The Urban Mortality Transition and Poor Country Urbanization

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Abstract

Today the world's fastest-growing cities lie in low-income countries, unlike the historical norm. Also unlike the "killer cities" of history, cities in low-income countries grow not just through in-migration but also through their own natural increase. First, we use novel historical data to document that many poor countries urbanized at the same time as the post-war urban mortality transition. Second, we develop a framework incorporating location choice with heterogeneity in demographics and congestion costs across locations to account for this. In the framework, people prefer to live in low-mortality locations, and the aggregate rate of population growth and the locational choice of individuals interact. Third, we calibrate this to data from a sample of poor countries, and find that informal urban areas (e.g. slums) can absorb additional population more easily than other locations. We show that between 1950 and 2005 the urban mortality transition could have doubled the urbanization rate as well as the size of informal urban areas in this sample. Of these effects, one-third could be attributed to the amenity effect of lower urban mortality rates, while the remainder is due to higher population growth disproportionately pushing people into informal urban areas. Fourth, simulations suggest that family planning programs, as well as industrialization or urban infrastructure and institutions may be effective in slowing poor country urbanization.

JEL Codes: E24; E26; O11; O40; OJ10; J11; R11; R13; N00

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Urbanization has gone hand in hand with economic growth throughout history (Henderson, 2010; Duranton, 2014b). However, the post-war period witnessed "poor country urbanization", i.e. fast urbanization in poor countries (Glaeser, 2014; Glaeser and Henderson, 2017). Dhaka, Karachi, Kinshasa, Lagos, and Manila are some of the largest cities on the planet today. In contrast, only six of the currently largest 30 cities (e.g. London, New York, Paris and Tokyo) are in high income countries. The prevalence of poor mega-cities today runs counter to historical experience. In the past, the world's largest cities were almost all in the most advanced economies.

We first document this phenomenon by building the largest available historical database on the spatial aspects of the demographic transition from antiquity to modern times, and show that in the post-war era the urban areas of poor countries experienced rates of natural increase - the birth rate minus the death rate - well above levels seen historically. This was due to the drop in urban death rates following the *urban mortality transition* of the mid-20th century. Cities in poor countries grew in absolute terms because of both in-migration *and* natural increase, setting them apart from historical "killer" cities that grew only through in-migration. We further show that cities in poor countries today are very densely populated relative to rich country cities, with much of this density due to a high share of population in slums.

Second, to account for this *poor country urbanization*, we build a framework incorporating the allocation of population across locations, and calibrate it to match the observed data. Our framework is similar in spirit to work done on structural change (Gollin, Parente and Rogerson, 2002; Duarte and Restuccia, 2010; Michaels, Rauch and Redding, 2012; Buera and Kaboski, 2012; Lagakos and Waugh, 2013), combined with elements of models of population and growth incorporates (Galor and Weil, 1999, 2000; Ashraf and Galor, 2011) and a preference of individuals to live in low mortality locations. Like the literature on equilibrium city size we allow for locational choice of individuals (Henderson, 1974; Duranton and Puga, 2004; Desmet and Rossi-Hansberg, 2013, 2014; Duranton, 2014b), but our framework does not contain an explicit model of agglomeration or congestion. In our setting we allow population to move freely among locations that differ in their demographics, productivity growth, and elasticity of welfare with respect to population. For a stable allocation of population across locations these elasticities are all negative, and their heterogeneity is consistent with locations having production functions that vary in the importance of fixed factors of production and/or in the strength of congestion and agglomeration effects.

A key insight of the framework is that the aggregate population growth rate influences the distribution of population across locations. In particular, an increase in the population growth rate (arising in any location) leads to an increase in the population share of the location with the lowest elasticity of welfare with respect to population. Those locations are able to absorb large population increases without lowering the welfare of residents significantly, and thus they disproportionately grow when population growth accelerates. Note that this does not mean these locations are uncrowded. Rather, precisely because of their low elasticity of welfare with respect to population they will absorb more people, and be the densest locations in the economy.

To quantify the effects of the urban mortality transition (UMT), we then calibrate the framework, matching the average urbanization rate and slum share from 1950 to 2005 for a set of 43 poor and initially un-urbanized countries. We use three types of locations so that we can match to the available data. In addition to *rural* locations, we specify two types of urban locations: *formal* and *informal*. A key outcome of the calibration is that informal urban areas display the lowest elasticity of welfare with respect to population of all the locations, and in turn absorbed a large fraction of the additional population growth created by the UMT.

We find that the UMT may have accounted for two-fifths of urbanization, and two-thirds of the growth in the slum share between 1950 and 2005. While we want to be careful about making welfare statements involving mortality, our calibrated model indicates that welfare might have been slightly lower due to the UMT, as the increased population growth created congestion effects that offset the calibrated gain in welfare arising from higher urban life expectancy. Our calibration indicates that roughly one-third of the effect of the UMT on urbanization may have acted through the *amenity* effect of lower urban mortality rates. The remaining two-thirds was potentially due to the relatively low *welfare elasticity* of informal urban areas, which allowed them to absorb a significant fraction of the additional population growth created by the UMT. We then use the framework calibrated to the experience of developing countries of the 20th century to study the urbanization of 20 currently rich countries between 1800 and 1950. The calibration can account for time path of urbanization and informal shares in these historical countries, and also shows that their slow mortality transition was, in part, responsible for their relatively slow urbanization and smaller informal shares.

Finally, simulations suggest that fast industrialization, better urban infrastructure investments and/or better urban institutions, and voluntary family planning programs could all be effective ways to increase aggregate welfare and reduce the size of informal urban areas. In contrast, restricting migration into cities generally, or specifically into informal urban areas (e.g. slum clearance), does little but lower welfare by forcing people to remain in rural areas.

This paper extends the literature on structural change and urbanization in several ways. There is a large body of literature that investigates the determinants of structural change in less-developed countries (see Herrendorf, Rogerson and Valentinyi (2014) for a recent survey), such as agricultural productivity growth (Matsuyama, 1992; Gollin, Parente and Rogerson, 2002, 2007; Restuccia, Yang and Zhu, 2008), industrial productivity growth (Hansen and Prescott, 2002; Alvarez-Cuadrado and Poschke, 2011), or trade costs (Gollin and Rogerson, 2014; Tombe, 2015). With the exception of Jedwab et al. (2015) and Leukhina and Turnovsky (2016), the literature has little studied the role of population growth on allocations across sectors or locations. Our quantitative analysis shows that this explanation is important, even if it does not rule out other explanations, such as urban bias (Ades and Glaeser, 1995; Davis and Henderson, 2003), conflict (Fay and Opal, 2000; Maystadt and Duranton, 2014; Dincecco and Onorato, 2016), natural disasters (Barrios et al., 2006; Henderson et al., 2016a), trade (Glaeser, 2014; Gollin et al., 2015) and

institutions (Glaeser, 2014; Henderson et al., 2016b).[1] Moreover, our framework for studying the interaction of population growth with structural change could readily be extended to phenomena beyond the UMT, and shows that the conditions under which population growth does *not* matter for urbanization are a special case.

Beyond that the paper offers contributions in several other areas. First, if knowledge spillovers are the "engines of growth" (Romer, 1986; Lucas, 1988), and if cities facilitate interactions between people (Jacobs, 1969), cities promote growth (Glaeser et al., 1992; Lucas, 2004). However, the rise of over-congested cities in poor countries raises questions about their origins, which we investigate.[2] Second, locational choices are explained by both local productivities and amenities (Rosen, 1979; Roback, 1982; Albouy, 2008; Albouy and Stuart, 2014). We show that a specific amenity – higher life expectancy – has contributed to urbanization in poor countries.[3] Third, we study congestion effects in poor countries. Related studies are Desmet and Rossi-Hansberg (2013, 2014), Duranton (2014a), Hanlon and Tian (2015), Hanlon (2016), Akbar and Duranton (2016) and Akbar et al. (2017). Lastly, our quantitative analysis is able to deliver policy prescriptions.[4]

Our work also adds to the literature on the economic effects of demography. First, while population growth promotes economic growth if high densities encourage human capital accumulation or technological progress (Becker et al., 1999; Galor and Weil, 2000; Lucas, 2004; Desmet et al., 2015), we show that "Malthusian"-type negative effects of population size on living standards may persist even as economies urbanize. Second, we demonstrate that poor country urbanization may have arisen because of the success of interventions that limited urban death rates while urban birth rates remained high. In this, our work is similar to Young (2005) and Voigtländer and Voth (2013), who emphasize the possible negative effects of lower mortality on development.[5] Other studies that consider the effect of differential mortality on growth include: Weil (2007); Bleakley (2007, 2010); Ashraf et al. (2013); Cervellati and Sunde (2015).[6] The paper

[1]Jedwab et al. (2015) study the correlations between natural increase and urbanization for a restricted sample of 40 developing countries from 1750 to date. Their work is descriptive, while our theoretical analysis allows us to characterize the trajectory of urban areas in poor countries, quantify the mechanisms by which urban mortality causes urbanization, and identify policies that may alleviate the problem of poor country urbanization.

[2]So far, little attention has been given to the growth of cities in *low-income* countries (see Duranton, 2014b; Desmet and Henderson, 2014; Glaeser and Henderson, 2017, for recent surveys). With the exception of Fay and Opal (2000), Glaeser (2014) and Henderson et al. (2016a,b), the literature has focused on middle-income countries (see Au and Henderson, 2006; Desmet and Rossi-Hansberg, 2013, 2014; Duranton, 2014b; Chauvin et al., 2016; Harari, 2016).

[3]The paper is also related to the literature on the economic role of urban sanitation (Ambrus et al., 2015; Ashraf et al., 2016). We use our framework to discuss the general equilibrium effects of lower urban death rates.

[4]Since 2015, the United Nations have adopted as their 11th *Sustainable Development Goals* the need to "make cities and human settlements inclusive, safe, resilient and sustainable." According to their website, "as more people migrate to cities in search of a better life and urban populations grow, housing issues intensify. Already in 2014, 30% of the [world's] urban population lived in slum-like conditions." Link to url: https://sustainabledevelopment.un.org/sdg11.

[5]Like those two papers we match a model to the data and quantify the effects of mortality. Unlike Acemoglu and Johnson (2007) we do not pursue reduced form empirics. We do not have sufficient data on wages, prices and amenities, across time or locations to run regressions. Nor is there a clear strategy to identify the causal effect of urban mortality relative to overall mortality.

[6]The literature on the relationship of population and growth is vast (see Jones, Schoonbroodt and Tertilt (2010) and Galor (2012) for recent surveys). Barro and Becker (1989), Becker et al. (1990) and Manuelli and Seshadri (2009) provide models of the negative relationship of income and fertility. Unified growth models depend on a rise in the demand for human capital to induce sustained growth, which is driven by acceleration in technological change (Galor and Weil, 1999, 2000; Ashraf and Galor, 2011). Other factors include child labor (Doepke and Zilibotti, 2005), health

also contributes to the literature documenting demographic patterns over time (Jones and Tertilt, 2006; Cutler et al., 2016). Other studies of urban mortality have focused on England or the U.S. (Costa and Kahn, 2006; Haines, 2008; Hanlon and Tian, 2015; Hanlon, 2016).

Lastly, the paper does not imply spatial misallocation, unlike the literature on the urban-rural income gap (Gollin et al., 2013; Young, 2013; Lagakos et al., 2017). While we can allow for migration restrictions in our analysis, low welfare comes from the fact that individuals do not internalize the negative externalities of their own fertility and location decisions.

