wages and crude death rates across locations.

To simulate the model, we require several additional parameters. Work by Vogl (2016) suggests that the utility weight on fertility is roughly equal to that on consumption, which in terms of this model implies that γ should be roughly equal to one.

For simulation, we need the elasticity of the crude birth rate with respect to both wages and crude death rates. Jones et al. (2010) provide elasticities of fertility with respect to income for the U.S. from 1826-1960, and find that they generally decline from between -0.30 and -0.40 in the 1800's to about -0.20 in the 1950's. Young (2005) estimates an elasticity of fertility with respect to wages of -0.35 using household survey data from South Africa. Total fertility rates and crude birth rates may deviate because of age structure. As a check on these elasticities, we use cross-country evidence from the United Nations (2012), and regressed the log crude birth rate on log GDP per capita using a panel of developing countries between 1950-2010, finding an elasticity of -0.20. We use a value of $\phi_w^n = -0.3$ in our calibration.

The elasticity of crude birth rates with respect to crude death rates, ϕ_{CDR}^n is much harder to pin down. In the end, the exact value does not turn out to be important, and the calibration is not sensitive to the exact choice of this elasticity. We use a value of $\phi_{CDR}^n = -0.30$ as a baseline, but modifying this between 0 and -1 does not create material differences in our results. The value of θ_j follows directly from the values of β, γ, and ϕ_{CDR}^n.

Finally, we require that the crude birth rates in each location in the initial period of the calibration are identical to those obseved in the data from 1950, $n(w_j, CDR_j, \tau_j) = CBR_{j,1950}$, which would implicitly set the values of τ_j. As we only require the changes in fertility over time, solving for these is not necessary.

To keep the simulations with endogenous fertility comparable, we keep the values of the G_j and ϵ_j terms identical to the baseline calibration. From (21) we know that these terms have a slightly different interpretation in the model with endogenous fertility. An alternative would be to entirely recalibrate the model in the endogenous fertility setting, and then replicate all aspects of the baseline analysis. We have done this, and the overall results are not demonstrably different from our baseline model. So for comparison purposes, we present the endogenous fertility results in the paper holding the values of the G_j and ϵ_j terms equal to their values in the baseline.

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