In the next section we document poor country urbanization, and the underlying demographic and economic features of the urban areas of poor countries. We then present and calibrate our framework, and quantify the role of the urban mortality transition in the urbanization process of poor countries. The final section discusses the policy implications of the findings.

1. Stylized Facts on Urban Mortality and Poor Country Urbanization

While the theoretical analysis of Section 3 will be conducted at the country level, we establish our stylized facts using both country-level data and city-level data, since historical data on urban demography is relatively more available for cities than for countries as a whole.

1.1. Poor Country Urbanization, 1700-2010

Historical Evidence from Countries. The link between urbanization and development has evolved over time. Figure 1 plots the urbanization rate and log per capita GDP (in PPP terms and constant 1990 dollars) for all available countries circa 1700, 1900, 1950, and 2010 (see notes under Figure 1 for details on the sources). The relationship between urbanization and development is estimated and plotted separately for each year. In 1700, development was low and related to urbanization. In 1900 and 1950, the relationship is similar, but the slope had increased relative to 1700, and there is a small shift upward in overall urbanization by 1950 at all levels of development. However, if we continue the analysis through 2010, we see a significant change of the relationship. In the period after World War II, poor countries saw urbanization rates increase rapidly. At GDP per capita of $1,100 (7.0 in logs), the urbanization rate was on the order of 40% in 2010, whereas it had been close to 20% in 1950. At the same time, urbanization rates among richer countries has barely changed by 2010. At GDP per capita of $8,100 (9.0 in logs) urbanization rates in 2010 were around 60%, similar to their level in 1950.

Historical Evidence from Cities. Table 1 shows the largest 30 cities in the world in select years from 1700 to 2015. The mega-cities of 1700 were located in the most advanced countries in that period. While London and Amsterdam had wages that were relatively high then, cities such as Beijing and Istanbul had wages equivalent to those found in cities such as Paris and Naples (Özmucur and Pamuk, 2002; Allen et al., 2011). By 1900, the cities dominating this list were the leading cities from the richest countries, such as London, New York, and Paris. Further down, we see Boston, Liverpool, Manchester, and Philadelphia. In 1950 the top cities remained those in

improvements (Cervellati and Sunde, 2005; Soares, 2005), parental education (Vogl, 2016), labor market competition (Doepke et al., 2015), trade (Galor and Mountford, 2008), or structural change (Vollrath, 2011).

advanced nations, but we see the beginnings of mega-city growth in poor countries. Kolkata and Shanghai both had more than 4 million inhabitants. Beijing, Cairo, Mexico, and Mumbai were all over 2 million inhabitants. In 2015, the composition of the list is now dominated by developing countries. Poor countries also have cities present on this list, such as Dhaka (Bangladesh), Karachi (Pakistan), Kinshasa (D.R.C.), Lagos (Nigeria), and Manila (Philippines). Relevant for our analysis here is that the rise of mega-cities is not simply a function of absolute population size, as these cities arose not just in China and India, but in countries with much smaller populations. This suggests the rise of mega-cities is more than just a mechanical reaction to population growth.

Further, city size in the past was a robust indicator of living standards, but that relationship has broken down over time. For the pre-1910 period, we collected data on welfare ratios calculated using wages and price indices for minimal consumption baskets (including food, housing and clothes) in different cities (see Web Appendix Section 1.1 for details). The 118 observations are at the city-year level, so that for several cities we have multiple observations over time. We rank these observations based on their city size, and then we rank these observations based on their welfare ratio, and plot the rank of welfare ratios against the rank of city size. The left panel of Figure 2 shows there was a positive relationship historically (correlation of 0.60). This is not to say that the cities of industrializing Europe or North America had high *absolute* living standards. But city size indicated something regarding *relative* living standards at the time. For the modern period, we do not have welfare ratios comparable to historical data. However, we do have a city development index for a sample of 118 cities of at least 500,000 inhabitants in 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 costs of living, and information on infrastructure, waste, health and education (details available in the UN reports). For these observations we plot the rank of living standard against the rank of size, and find a correlation of only 0.31 (Figure 2).[7]

To highlight the differences over time, several cities are shown in the right panel of Figure 2. From 1700 to 1900 both Amsterdam and London shift to the top right, indicating they were growing in relative size as they developed. New York in 1900 was one of the wealthiest, but also one of the largest cities. From that point forward, however, these cities slipped down the rankings in size while maintaining their position in living standards. In comparison we have plotted a number of poor cities. Delhi in 1875, Jakarta in 1900, Lagos in 1910 and Nairobi in 1930 were all relatively small and poor. Yet they have all moved up to become some of the world's largest cities by 2010. However, this has not been associated, overall, with a move up in the rankings in living standards.

This change in the composition of the largest cities is going to be exacerbated in the future. The final column ($\Delta\%2015 - 2030$) of Table 1 shows the projected growth rate from 2015–2030 for each mega-city according to United Nations (2014). Rich mega-cities such as New York (0.5) Paris (0.6) and London (0.7) have rates close to zero. In comparison, poor mega-cities similar in size to the rich mega-cities are still growing fast, such as Lagos (4.2), Kinshasa (3.7) and Dhaka (3.0).

[7]The city development index is available for 204 cities in 1998 and/or 2012. However, since we have data on welfare ratios for only 118 observations pre-1910, the comparison in Figure 2 is restricted to the 118 largest cities in 2010.

Historical Evidence from Slums. While consistent historical data on slum shares does not exist, historical evidence suggests that cities in poor countries were more formal in 1950 than today (e.g. Njoh and Akiwumi, 2011; Njoh, 2013, 2016; Fox, 2014). UN-Habitat (2003a) describes how various cities saw a boom in their slum areas starting in the 1950s, and especially in the 1960s-1970s. For example, "17.1 per cent of Ahmedabad's population lived in slums in 1971. This rose to an estimated 21.4 per cent in 1982 [...] for the year 1991 [...] 40 per cent of households lived in slums." Then, the "well-planned town [of Ibadan, the 3rd largest city of Nigeria] turned into a slum. In 1963, half of the city's core area consisted of slum dwellings, growing to 70 per cent of the town's total number of derelict housing in 1985." In Karachi, the share of shacks increased from 36.8% in 1978 to 51.0% in 2000. Lima's "population growth since the 1960s has been concentrated in barriadas. The barriadas housed 10 per cent of the population of Lima in 1955, 25 per cent in 1970, and probably house 35 per cent of the population today." In Nairobi between 1971 and 1995, "the share of informal-settlement village inhabitants rose from one third to an estimated 60 per cent." Marghany and Genderen (2014, p.3) writes: "Slums in Cairo started to rise in the 1960s with little to no formal attention or control over its crawl." Perlman (2006, p.156) writes: "Whereas only 7 percent of Rio's population lived in favelas in 1950, five decades later the figure had grown to 19 percent." These case studies rely on different definitions of slums, yet they all paint a similar picture of informalization in the immediate post-WW2 period.

Slum shares have undoubtedly decreased recently. Nonetheless, for the poorest countries, slum shares may still remain higher today than in 1950. More specifically, we will focus our calibration analysis on 43 "poor" countries in 1950-2005. For these countries, the average slum share actually decreased from 69.6% in 1990 (earliest available year with data) to 62.2% in 2005 according to data from UN-Habitat (2003b, 2012). However, the prior evidence suggests their slum shares increased between 1950 and 1990, and increased overall between 1950 and 2005.

1.2. The Urban Mortality Transition, from Antiquity to the Present

New Data on Urban Demography. Historically, in-migration was the dominant source of new city dwellers as the rates of natural increase were low in urban areas, typically because of high urban death rates. This can be seen in Figure 3, where we compare the crude birth rate (CBR) and crude death rate (CDR) of selected cities across different eras. We used various sources described for each country-period in Web Appendix Section 1.1 – censuses, demographic surveys, sanitary reports, and historical studies (e.g., books, theses and articles) – to reconstruct demographic data for a sample of the largest cities in the world, from antiquity to date. For most observations, the sources directly report the crude rate of birth and/or death and/or natural increase.[8] For the 392 city-period observations in our sample, we also obtained when possible the same demographic data for the *urban areas* and the *rural areas* of the same country-period. Note that among the 229 observations available for the pre-WWII period the rates of the corresponding urban areas are

[8]For example, for Paris, we obtain the demographic rates: (i) in the 17th century, and the 1700s, 1750s, 1800s and 1820s from Woods (2003) and *Recherches statistiques sur la ville de Paris et le départment de la Seine*. 1826-1829. Bulletin Universel des Sciences et de l'Industrie; (ii) in the 1850s, 1880s and 1900s from *Statistique Annuelle du Mouvement de la Population.* 1901. Imprimerie Nationale; (iii) in the 1950s from *La Population de la France*. 1974. CICRED; and (iv) in the 2000s from *Recensement de la Population*. 2008. Institut National de la Statistique et des Etudes Economiques.

missing for 66 observations, hence our focus on the largest cities in this Section.

Historical Era. We first study the 100 largest cities as of 1900, according to Chandler (1987). Panel A of Figure 3 plots the CBRs and CDRs for 38 of these cities in or before 1800 where we have data. The sample includes various pre-industrial cities such as ancient Rome, Teotihuacan, Renaissance Florence, London in the 17th century, and Boston and Philadelphia in 1750. As can be seen, CBRs were high on average (38.1 per 1,000 people), but CDRs were also high (36.1). Mortality was high due to poor water quality, inadequate waste disposal, insalubrious housing conditions, dense areas favoring the spread of contagious diseases, and frequent epidemics (Landers, 1993; Galley, 1998; Woods, 2003; Costa and Kahn, 2006; Haines, 2008; Clark and Cummins, 2009; Voigtländer and Voth, 2013). As a result, the cities all lie near the 45-degree line, indicating that they experienced almost no natural increase (2.0, i.e. 0.2% per year).[9]

Panels B-D show that cities remained near the 45-degree line in the first and second half of the 19th century (Panel B: 1820s-1850s; Panel C: 1880s), and at the turn of the 20th century (Panel D: 1900s), using available data from the 100 largest cities in 1900 (33, 69 and 89 observations, respectively). City natural increase was still low on average, at 5.0-6.1 per 1,000 people (0.5-0.6% per year). The samples include various emblematic cities of the Industrial Revolution, such as Boston, Liverpool, Manchester, New York and Philadelphia (see Panel C; 1880s), cities which all had high CDRs due to industrial pollution in addition to the factors listed in the previous paragraph (Williamson, 1990; Steckel and Floud, 1997; Haines, 2004; Hanlon and Tian, 2015; Hanlon, 2016; Beach and Hanlon, 2017). Their growth, which averaged 3% per year in the 19th century, mostly occurred through in-migration (Williamson, 1990; Jedwab et al., 2015). In the developing world during the same period, CBRs and CDRs were also high, and rates of natural increase low, as seen for Beijing, Cairo, Mexico and Mumbai in Panel D (1900s).

Modern Era. In the post-war era, there was a distinct change in city demographics. In Panels E and F, we study the 100 largest cities of the future – in 2030 according to projections by the United Nations (2014) –, and show their CBRs and CDRs when available in the 1960s (N = 63) and the 2000s (N = 100) respectively. We choose the largest cities of 2030 in order to include more mega-cities from poor countries. Indeed, based on the data from United Nations (2014), many African and Asian mega-cities that are not yet in the top 100 will be so in the next decade. Our focus is on poor country urbanization, hence the need for our sample to be representative of poor countries.[10]

Focus first on the relatively rich cities in the lower left of Panel E, in the 1960s (e.g., London, New York and Paris). Their CBRs fell along with their CDRs, and so their rate of natural increase remained small. Overall, it is apparent from Panels A to E that historically cities were "sliding down" the 45 degree line as they grew. In comparison are the nascent poor mega-cities in the upper left of Panel E, well above the 45 degree line. In the 1960s these cities differed from earlier eras in one distinct way: their CDRs were very low. Dhaka, Karachi, Kinshasa and Lagos, despite being in countries with much lower income levels, all had CDRs that were similar to those seen

[9] All the points in Panel A represent "normal" periods, but each city was at times afflicted by severe shocks to mortality. For example, during the Black Death, cities had death rates of 250-750 (i.e. 25-75%).

[10] Graphical results are similar if we restrict our sample to the cities that were also among the top 100 cities in 2015.

in London, New York or Paris in the same year. Developing mega-cities in the 1960s were mainly "shifted left". This can also be seen by comparing the respective locations of Cairo, Delhi and Mexico in Panels D (1900s) and E (1960s). This led to large rates of natural increase for emerging mega-cities. For example, in the African cities in the figure, rates of natural increase were roughly 3.5% per year. Even absent migration, these cities would have doubled in size every 20 years.

This difference continued in the 2000s (Panel F). Rich mega-cities remained in the same position as in the 1960s. Poor mega-cities shifted down to lower CBRs. However, the CDRs in poor mega-cities were lower than the historical comparisons. Thus in the 2000s poor mega-cities continued to have rapid rates of natural increase (e.g., Karachi, Kinshasa, Lagos and Manila). A notable exception were Chinese cities (e.g. Beijing), which in the 1960s (Panel E) looked similar to other developing cities, but moved in the 2000s (Panel F) to a pattern of CDRs and CBRs similar to rich mega-cities. One other outlier is Johannesburg, which has a high CDR due to HIV.

Mortality transition. The deviation of developing cities from the historical norms appears due to the *mortality transition*. Following World War II (WW2), there was a sudden improvement in health in poor countries (Stolnitz, 1955; Davis, 1956; Preston, 1975), due to: (i) the discovery of effective techniques for mass production of antibiotics such as penicillin (1942) and streptomycin (1946), (ii) the invention of vaccines against the yellow fever (1937), poliomyelitis (1962) and measles (1963), (iii) the creation of the World Health Organization (1948), and (iv) disease eradication campaigns. From the perspective of the poor countries of that period, this *international epidemiological transition* represented an exogenous shock to mortality. Acemoglu and Johnson (2007, p.935-936) writes that "until 1940 there were limited improvements in health conditions in most of the Americas, Africa, and Asia" and that the factors listed above "caused a dramatic improvement in life expectancy in much of the world, especially in the lesser-developed parts of the globe, starting in the 1940s."

Urban mortality transition (UMT). The left panel of Figure 4 shows the average crude rates of birth, death and natural increase for the mega-cities, the urban areas and the rural areas in our full sample of 392 observations. The urban areas, which include all cities, have experienced the same patterns as for the mega-cities only, with CBRs being stable until recently and CDRs decreasing over time. Another consequence of the UMT was to raise rates of natural increase in urban areas up to the rates typically seen in rural areas. Rural natural increase was already high before the 20th century (Panel C), due to high rural CBRs (Panel A) and low rural CDRs (Panel B).

In the right panel of Figure 4 we focus on the sample of 167 observations in developing countries[11] The urban CBR has remained high at around 40 until the 1960s, after which it decreased to 20 (Panel A). The UMT is clearly apparent now, with urban CDRs falling from 30 in the 1900s to 15 in the 1960s (Panel B). As a result, the urban crude rate of natural increase dramatically increased from 7.5 in the 1900s to 25 in the 1960s (Panel C).

Note that restricting the sample to only observations from developing countries today helps us minimize compositional biases potentially arising from using different lists of cities over time

[11]We define developing countries based on their 2015 GDP per capita, i.e. the countries whose income level is below the income of Slovakia, the last country to have become a developed country according to the International Monetary Fund. Link to url (see April 2009): https://www.imf.org/external/pubs/ft/weo/data/changes.htm.

(the top 100 cities in 1900 and 2030 for the pre-1900 and post-1900 periods respectively). We also find similar patterns if we only use observations for cities that will be in the top 100 by 2030 or cities that were in the top 100 in 1900 (not shown, but available upon request).

The disproportionate mortality changes seen in the urban areas of developing countries post-WW2 are due to the facts that the international epidemiological transition first diffused to their "modern" areas and that colonizers significantly invested in urban public health by building water supply and sewerage systems and managing urban health centers aimed at preventing disease outbreaks (Njoh and Akiwumi, 2011; Njoh, 2013; Fox, 2014; Fox and Goodfellow, 2016; Njoh, 2016). Garenne (2016, p.181-182) writes that "before and in the early stage of the [health] transition [in Europe], urban mortality was higher, sometimes much higher, than rural mortality. This is often called the 'urban penalty' [...] The situation in developing countries is very different [...] Cities could benefit from the start from modern health and medical technology, and as a result, by 1950 urban mortality was lower than rural mortality." Likewise, May (2012, p.4) writes that "Before World War II, colonial powers as well as independent governments in Asia, Africa and Latin America had adopted public health measures, launched disease vector control programs, and improved schooling, nutrition and sanitation (e.g., water purification, drainage, and waste treatment). They had also organized targeted campaigns to bring down high mortality levels, most notably in urban areas.". Lastly, Gould (2015, p.100) writes that "before the 1950s and 1960s formal medical care was concentrated in large hospitals, mainly located in urban areas. In Africa this was a legacy of colonial medical systems, directed initially to serve the needs of the colonisers or colonial administrators, and thus was quite the opposite of an urban penalty."

In the calibration section, we will focus on the urban mortality transition, although there was also a slow rural mortality transition, as rural rates of natural increase gradually increased. Based on our data, and the analysis above, we will use as initial pre-UMT conditions in 1950 a CBR of 40 in the urban areas and 43 in the rural areas (1960s in Panel A of the right panel) and a CDR of 40 in the urban areas and 20 in the rural areas (in order to take the rural mortality transition as given). We will then study the effects of a reduction in the urban CDR from 40 to 15. 40 was the urban CDR of the poorest countries in our sample in the 1900s, before the UMT took place circa 1950. 40 was also the urban CDR of developed countries before they started developing with the Industrial Revolution (e.g., England in 1750, and also see Panel A of Figure 3 for selected pre-industrial cities). 15 was the urban CDR of poor countries in the 1960s, after the UMT.

Population Growth. Panel C also shows the mean population growth rate of the entire country (see *Total*). Population growth accelerated between 1900-1960. When crudely decomposing the change in total natural increase for the developing countries of the right panel between the 1900s and the 1960s into its two main sources, urban natural increase and rural natural increase, we find that half of it could be explained by the former (details available upon request). The urban rate of natural increase dramatically increased during the same period. In addition, these countries also slightly urbanized between 1900-1960. Had urban natural increase remained lower than rural natural increase, this increased urbanization would have slowed population growth. But since

urban natural increase was high, urbanization increased total population growth.

Demography in Formal vs. Informal Areas. How much of urban natural increase comes from the informal areas versus the formal areas of cities will prove important when quantifying the effects of the UMT. To answer this question, we used similar sources as for the largest cities to obtain the CBR and CDR of the slum areas of four industrializing cities in the late 19th century: London in 1886, Manchester in 1894, New York in 1890-1895 and Paris in 1864. Knowing the city population share of the slum areas, we reconstruct the demographic rates of the non-slum areas.[12] We then do likewise for seven poor mega-cities today (Cairo, Dhaka, Karachi, Manila, Mexico, Mumbai and Naibori, see Web Appendix Section 1.1 for details).[13] Note that we could not find data for more cities, as such data usually do not exist. For example, the *Demographic and Health Surveys* only report death rates for peri-urban areas (so not necessarily slums). The other caveat is that there are different definitions of slums. However, we use data for areas that are widely recognized as slums by local authorities and academic studies. In the following paragraph, we use the average of each set of cities (industrializing cities; poor mega-cities) to discuss the slum share.

In the late 19th century, both slum and non-slum areas had low rates of natural increase, at 1.0% per year. Slum CBRs were high (at 37.4 per 1,000 people), but slum CDRs were also high (27.2). In the poor mega-cities of today, the rates of natural increase are higher, at 2.7% per year in the non-slum areas and 1.1% per year in the slum areas. Slum CBRs are similar to our historical cities (at 33.7 per 1,000 people), but slum CDRs are now almost as low in the non-slum areas (6.8 vs 6.3). Natural increase is thus disproportionately higher in slums now, which suggests that poor mega-cities are likely to remain informal in the future. Given the fact that natural increase has barely changed in non-slum areas (1.1% today vs. 1.0% in the late 19th century), simple decompositions show that almost 90% of the change in urban natural increase between the late 19th century and today could potentially be explained by the higher rate of natural increase in slums.

1.3. The Urban Mortality Transition, Urban Growth, and Urban Congestion

We now document how measures of urban growth and poverty relate to urban natural increase in our sample corresponding to the 100 future mega-cities (see Web Appendix Section 1.1 for details). The correlations in the figures do not necessarily show causal relationships. Our goal is simply to characterize the conditions for a self-reinforcing trajectory in poor country urbanization.

Urban vs. Rural Natural Increase. Figure 5.A plots the growth rates of the urban population and the rural population between 1950-2015 (source: United Nations (2014)) against their respective rates of natural increase in the 1960s. The relationship is strongly positive for urban areas (slope β of 0.13***; R-squared of 0.60), which indicates that urban natural increase may have been a meaningful driver of urban growth. The correlation is significantly weaker for rural

[12] For London (1886), we use data for the 7 *Sanitary Districts* of the East End from British Medical Journal (1887, p.855). For Manchester (1894), we use data for the *Township* areas from The Lancet (1894, p.824). For New York (1890-1895), we use data for the 8 *Great Tenement House Districts* from New York Department of Health (1897, p.404) and Census Office (1895, p.11). For Paris (1865), we use data for the 7 *Arrondissements pauvres* from Vacher (1866, p.57-59).

[13] For example, for Nairobi, we obtain birth rate data from *Population and Health Dynamics in Nairobi's Informal Settlements Report of the Nairobi Cross-sectional Slums Survey* of 2012 (p.23) and death rate data from Abdhalah K Ziraba and Ezeh (2013, p.1) who use data from the INDEPTH standard survey (2003-2007).

areas (slope β of 0.04*; R-squared of 0.07), which suggests that rural natural increase may not necessarily increase rural population size. One possible interpretation is that when rural areas become "congested" due to rural natural increase, rural residents can move to the urban areas

Total Natural Increase. Figure 5.B plots the growth rates of the urban population and the rural population between 1950-2015 (source: United Nations (2014)) against the rate of natural increase for the whole country in the 1960s. As before, the relationship is strongly positive for urban growth (slope β of 0.12***; R-squared of 0.44), and weaker for rural growth (slope β of 0.06***; R-squared of 0.17). When population grows fast, urban areas grow disproportionately faster than rural areas. This suggests that the urban areas may help absorb the extra population growth.[14]

Urban areas that grow through natural increase possibly differ from urban areas that grew through in-migration. Figures 5.C-5.H plot several characteristics of urban areas, or megacities when data is not available for the urban areas, against their rate of natural increase in the 1960s.

Population Density. First, in figure 5.C is log density, which shows a positive relationship (source: Demographia (2014)). Rich mega-cities such as New York (2,000 inh. per sq km), London (6,000) or Paris (4,000) are much less densely populated than poor mega-cities such as Dhaka (44,000), Karachi (23,000) or Kinshasa (17,000). While density is used as a proxy for economic development when comparing the cities *within* a country, it may measure underdevelopment when comparing the cities *across* countries. Consistent with the literature showing that the income elasticity of housing demand is positive (see Rosenthal and Ross, 2015), people consume more housing space in wealthier cities, which contributes to lower densities in rich countries.[15]

Slums and Infrastructure. Figure 5.D shows that national slum shares are much higher in countries with high urban natural increase (sources: UN-Habitat (2003b, 2012); R-squared of 0.40). Two-thirds of the urban residents live in slums in Bangladesh, the D.R.C., Nigeria and Pakistan. Figure 5.E shows the strong negative correlation between the "city infrastructure index" of UN-Habitat (1998, 2012) — which combines information on access to water, sanitation, electricity, roads, and housing (details available in the reports) — and city natural increase (R-squared of 0.40). This is not surprising considering that poor mega-cities with high natural increase had annual growth rates of 3-7% in 1950-2010, thus doubling in population size every 10-25 years (vs. 35 years for rich mega-cities during the Industrial Revolution, see Jedwab et al. (2015)).

Dependency Ratios and Human Capital. The high density in urban areas growing through natural increase does not indicate a large supply of productive workers. Figure 5.F shows the child dependency ratio (the share of those under 14 to population aged 15-64) across our sample

[14] Another consequence of the fall in urban mortality was that the absolute growth of cities expanded to previously unseen levels. For each of the 30 largest cities in 2015 (Table 1), we collected information on the largest annual change in population experienced by the city, as well as the decade this occurred. Poor mega-cities such as Delhi (620 thousand; 2000s), Dhaka (440; 2000s), Karachi (410; 2000s) and Lagos (350; 2000s) added population at rates well above those seen in historical mega-cities such as London (90; 1890s), New York (220; 1920s) and Paris (110; 1950s).

[15] Densities are defined using both the population and the area of the agglomeration. Focusing on the central place or slums should not affect the results. Manhattan's density is 28,000 people per sq km. However, poor mega-cities contain areas with even higher densities. The slums of Mumbai, Nairobi, Dhaka and Cairo have densities of 350,000, 300,000, 200,000 and 110,000 respectively. The Lower East Side in New York was the densest slum of the U.S. (140,000 in 1910). Other slums in rich cities were less dense: Les Halles in Paris (100,000) and the East End in London (90,000).

of cities in the 2000s (source: reconstructed for all urban areas using the *Demographic and Health Surveys* (DHS) and census information from IPUMS). In cities with high natural increase in the 1960s such as Dar es Salaam, Karachi, Kinshasa and Lagos, this ratio reaches more than 50 percent (R-squared of 0.26, but R-squared of 0.68 if we use city natural increase in the 2000s instead, since the age structure is by construction more strongly determined by current demographic rates). Further, the labor force that does exist in these urban areas is low skilled. In poor cities such as Dar es Salaam, Karachi, Kinshasa and Lagos, the urban share of college-educated workers is close to 5-10% (Figure 5.G; sources: DHS and IPUMS).

Economic Development. Lastly, in Figure 5.H, we show that city natural increase in the 1960s correlates negatively with the "city development index" of UN-Habitat (1998, 2012) for the 2000s (R-squared of 0.42). It could be that urban areas/mega-cities that grow through natural increase are poor because they are highly congested, whether in terms of housing, infrastructure, children or unskilled workers. Or CBRs could remain high in poor urban areas/mega-cities, because their residents do not have the incentives to have and invest in fewer children.[16]

Urban Areas vs. Rural Areas. Note that one should not necessarily expect to observe the same relationships for the rural areas (or the country as a whole). First, we only find a weak correlation between rural population growth and rural natural increase. Additionally, the relationship between natural increase and child dependency ratios is stronger for the rural areas than for the urban areas (not shown, but available upon request). If rural-to-urban migrants leaving congested rural areas are mostly of working-age, rural areas are disproportionately left with children. Poor megacities today also have higher child dependency ratios than rich megacities in the past. The ratios for Bamako, Karachi and Kinshasa are 72%, 63% and 70% respectively. This is higher than the same ratios for London in 1851 (45%; source: 1851 census), New York in 1870 (50%; source: *1870 census*), and close to ratios for the rural areas of the UK and the U.S. in the same years (65% and 70% respectively). Lastly, the gap between urban and rural tertiary completion rates are smaller for countries with a high rate of natural increase (not shown), thus suggesting that urban areas are not that different from their rural areas. Poor megacities today also have lower literacy rates than rich megacities in the past. When using the DHS and IPUMS, the literacy rates that we obtain for Bamako, Dakar, Dhaka and Karachi are 43%, 48%, 67% and 62% respectively. This is lower than the literacy rate for London in 1851 (80%; source: 1851 census), and New York and the rural areas of the U.S. in 1870 (95% and 80% respectively; source: 1870 census).

Overall, the urban areas growing through natural increase appear to be developing as "giant villages" rather than as high-productivity agglomerations. This seems to hold for mega-cities as well, although they often constitute the most "modern" urban areas of their countries.

[16]Results hold if we use data on the housing price-to-income ratio, rent-to-income ratio, floor area per person, persons per room, squatter housing, access to water, waste management, commuting, total dependency ratios (the share of those under 14 or above 65 to population aged 15-64), primary and secondary completion rates, informal employment, unemployment, and poverty (not shown, but available upon request). The main sources used are the first version (1993) and second version (1998) of the *Global Urban Indicators Database* of UN-Habitat, as well as the DHS and IPUMS.

2. Demographics, Locational Choice and Growth

We build a framework to account for the effect of demographics and population growth on location choice and welfare. This framework allows for heterogeneity in the effect of population on welfare across different locations (e.g. formal urban areas, informal urban areas, and rural areas), and implies that aggregate population growth influences the distribution of population across those locations. With people moving between locations, the growth in welfare will be equalized across them. But because the welfare elasticity with respect to population varies, locations with low elasticities absorb a larger share in population than locations with high elasticities. This interacts with a preference by individuals for locations with low mortality. Combined, the framework will allow us to account for the role that the UMT had in driving the differential growth of locations in developing countries.

2.1. Individual Utility

We assume that all individuals in the economy are identical, except that they reside in a specific location j from a given set J. Their utility is determined by

$$V_j = \ln Q_j + \beta \ln(1/CDR_j). \tag{1}$$

where Q_j is an aggregate of the qualities of location j, and implicitly includes the wage (which can incorporate agglomeration effects), housing costs, and amenities available in location j. We show in Web Appendix Section 2, and discuss as part of our robustness checks below, an explicit model of the components of Q_j, but for the purposes of our baseline results it is not necessary to specify these. CDR_j is the crude death rate in location j to which an individual is exposed, and hence $1/CDR_j$ can be seen as a measure of life expectancy.[17] β measures the utility weight of life expectancy. Taking as given the sets of (Q_j, CDR_j) in each location, individuals move between locations until V_j is equalized across locations.

2.2. Agglomeration, Congestion, and the Distribution of Population

Let

$$\ln Q_j = \ln a_j - \epsilon_j \ln N_j, \tag{2}$$

where a_j is the exogenous determinant of the qualities of location j, and may grow over time, but does not depend on the size of the population. ϵ_j is the elasticity of location quality with respect to population size in location j, N_j. This term captures any agglomeration or congestion effects arising from population size. The number of workers will affect nominal wages through the production function for output. Population size will affect housing prices and commuting costs through the production functions for housing and transportation. Finally, the number of people affects the welfare value of amenities, depending on the production function for those amenities.

Given the specification in (2), we can write the utility function more concisely as

$$V_j = \ln a_j - \epsilon_j \ln N_j - \beta \ln CDR_j, \tag{3}$$

[17] We do not have the data to do age-specific death rates separately by location, so we proceed as if the death rate is constant at all ages. In this case the mapping from the death rate to life expectancy is exact.

Given the specification in (3) we can now describe the conditions for the equilibrium distribution of individuals across locations.

1. **Labor mobility**. Individuals move costlessly between locations, implying that $V_j = \overline{V}$ for all locations j, where $\overline{V}$ is the equilibrium level of utility.
2. **Stability**. $\epsilon_j > 0$ for all locations j.
3. **Adding up**. $\sum_{j=J} N_j = N$. This closes the model and determines $\overline{V}$.

The condition regarding stability states that for each location the effect of population on welfare is negative. With this assumption, the equilibrium is stable to any perturbations. If one person were to randomly move away from location j to location k, then welfare would rise in location j and fall in location k. Given labor mobility, this would incent someone to move back from k to j, restoring the original equilibrium. In contrast, if $\epsilon_j < 0$ and hence welfare is *increasing* in population size, then if someone leaves location j for location k, welfare in j actually *falls*, but *rises* in location k. This would incent more migration away from j and into k, meaning the original equilibrium was not stable. With the assumption of free mobility and all $\epsilon_j > 0$, this implies that the economy is at a stable location equilibrium. The exact allocation across locations will change over time due to changes in demographic conditions, changes in the level of wages/amenities/housing costs, and as we will see below, changes in the aggregate population.

Assuming $\epsilon_j > 0$ does not exclude the possibility of, or assume away, agglomeration effects. There may be agglomeration effects at work, but as in standard models of urban areas (Henderson, 1974; Duranton and Puga, 2004) the allocation of population across locations will only be stable if agglomeration effects are more than offset by congestion effects or diminishing marginal returns to labor. One could imagine that agglomeration effects dominate congestion and the impact of fixed factors in some locations within low-population countries (Becker et al., 1999; Desmet et al., 2015). While this hypothesis may apply to prehistorical, antique and medieval societies that were characterized by low population densities, they may not characterize well poor countries in the 20th century, which were already densely populated by the time of the UMT. We will discuss specific sources consistent with the assumption that $\epsilon_j > 0$ in section 3.6 below.

Denote the growth rate of any variable X by using a "hat", so that $\hat{X} = \dot{X}/X$. Then we can write the growth rate of welfare in location j as

$$\hat{V}_j = G_j - \epsilon_j \hat{N}_j - \beta C \hat{D} R_j \tag{4}$$

where

$$G_j = \hat{a}_j. \tag{5}$$

G_j captures changes in welfare unrelated to the population growth rate of location j, whether due to productivity, amenities, or housing.

2.3. The Dynamics of Location Size and Welfare

At this point, we can establish several results regarding population, location, and welfare, and how they relate to changes in location-specific mortality rates.

The effect of aggregate population growth on welfare. Define the share of population in location j as $s_j = N_j/N$. By definition, the growth rate of aggregate population, N, can be written as the weighted sum

$$\hat{N} = \sum_{j=1}^{J} s_j \hat{N}_j. \tag{6}$$

If we rearrange (4) we have that $\hat{N}_j = (G_j - \beta C\hat{D}R_j - \hat{V}_j)/\epsilon_j$ for each location. Inserting this into (6) yields the following relationship

$$\hat{N} = \sum_{j=1}^{J} s_j \frac{G_j - \beta C\hat{D}R_j - \hat{V}_j}{\epsilon_j}. \tag{7}$$

To proceed further, note that because individuals are fully mobile over locations, it must be the case that $\hat{V}_j = \hat{V}$ for any location. Using that fact, we can solve for

$$\hat{V} = \bar{\epsilon}\left[\sum_{j=1}^{J} \frac{s_j}{\epsilon_j}\left(G_j - \beta C\hat{D}R_j\right)\right] - \bar{\epsilon}\hat{N} \tag{8}$$

where

$$\bar{\epsilon} = \frac{1}{\sum_{j=1}^{J} \frac{s_j}{\epsilon_j}} \tag{9}$$

is the harmonic mean of the elasticities across all locations. Note that by the assumption that $\epsilon_j > 0$ for all locations, it must be that $\bar{\epsilon} > 0$ as well.

Aggregate welfare growth is similar to welfare growth in any given location. It depends on a weighted sum of the location-specific rates G_j and crude death rates $C\hat{D}R_j$, where the weights depend both on their share in population, s_j, and their elasticities, ϵ_j. A higher elasticity ϵ_j mutes the effect of any given G_j, because the high elasticity means that the growth of the population in that location cannot be very large without lowering welfare. On the presumption that $\beta > 0$, declines in the crude death rate in any location, $C\hat{D}R_j < 0$, also contribute positively to welfare.

Finally, *aggregate* population growth, $\hat{N}$, detracts from welfare growth in all locations, with the size of the effect depending on $\bar{\epsilon}$, the aggregate elasticity.

The effect of aggregate population growth on the distribution of population. Using the aggregate welfare growth in (8), we can combine that with (4) to solve for the location-specific growth rate of population in location i as

$$\hat{N}_i = \frac{\bar{\epsilon}}{\epsilon_i}\left(\hat{N} + (G_i - \beta C\hat{D}R_i) - \sum_{j=1}^{J} \frac{s_j}{\epsilon_j}\left(G_j - \beta C\hat{D}R_j\right)\right). \tag{10}$$

Aggregate population growth, $\hat{N}$, is positively related to population growth in location i. Regardless of where new people originate, the additional population is spread across locations to ensure that welfare is equalized. The strength of $\hat{N}$ on $\hat{N}_i$ depends on the ratio $\bar{\epsilon}/\epsilon_i$, the aggregate

elasticity relative to the location-specific elasticity. When $\epsilon_i < \bar{\epsilon}$, location i will tend to grow faster than the aggregate population, and hence its share of the population will increase. ϵ_i is the percent loss of welfare for a percent gain in population, so the lower is ϵ_i, the higher the percent gain in population a location can absorb while still maintaining similar welfare growth to other locations. The logic for a location with $\epsilon_i > \bar{\epsilon}$ is just the opposite, and these locations will grow slower.

In both cases, however, these direct effects of population growth are potentially offset or exaggerated by differentials in welfare growth from G_i, and changes in crude death rates $C\hat{D}R_j$. The second two terms in (10) capture the difference between these individual effects and their aggregates across locations. If $(G_i - \beta C\hat{D}R_i) > \sum_j (G_j - \beta C\hat{D}R_j)s_j/\epsilon_j$, then location i will grow relatively quickly as people move there to take advantage of its higher productivity, better amenities, and/or lower mortality.

Regardless, the speed of aggregate population growth will always influence the growth rate of locations. To be more concrete, the share of population in each location, s_i, evolves according to the following simple relationship

$$\hat{s}_i = \hat{N}_i - \hat{N}. \tag{11}$$

The derivative of the growth rate of population share, $\hat{s}_i$, with respect to aggregate population growth, $\hat{N}$, can be found using (10),

$$\frac{\partial \hat{s}_i}{\partial \hat{N}} \begin{cases} > 0, & \text{if } \epsilon_i < \bar{\epsilon} \\ < 0, & \text{if } \epsilon_i > \bar{\epsilon} \\ = 0, & \text{if } \epsilon_i = \bar{\epsilon} \end{cases} \tag{12}$$

Unless all locations have identical values of ϵ, then there must exist at least one location with $\epsilon_i > \bar{\epsilon}$ and one with $\epsilon_i < \bar{\epsilon}$. Heterogeneity in elasticities across locations implies that the aggregate population growth rate influences the distribution of population across locations.

Amenity effects of mortality changes on the distribution of population. As can be seen in (10), if the death rate in location j is falling, $C\hat{D}R_j < 0$, then this will increase the growth rate of population in location j as individuals move there to take advantage of it. The strength of this effect depends on the ratio of $\bar{\epsilon}/\epsilon_j$, not only on the size of β, the utility weight on life expectancy. Hence changes in crude death rates in low elasticity locations will result in bigger shifts of population than will changes in death rates in high elasticity locations.

Effects of population growth on future population growth. The full consequences of population growth depend on how the changing distribution of population influences population growth itself. Each location has an exogenous birth rate, denoted CBR_j. We will explore extensions of this to allow for endogenous changes in birth rates after showing the calibrations. Aggregate population growth is dictated by these birth rates combined with the death rates, CDR_j,

$$\hat{N} = \sum_{j=1}^{J} s_j \left(CBR_j - CDR_j\right). \tag{13}$$

The shares s_j are the way in which aggregate population growth is endogenous in this framework. As population shares change, this may lower or raise $\hat{N}$ itself depending on the pattern of child costs or death rates across locations. If higher population growth leads to a shift into locations with lower child costs or death rates, then it will accelerate population growth, which would imply even further shifts of population into that location. The possibility exists that population growth begets more population growth, and leads to a concentration of population in a low-elasticity location.[18]

3. The Role of the Urban Mortality Transition

We now use the framework constructed in the prior section, and calibrate it to match the observed experience of poor countries so that we can perform counterfactuals. To begin, we must be more specific about what we mean by locations, so that we can match them up to available data. We will work with three locations: *rural, formal urban, and informal urban*, which we think of as differing along several dimensions, for example production, housing, and amenities.[19]

The *rural* location (denoted by subscript r below) involves production of not only agriculture, but also service or manufacturing activities of rural residents. Housing consists of individual houses, with few space constraints. There are few amenities. In comparison, the *formal* location (subscript f) operates a "modern" sector production technology. Manufacturing and professional services are examples of what we have in mind. Housing involves multi-unit buildings, and faces both physical and institutional constraints. Amenities are organized centrally. Finally, the *informal* location (subscript l) is located in an urban area and involves a production technology that involves low-level personal services. Housing faces some space constraints, but is not subject to strict institutional limits, and consists mainly of individual houses (e.g., shacks). Amenities are organized unofficially. Slums are an example of an informal location.[20]

3.1. Externally Set Parameters

For many parameters, we are able to rely on outside sources, or the data we described in Section 1.. The top panel of Table 2 summarizes the values we describe in this section.

Crude death rates (CDRs). As discussed in Subsection 1.2., the initial CDR in 1950 for both urban locations is set to 40 (per thousand). After the UMT is completed, the CDR for both urban formal and informal locations is set to 15. To capture the onset of the UMT we let the urban CDRs decay

[18]Ways to endogenize population growth would work through the parameters related to child costs or the death rate itself. Following Becker (1960) - through income effects - or Galor (2011) - through the value of human capital - we could introduce changes to child costs related to the composition of population across locations. Changes in mortality rates (Kalemli-Ozcan, 2002; Soares, 2005), by changing the expected value of children, would be an alternative way of modeling endogenous population growth changes. We explore some of these possibilities after the baseline calibration.

[19]One could easily allow for a large number of smaller locations that fall under each category; there could be multiple rural locations, for example. We are assuming that all of those smaller locations of a given type have a common growth rate, G_i, and a common elasticity, ϵ_i. With that being the case, examining (8) and (10) it is clear that tracking the individual locations will not offer any additional information beyond that found in tracking the three major categories.

[20]While the characteristics of locations differ, we assume that all individuals are homogenous, and do not have location-specific preferences or skills. For example, we do not assume that people born in informal locations have preferences for or are more capable of working in formal locations than people born in rural areas.

exponentially from 1950 forwards, with a half-life of 3 years. This implies that by 1959, urban CDRs are only 18.25. For the rural location, we set the CDR to be 20, in line with our data, and that is held constant over the entire period from 1950 to 2005. Our calibration thus takes the *rural* mortality transition as a given, so that we can focus on the effects of the UMT.

Crude birth rates (CBRs). We use information from the demographic data presented earlier, along with the crude rates of natural increase in our sample of 43 poor countries over time, to set the time path of crude birth rates. For 1950, we set the initial rural CBR to 43 (per thousand), the informal CBR to 43, and the formal CBR to 38. These initial CBRs combined with our initial CDRs mean that our calibration matches the observed crude rate of natural increase in 1950 in our sample.

For the 43 countries, there was a demonstrable rise in the aggregate crude rate of natural increase from 1950 to roughly 1985, and then it began to decline. The crude rate of natural increase was 22.6 in 1960, rose to 28.7 in 1985, and then fell to 24.5 in 2005. This fluctuation was largely due to changes in CBRs. To capture this, we parametrically set the changes in crude birth rates in the calibration to match the observed behavior in our sample. Specifically, we use the quadratic

$$\Delta CBR_{t+1} = \phi_1 \times t + \phi_2 \times t^2. \tag{14}$$

Fitting this to the data, we set $\phi_1 = 0.457$ and $\phi_2 = -0.006$. We discuss below the nature of these changes in the birth rate, as they may be related to mortality. For the purposes of calibrating, however, we require the actual time path of the birth rates to match the data.

Exogenous quality growth. The exogenous rate G_i in a location includes the growth of wages and amenities unrelated to population size. For our purposes, assigning the *relative* values of G_i across locations is most important, as these will dictate the movement of people across locations, and allow us to determine the *change* in welfare growth between different counterfactual scenarios. The absolute size of the the G_i terms will dictate the absolute growth in welfare over this period, something we cannot measure and so the choice of the absolute levels of G_i will necessarily be arbitrary. Our presumption is that wages are the main factor in the quality of a location, and so we derive our values for G_i primarily from estimates of productivity growth.

In relative terms, we assume that G_i in rural and informal locations is identical. Fuglie (2010) shows that agricultural TFP growth was below 1% for nearly all developing regions in the 1960s-1970s. However, since that time TFP growth rates have increased across all regions, reaching 2-3% per year in some cases. Overall, he reports developing countries with agricultural TFP growth of 1.4% from 1961-2007. Block (2010) reports agricultural TFP growth rates for Africa over different time periods as well. Growth rates are negative through much of the 1960s and 1970s, but have been as high as 2.8% in the most recent decade, and were 2% from the 1980s into the 1990s. For informal locations, they are dominated by workers in personal services and small-scale retail trade, so they are likely to have low TFP growth (Duarte and Restuccia, 2010; McMillan et al., 2014). Duarte and Restuccia indicate that productivity growth in services among the poorest countries in their sample was around 1% per year. We set $G_l = G_r = 0.025$ to account for both productivity growth and any unobserved amenity growth in these locations.

We assume that $G_f = 0.05$, twice as large as in the other locations. This choice implies that absent any population growth or changes in death rates, workers would be moving from rural to formal areas to take advantage of the higher productivity and/or amenities there. The justification for assuming that G_f is larger than in informal or rural areas is based, from the productivity perspective, on the industries we associate with formal locations. Manufacturing experiences unconditional convergence (Rodrik, 2013), and hence growth rates of productivity are rapid relative to informal locations. Duarte and Restuccia (2010) and McMillan et al. (2014) both find evidence that productivity growth in sectors we associate with formal locations - manufacturing and finance - had faster productivity growth than other sectors. It seems also valid to assert that amenity growth in formal locations was as least as rapid as in other locations over this period.

Preferences. The utility weight on life expectancy (β) will determine how important changes in the CDR's across locations are to changing the distribution of population. We follow Becker et al. (2005) and Weil (2010) who compare the value of changes in life expectancy with changes in income per capita. Specifically, Becker et al. (2005) convert the changes in life expectancy to equivalent changes in annual income. Using this information, we can back out an implied value of β such that the observed growth in life expectancy is equivalent to their equivalent change in annual income. We use their estimates for Africa, as the majority of our sample comes from that region. Becker et al. (2005) calculate that the increase in life expectancy in this region between 1960 and 2000 (a 12% increase from 41 to 46 years) was equivalent to an increase of 72 intl. dollars (a 4.9% increase on a base of 1,470 dollars). This implies a value of β of 0.41.

Rural elasticity. For the rural location elasticity ϵ_r, sources point to a high negative elasticity of output per capita with respect to population size in predominantly rural countries. Weir (1991) finds an elasticity of -1.2 and Lee (1987) finds -1.6, both using an agricultural production function with a low degree of substitutability between land and population, and pre-Industrial Revolution data. Lee (1997) updated his own estimate to -1.0. Acemoglu and Johnson (2007) have work on the effect of the international epidemiological transition that implies an elasticity of -1.2 in a sample of low and middle-income countries in 1940-1980, all of which had very low urbanization rates in 1950.[21] This elasticity is derived from the production technology alone. However, this is a good approximation for rural areas, as housing faces few constraints in terms of space, and due to their low densities, their amenities are less prone to congestion. Hence we use -1.2 as our preferred estimate of ϵ_r. We will show that results are robust to using alternative estimates.

Note that a value of this rural elasticity of one, or more, is still consistent with a constant returns rural production function in which the elasticity of output with respect to labor is less than one. Adding a new non-working resident to a rural area lowers output *per capita* without raising output, with an elasticity of negative one, close to our preferred value.[22]

[21] -1.2 comes from dividing their estimate of the effect of life expectancy on GDP per capita, -2.43, by the effect of life expectancy on population, 2.04 (see column (3) of their Tables 8 and 9).

[22] Further, starting with an assumed value of the $0 > \epsilon_r > -1$, as would be implied by a constant returns production function, alters the calibrated values of the other elasticities, but changes little the effects of the UMT (see below).

3.2. Initial Conditions and Calibrated Parameters

Given the externally set parameters, we still require values for the elasticities of welfare with respect to population for the formal urban and informal urban locations. To set these in our baseline, we match our framework to observed data from a set of 43 poor countries that experienced the UMT. We are asking here whether there are *any* elasticities for formal and informal urban locations that allow our framework to match the given data on urbanization and informal rates, without requiring those elasticities to conform to any underlying model of agglomeration or congestion. After we do this baseline calibration and use it to discuss the role that the UMT had in driving poor country urbanization, we return to the values of these urban elasticities in Section 3.6., and ask if they are empirically reasonable.

Country data. The set of 43 poor countries we match to includes 29 countries from Sub-Saharan Africa, 11 from Asia, 2 from Latin America and 1 from the Middle East (see Web Appendix Section 1.2 for the full list of countries). 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 (sources: UN-Habitat (2003b, 2012)).[23]

Urban and informal shares. We use 1950 as the initial period for our calibration. For our set of countries, the average urbanization rate in 1950 is 9.1%. Explicit information on the informal share of either the housing or labor market in 1950 does not exist. We thus assumed a value of 50%. In 2005, the average slum share for the 43 countries is 62.2%, so 50% implies an increase from 1950 to 2005. We will later show that results are similar if we assume that their urban areas were mostly formal (i.e. a formal share of 60%) or informal (a formal share of 40%) in 1950.

Urban welfare elasticities. To calibrate, we use a discrete-time version of the framework to solve for values of the formal elasticity ϵ_f and the informal elasticity ϵ_l that make it match the average urbanization rate and informal share of urban areas from our 43 countries in 2005, given the initial conditions of those 43 countries and the external parameters set in the prior section.

In particular, we set the initial shares of population in the three locations (formal share: $s_{f,1950}$; informal share: $s_{l,1950}$; rural share: $s_{r,1950}$) using the average values from our set of 43 countries in 1950. The urbanization rate of 9.1% pins down $s_{f,1950} + s_{l,1950}$, and thus $s_{r,1950}$ is equal to 90.9%. Our assumed informal share of 50% implies that $s_{f,1950} = s_{l,1950} = 4.55\%$ in 1950.

Given those initial conditions, we then proceed with the following algorithm. We use equation (13) to solve for the growth rate of aggregate population ($\hat{N}_{1950}$), and then use equation (10) to solve for the growth rate of population in each location ($\hat{N}_{f,1950}$; $\hat{N}_{l,1950}$; $\hat{N}_{r,1950}$). Using (11) we can get the growth rate of the share of population in each location, and thus obtain the share of population in each location in the following period ($s_{f,1951}$; $s_{l,1951}$; $s_{r,1951}$). We continue this process period-by-period until we reach 2005, and retrieve predicted values of the urbanization

[23] UN-Habitat defines slums similarly for all countries. In particular, the slum population is "the urban population living in households with at least one of the following four characteristics. Lack of access to improved drinking water. Lack of access to improved sanitation. Overcrowding. Dwellings made of non-durable material."

rate ($s_{f,2005} + s_{l,2005}$) and the informal share ($s_{l,2005}/(s_{f,2005} + s_{l,2005})$).

We repeat the algorithm using different values of ϵ_f and ϵ_l until we find those values that make the predicted values for urbanization and the informal share match the observed averages in 2005 (31.2% and 62.2%, respectively). Practically, this search for the values of ϵ_f and ϵ_l is not computationally intense, given that the framework is a series of static allocation problems. We use a non-linear least squares routine to find the values of ϵ_f and ϵ_l that match the predictions to the data moments. Table 2 shows the results of the calibration. We find that $\epsilon_f = 1.29$ and $\epsilon_l = 0.64$. The data suggests that formal locations have elasticities slightly higher than rural ones, while informal locations have elasticities about half of the rural value. In other words, rural and formal sectors cannot absorb new residents as easily as the informal sector.

Additional clarifications. First, the elasticities we calibrate differ from the "net agglomeration effects" that have been studied in the literature, where one regresses measures of productivity and pecuniary and non-pecuniary living costs on population for a sample of cities. Econometrically, the effects that studies estimate are the *relative* effects of moving one person from one city to another larger city within a same country. The effects that we are calibrating are the *absolute* effects of adding an extra person to the whole urban sector of one country. In that case, the entire urban sector may become more congested. To our knowledge, this parameter has not been estimated in the literature, hence our need to rely on calibration. For the time being, we will take our elasticities as given, but will show later that they can be decomposed into wage elasticities, agglomeration effects, house price elasticities, and amenity elasticities, for which estimates exist in the literature, and this will allow us to discuss their possible micro-foundations. We will also use that analysis to show why in poor countries welfare in the formal locations may be more sensitive to population size than rural areas, and clearly more sensitive to population size than in informal locations.

Second, these elasticities are held constant with respect to the absolute size of the urban or informal population. It could be the case that the informal elasticity has risen in the last decades as slums have become so large in absolute terms that mortality is more sensitive to further population growth than in the past. However, urban CDRs have, if anything, further decreased for developing countries between the 1960s and the 2000s, as can be observed in Panel B in the right panel of Figure 4. Furthermore, in our sample of 7 "poor" mega-cities for which we have CDR data on slums in the 2000s, the mean slum CDR (6.8) is barely above the mean non-slum CDR (6.3) (see Section 1.2.). While slums have higher child mortality rates than non-slum areas (Fink et al., 2016), they tend to have a younger population (UN-Habitat, 2003a), which limits the feedback effects of slum expansion on urban CDRs, since CDRs also depend on non-child mortality and age structure. In addition, the epidemiological transition targeted epidemic diseases likely to propagate in urban environments, making high densities less consequential from a health perspective.

3.3. Implications of Calibration

Based on the parameters and estimated elasticities, the UMT should have had several effects:

1. The economy urbanized faster. The UMT had a direct effect on urbanization by making urban locations more desirable to live in given individual's preference for lower CDRs. In addition, there

was an indirect effect of the UMT on urbanization given the differences in elasticities between locations. The values of the elasticities, along with the initial shares of population, indicate that $\epsilon_r > \bar{\epsilon}$. Hence in response to the increase in population growth from the UMT, the growth rate of the rural population share, $\hat{s}_r$, fell, and hence urbanization occurred faster.

2. Urbanization occurred through informalization. With $\epsilon_l < \bar{\epsilon}$ the growth rate of the informal share, $\hat{s}_l$, rose in response to the UMT. At the same time, with $\epsilon_f > \bar{\epsilon}$, the growth rate of the formal share was pulled down by faster population growth. The UMT not only urbanized the economy, but did so by pushing people into the location with the lowest welfare elasticity - informal areas.

3. Population growth sped up. The UMT raised $\hat{N}$ directly. But in addition, by urbanizing the economy through informalization, the UMT led to higher aggregate $CRNI$ as population moved into high-population-growth informal locations. The UMT thus eliminated the natural limitation on population growth that historical economies experienced as they urbanized.

4. Ambiguous welfare effects. By raising $\hat{N}$, welfare growth was pushed down. But in addition, because informal locations have low exogenous welfare growth, the increased share of population in informal locations meant that aggregate welfare growth became slower. On the other hand, because the CDR fell, there was an increase in welfare given that people value lower mortality.

3.4. Effects of the UMT, 1950-2005

Observed data. In Table 3 we work through several scenarios to quantify the role of the UMT. Row 1 shows the average urbanization rate, both in 1950 (9.1%) and 2005 (31.2%), for our set of 43 poor countries. In addition, it shows the relative size of urban populations in 2005, and urban populations grew by a factor of 14.8 from 1950 to 2005 in our sample. We do not have data on slum shares in 1950, which we use to measure the informal share. But in 2005, this share was 62.2%. The relative size of informal locations was 17.3 in 2005 compared to 1950.[24]

Calibrated results. Row 2 presents outcomes from our calibration. We take the initial urbanization and informal shares as given, and target the final urbanization and informal shares of 31.2% and 62.2%. Those are thus matched exactly. We did not match either the absolute size of the urban population, nor the informal population, but the calibration does a good job in capturing their growth from 1950 to 2005. For urban size, the calibration finds that urban areas are larger by a factor 16.8, compared to the average value of 14.8. For the relative size of informal areas, the calibration delivers a value of 20.8, compared to the actual value of 17.3 in the data.

Removing the UMT. In row 3, we simulate outcomes from 1950 to 2005, but this time we remove the UMT. The formal and informal CDRs stay at 40 throughout. In this case, the urbanization rate would only have been 21.8% in 2005. Compared to the observed data, this indicates that the UMT accounted for 9.4 percentage points of urbanization between 1950 and 2005 (31.2 minus 21.8), or roughly 40% of the increase in the urbanization rate in this period. Urban areas in 2005

[24]The size of the population in 2005 was roughly 5 times that of 1950. Productivity growth (or lower international transport costs for food as in Glaeser (2014)) must have been sufficient to either produce, or import, enough food to support this increase in population while allowing for higher urbanization rates. Our wage/amenity growth rates implicitly take this into account, and this is why we have not explicitly accounted for food demand.

were roughly 75% larger (16.8 versus 9.7) because of the UMT. The informal share would have been 53.7%, compared to 62.2% in the observed data. This is roughly 70% of the increase in the informal rate from 1950 to 2005. Informal areas in 2005 would have been 10.4 times larger than in 1950, compared with the actual ratio of 20.8. From a welfare perspective, there are two conflicting effects at work. First, without the UMT mortality is higher and hence welfare is lower. Second, slower population growth reduces the drag on welfare due to crowding effects. In our calibration, the net result is that welfare in 2005 could have been 9% *higher* without the UMT.

Direct congestion effects. In row 4, we simulate the outcomes using our framework again, with the UMT occurring, but set the preference parameter on life expectancy, β, to zero. Thus the UMT does not provide any direct incentive to move to urban areas. Urbanization in this case is driven only by differentials in the underlying wage/amenity growth rates, G_i, and differentials in elasticities, ϵ_i. Here, the results show that urbanization in 2005 would have been 23.2%, or 1.4 percentage points higher than without the UMT. Similarly, an informal share of 57.6, compared to 53.7 without the UMT, indicates that these effects added 3.9 percentage points to the informal share of urban areas. Welfare in this scenario is reported as 89% of the baseline welfare *with* the UMT, but this is attributable to removing the benefits of lower urban death rates.

Life expectancy effects. Row 5 looks at the effects of the UMT arising purely from preferences for lower CDRs. We resimulate the outcomes, including the UMT, but we set the values of the elasticities, ϵ_i, in all locations to be equal.[25] The urbanization rate is 24.9, which is 3.1 percentage points higher than without the UMT. For the informal share, the implied size is only 21.6%, meaning that informal areas would have shrunk as a share of urban areas. With the informal location elasticity equal to the other locations, the advantages of this location dissipate.

Life expectancy vs. direct and indirect congestion effects. One-third (3.1/9.4) of the urbanization due to the UMT remained when we removed the differential elasticities (row 5). The remaining two-thirds is due both to the direct effect of differential elasticities (row 4), and the interaction of the mortality preference with these differential elasticities. The low elasticity in informal areas means that when individuals move to these locations out of a desire for lower mortality, the wages/amenities in informal areas do not fall much, and hence even more individuals can move into the urban areas in search of lower mortality rates. The two effects reinforce each other. Preferences for lower mortality (row 5) alone would have *shrunk* the informal sector as a share of urban population, as people would have moved almost exclusively to formal locations if the elasticities are equal across locations. But absent the amenity effect of lower mortality (row 4), informal areas still would have grown to 57.6% of urban population due to the lower elasticities in informal areas. The combination of the two, with the low elasticity amplifying the effect of mortality preferences, is necessary to account for the 8.5 percentage point effect on the informal share (62.2% versus 53.7%). The lower elasticity in informal areas accounts for more than 100% of the growth in the informal share from the UMT. While one cannot take a percentage greater than 100% too seriously, it indicates how important the differential elasticity effects were.[26]

[25] We use $\epsilon_i = 1.03$, the harmonic mean in 2005 of the three sectoral elasticities from the baseline calibration.

[26] The analysis could be different if we were able to account separately for urban child and adult mortality changes.

3.5. Endogenous Fertility and Effects of the UMT, 1950-2005

So far, we held the fertility behavior equal to that observed in the data. Here, we show this implied impact of the UMT on urbanization and informalization may be *understated*.

Fertility bulge. Under almost any reasonable setting, endogenous responses of fertility to the UMT will make CBRs *higher*, at least temporarily. This occurs through several channels. First, the drop in CDRs contributes to higher CBRs by ensuring cohorts survive longer through child-bearing ages. This demographic momentum effect is larger, the faster is the decline in CDRs (Heuveline, 1999; Guillot, 2005). Second, while total fertility rates may fall after declines in mortality due to risk-aversion or the value of human capital (Kalemli-Ozcan, 2002; Soares, 2005), the CBR will not necessarily fall, and will likely increase (Doepke, 2005). Last, if fertility is linked to the opportunity cost of parents time (Becker, 1960), then lower wages induced by congestion following the UMT would raise fertility rates. These mechanisms all indicate that in the *absence* of the UMT, the CBR would have been *lower*. That is, our counter-factual simulation in row 3 of Table 3 understates the effects of the UMT on urbanization because it holds constant the observed time path of CBRs, which includes their rise from 1950 to 1985. If we incorporate endogenous fertility, this will result in lower CBRs, and result in less urbanization and informality, and higher welfare.

Constant fertility. As a crude means of establishing the possible consequences of endogenous fertility, we first show in row 6 of Table 3 a counter-factual in which we remove the UMT, and also hold CBRs constant at their 1950 level. The results show that urbanization and informal shares would have been lower, and welfare higher, than in our first counter-factual (row 3).

Endogenous fertility. We cannot incorporate age-specific effects related to population momentum due to the lack of location-specific data on age distributions and demographic behavior. We can, however, build in responses based on wages and CDRs (details available in Web Appendix Section 3). The crucial elements are as follows. First, the fertility decision is assumed to depend on both the wage, w_j, and death rate, CDR_j, in location j. Second, in line with literature, CBRs are negatively related to wages and CDRs (note that this does not imply that total fertility rates are negatively related to CDRs). Specifically, the elasticity of fertility with respect to wages is set to -0.30, and the elasticity of fertility with respect to the CDR is set to -0.30, based on outside sources (see Web Appendix Section 3). The utility weight on fertility is set to be equal to that on life expectancy, also consistent with outside evidence.[27] As can be seen in row 7, the results are similar to those where we hold CBRs at their pre-UMT levels in 1950. The higher wages induced by lower population growth in turn push down CBRs, which in turn helps keep wages high.

Drops in child mortality may create a stronger amenity effect. Drops in adult mortality may have less of an amenity effect, but could lead to bigger congestion effects if adults take more "space" than children. Using national-level data, we find that adult and child mortality each account for half of the decline in death rates during the UMT, so our decomposition is not necessarily over- or under-estimating the amenity versus congestion effects.

[27] The elasticities have the same value (-0.30), but this was a coincidence. We examined outcomes with values ranging between -0.05 and -0.75 for the elasticity of fertility with respect to the CDR and wages, and the results hold (not shown).

3.6. Main Robustness Checks and Possible Micro-Foundations of the Elasticities

The location-specific elasticities are central to our quantitative assessment of the UMT. In Table 4, we show variations in how those elasticities are determined, and that the importance of the UMT remains robust. We also discuss the possible micro-foundations of the elasticities.

Row 1 shows our baseline results, with the rural elasticity set to $\epsilon_r = 1.2$, and the formal and informal elasticities calibrated to match the targets (the final urban and informal shares) shown in Table 3. Columns (1)-(3) of Table 4 show the elasticities. Columns (4) and (5) show how much lower the urbanization and informal shares would have been in 2005 without the UMT, whereas column (6) shows how much higher welfare would have been.

Individually calibrated urban elasticities. We can instead calibrate for *each* country separately, given a rural elasticity of $\epsilon_r = 1.2$, and find values of ϵ_f and ϵ_l unique to each country. In each individual case, the formal elasticity (mean: 1.76; median: 1.41; min: 0.83; max: 4.99) is larger than the informal elasticity (mean: 0.69; median: 0.65; min: 0.49; max: 1.22). Interestingly, the informal elasticities are close to each other (standard deviation: 0.16), while the formal elasticity varies more across countries (standard deviation: 1.04), suggesting that informal sectors are not that different when comparing countries, while formal sectors are. We discuss below how the individual formal elasticities may measure country-specific constraints on formal development.

In Rows 2 and 3, we show the effect of the UMT if we use the mean and median of the individual elasticities. In both cases, the values of the elasticities are similar to the baseline, and the implied effect of the UMT is as well. Note that results also hold if we keep the 30 countries with the lowest formal elasticities, highest formal elasticities, lowest informal elasticities or highest informal elasticities, to show that our results are not driven by outliers (results not shown but available upon request).

Using micro-founded elasticities. Here we provide evidence that the calibrated elasticities we have been using to fit the framework to the data are empirically reasonable. In Web Appendix Section 2, we have extended the framework to include explicit sources of congestion and agglomeration on the size of Q_j, the quality of a location. This allows our aggregate elasticities to be decomposed into: (a) the elasticity of wages with respect to the number of workers, which can be inferred from the factor share of land and capital in the production function, (b) agglomeration effects, measured as the elasticity of productivity with respect to the number of workers, (c) housing effects, measured as the elasticity of housing prices with respect to population, weighted by the expenditure share on housing, and (d) amenity effects, measured by the elasticity of amenity value with respect to population, weighted by a measure of how important amenities are in welfare. For each of these four components, we can draw on estimates from the literature to build up an aggregate elasticity for each location.

For the agricultural sector, Valentinyi and Herrendorf (2008) find a factor share of land and capital of 0.54 for the U.S., whereas Restuccia and Santaeulalia-Llopis (2017) estimate a share of 0.58 for Malawi, which Chen et al. (2017) also assume for Ethiopia. We thus adopt an intermediary

value of 0.56 for the factor share of land and capital in the rural location. For housing in rural locations, we set the house price elasticity to 2.0, in line with the lowest estimates found in developing countries, which we feel is appropriate as rural areas are likely to have the fewest housing regulations and limits to development.[28] The average share of expenditure on housing is equal to 10% for 35 countries out of the 43 poor countries for which we have data on consumption shares from the *Global Consumption Database* of the World Bank.[29] Last, we assume that there are no agglomeration effects within rural locations, consistent with evidence mentioned below, nor are there any amenity effects of population size. Combined, this implies a rural elasticity of $\epsilon_r = 0.56 + 0.1 \times 2.0 = 0.76$.

Using 0.76 as our given rural elasticity, we then calibrate a formal (1.06) and informal (0.45) elasticity to match our target data, just as in our baseline. In Row 4, one can see that the UMT continues to explain a meaningful portion of urbanization (11.5 percentage points) and informalization (12.1 percentage points). This exercise also demonstrates that it is not the absolute size of the elasticities that is relevant for finding a large role for the UMT, but rather their relative size. Our results are not dependent on the choice of $\epsilon_r = 1.2$ in the baseline calibration.

To this point we have been calibrating the formal and informal elasticities, given a rural elasticity. For the final panel of Table 4, we use additional sources to create micro-founded elasticities for *each* urban location in addition to the rural location. This provides something of a "sanity check" on our baseline, and shows that our calibrated elasticities take on plausible values.

For the factor share of land and capital in the formal location, the Valentinyi and Herrendorf (2008) data is less useful, because it remains (for us) at a very high level of aggregation, with all manufacturing sectors and all service sectors lumped together. Young (2010) looks at labor shares at a more disaggregate level for the United States, but does not make the same adjustments for proprietors' income that Valentinyi and Herrendorf (2008) do. With that caveat in mind, Young's numbers show high labor shares, and hence low values of capital shares for several sectors we consider associated with formal locations: 0.66 for utilities, 0.56 for finance, and 0.50 for communications as well as heavy industries such as chemicals. Zuleta et al. (2009) use data from Colombia, and find high capital shares for public services (0.74), finance (0.63) and manufacturing (0.49). Using KLEMS data from India, which has reported labor shares by sub-sector, we find that heavy manufacturing industries, as well as business services, have implied non-labor shares greater than 0.60. Based on all this information, we set the formal capital/land share, and hence the formal wage elasticity, to 0.60.

[28] While the price elasticity of housing supply ranges from 0.5-3.0 in developed countries (Gyourko, 2009; Saiz, 2010; Caldera and Johansson, 2013), it ranges from 0.1-0.5 in developing countries (see Malpezzi and Mayo (1997) for Malaysia and Lall et al. (2007) for Brazil). Inverting this elasticity to get the elasticity of price with respect to the supply of housing, we get estimates of between 2 (1/0.5) and 10 (1/0.1) for developing countries. Assuming that population and the number of housing units are proportional within a given location (which does not require that the household size is similar across locations), then this is also the elasticity of housing price with respect to population size.

[29] This low value is due to their poverty. For the same set of countries, the food expenditure share is 53%. However, even if we were to assume a larger housing expenditure share, similar to shares in developed countries (17% for 29 OECD countries in 2010 according to *OECD.Stat*), this will not result in an appreciable difference in the results we find.

For sectors we associate with informal locations, Young (2010) finds for the United States low capital shares for trade (0.23), and services in general (0.31). Certain manufacturing sub-sectors, such as apparel, also have low capital shares (0.15). Zuleta et al. (2009) find for Colombia low capital shares for commerce and food service (0.18), social and personal services (0.23) and transport and storage (0.17). Valentinyi and Herrendorf's broad service sector has a capital share of 0.34, above these individual estimates. The KLEMS data from India reports the smallest implied values of the capital shares to be around 0.15-0.40 for personal services, health and social work, and food service. To be conservative, we set the informal capital/land share, and hence the informal wage elasticity, to 0.30.

To obtain the formal and informal house price elasticities, we use the results of Saiz (2010), who finds that the house price elasticity varies by the strictness of land use regulations measured by the *Wharton Regulation Index* (WRI) of Gyourko et al. (2008), as well as by the geographic limitations on housing.[30] The impact of geography alone makes Saiz (2010)'s elasticity twice as large in the least geographically restricted cities compared to the most restricted, and variation in the WRI only expands that difference. If we use very restricted cities as an analogy for formal locations, and very unrestricted cities as an analogy for informal ones, then this implies that the elasticity should be (at least) twice as large in formal locations as in informal ones. Taking the low end house price elasticity estimate of 2.0 from above to capture the informal elasticity, then this would imply a formal elasticity of 4.0, or more. Limiting the difference between these two works against our outcomes, so we will work with this gap of 2. We retain the assumption that the expenditure share on housing is 10%.

For urban locations, we also allow for agglomeration effects in terms of the elasticity of productivity with respect to population size. Typical values for the elasticity are between 0.04 and 0.07 for higher-income countries (Combes and Gobillon, 2015; Duranton, 2016), but higher in lower-income countries, for example 0.09-0.12 in China and India (Chauvin et al., 2016; Combes et al., 2017). While Duranton (2016) finds an elasticity of 0.054 for all workers in Colombia, he finds a lower elasticity for formal workers, at 0.036, and explains that: "Smaller agglomeration effects in the formal sector may arise from the fact that workers in the informal sector may sell their products locally so that their income is more directly tied to local housing and transportation costs. [...] the elasticity of wages with respect to city population is closer to the same elasticity estimated in more developed countries when only workers in formal employment are considered." Based on all this information, we use 0.036 for the formal sector and 0.075 for the informal sector.

Finally, for amenities there does not appear to be any significant elasticity of their value with respect to population (Albouy, 2008). Besides, while amenities significantly explain population patterns in developed countries (Albouy and Stuart, 2014; Diamond, 2016), Chauvin et al. (2016) and Duranton (2016) find little role for them in developing countries. Chauvin et al. (2016) writes that it may be because "these countries are not rich enough for ordinary workers to sacrifice earnings" for better amenities. In our 43 poor countries, food and housing, two subsistence

[30]Other studies on land use regulations include Glaeser et al. (2006), Albouy and Ehrlich (2012) and Harari (2016).

consumption items, already account for almost two-thirds of total consumption. We thus assume that amenities do not alter the aggregate elasticities.

Combined, this information leads to an aggregate formal elasticity of $\epsilon_f = 0.6 + 0.1 \times 4.0 - 0.036 + 0 \times 0 = 0.96$ and an aggregate informal elasticity of $\epsilon_l = 0.3 + 0.1 \times 2.0 - 0.075 + 0 \times 0 = 0.43$. Row 5 shows the three constructed elasticities. Most relevant for our purposes is the comparison of the elasticities in Row 5 with those in Row 4. While the rural elasticities match by construction, one can compare our calibrated urban elasticities (Row 4) with the constructed urban elasticities (Row 5). Given the rural elasticity, our calibration delivers elasticities quite close to those inferred from the underlying sources (1.06 versus 0.96 for formal locations, 0.45 versus 0.43 for informal locations). The pattern of these elasticities in Row 5 also conforms to the pattern we find in our baseline calibration (1.29 and 0.64 respectively), even though the absolute sizes are smaller now. The effects of the UMT on urbanization and informalization remain similar.

Last, the implied effect of the UMT is driven in large part by the relatively low informal elasticity we find in both the data and our calibration. As a final robustness check, we show in Row 6 how the calibration performs if we arbitrarily set the informal elasticity 0.20 higher than what is implied by the sources, to $\epsilon_l = 0.63$. This could capture either a higher wage elasticity with respect to population, smaller agglomeration effects, a larger house price elasticity, or an effect of population on amenities in these locations that the literature has not identified. Regardless of the source, raising the informal elasticity will lower the implied effect of the UMT, and that can be seen in columns (4) and (5). While lower, there is still a meaningful amount of urbanization and the informal share that would be attributed to the UMT in this scenario.[31]

Interpretations of the elasticities. No matter how we obtain the elasticities, welfare in the formal locations appears to be more sensitive to population size than in rural locations, and much more sensitive to population size than in informal locations. Based on the production function and agglomeration effects, the rural and formal locations have similar elasticities (about 0.56 vs 0.60-0.036 = 0.564), but formal housing supply is at least half as elastic as rural housing supply. While the housing expenditure share is low in poor countries, formal housing supply is inelastic enough that formal locations have the least absorptive capacity. Next, informal locations have a much lower elasticity based on the production function and agglomeration effects (0.30-0.075 = 0.225), and informal housing supply is also twice more elastic than formal housing supply. Thus, almost two-thirds of the difference between the formal and informal elasticities could be explained by the production function and agglomeration effects, while housing effects account for the rest.

Now, if we compare the assumed/calibrated elasticities and the micro-founded elasticities, one can see that the former are 34-58% higher in levels than the latter. First, there are other congestion effects that we do not model, for example in terms of food prices or traffic congestion, mostly due to lack of estimates. The true elasticities are likely to be higher than the micro-founded elasticities. Second, the assumed/calibrated elasticities match the data for low-income countries, whereas

[31] One note is that the simulations in Row 5 and 6 are not disciplined to match the target data, as we are setting all the elasticities from outside the framework. In both cases, the calibration over-predicts urbanization and the informal share by a few percentage points, but the comparison of the two rows remains informative.

the micro-founded elasticities disproportionately rely on estimates from middle- or high-income countries. If there are additional constraints in low-income countries, the elasticities will be higher. For example, low-income countries are likely to use backward technologies in production and housing that are more susceptible to congestion. For example, the housing sector may consist mostly of low-rise structures, although skyscrapers could help relieve space constraints. The institutional structure may mean that production and housing cannot expand at a pace equal to that of population. This may be especially true for the formal sector. In contrast, informal locations can adapt relatively easily to population inflows because their production (e.g. street vending) and housing (e.g. shacks) have low fixed costs and are not subject to the same institutional constraints as in formal areas.[32]

3.7. Other Sensitivity Checks for the Effects of the UMT, 1950-2005

Table 5 shows the effects of changing the assumptions regarding the externally set parameters, and in the choice of data to match to. Row 1 reproduces our baseline results (see Rows 2-3 of Table 3). Columns (2) and (3) show how much lower the urbanization and informal shares would have been in 2005 without the UMT, whereas column (4) shows how much higher welfare would have been. Columns (5) and (6) display the calibrated values of the formal and informal elasticities, ϵ_f and ϵ_l, respectively. These remain somewhat stable across all robustness checks.

Matching data. Rows 2-4 show results hold if we calibrate to all countries with urbanization rates below 30 percent (row 2; N = 52), 40 percent (row 3; 62) or 50 percent (row 4; 66) in 1950, rather than only those with an urbanization rate below 20. Next, there are 8 countries with an urbanization rate below 20 in 1950 but for which the slum share is unavailable. Knowing from World Bank (2017) the respective shares of the urban population with access to improved sanitation facilities or an improved water source circa 2005, we impute a slum share for all countries.[33] Results are unchanged if we replace the missing slum shares by the imputed shares (row 5; 51) or use the imputed shares for all countries instead of the actual share (row 6; 51).[34]

CDR shocks. In rows 7, 8 and 9, we limit the set of countries we calibrate to based solely on the change in their crude death rate, so that we capture only countries that experienced a significant UMT. We include countries that saw their aggregate CDR fall by more than 7 per 1,000 people (the median drop across all countries), 12 (the 25th percentile), and 16 per thousand (the 10th percentile) between 1950-1980, respectively. In all cases the results are similar.

Initial informal shares. In our baseline, we set the informal share of cities to 50% in 1950. However, altering this assumption to be 40% or 60% informal in 1950, as in rows 10 and 11, does little to change the outcome of removing the UMT.

[32]For the 43 countries we find a negative correlation between the estimated individual formal elasticity and regulatory quality (-0.48, p-value of 0.11), government effectiveness (-0.82**), accountability (-0.40*), the rule of law (-0.53**) and the control of corruption (-0.57*) for the period 1996-2005 (data not available before) when using the *World Governance Indicators* of the World Bank. We also find a positive correlation of the ease of doing business index (1 = easiest to 185 = most difficult) (0.008**) when using the *Doing Business Indicators* of the World Bank.

[33]We use 100 - max(share of population without access to sanitation; share of population without access to water).

[34]Eliminating China and India, or ex-Communist countries, does not affect the results (not shown, but available upon request). This shows that countries with limited movement between rural and urban areas are not driving our results.

Initial urban CDRs. In our baseline calibration, we use an initial urban CDR of 40, because that was the CDR of the poorest countries in our sample in the 1900s, before the UMT took place circa 1950 (see Section 1.2.). However, developing countries had on average an urban CDR of 30 in the 1900s. In rows 12 and 13, we set the urban CDR to 35 and 30, respectively. In both cases, the implied change in urbanization and informal share from removing the UMT are only slightly smaller than in our baseline. Row 14 sets up a differential in the formal and informal sectors CDR in 1950, at 30 and 40, respectively. In this case, the results are close to the baseline.

Rural mortality transition (RMT). In our baseline, we set the rural CDR to 20 throughout, implying that the RMT had already occurred, allowing us to focus purely on the UMT. Row 15 addresses this by setting the initial rural CDR to 40, and then letting it decline towards 20 over time. The counterfactual is then calculated removing the mortality transition for all locations. As can be seen, this results in even larger drops in the urbanization and informal share.

Urban productivity/amenity growth. In our baseline calibration, we assumed that the formal sector had a growth rate of 5%, 2.5 percentage points higher than in the informal areas. The economy is dualistic, with a fast-growing modern sector and lagging traditional sectors. But as rows 16-19 show, reducing formal growth to 4% or 3% or raising informal growth to 3.5% or 4.5% does not eliminate the results, except that the amount of the informal share explained is lower. This occurs because to match the observed data, the gap between the formal and informal elasticities has to decrease. As a result, the UMT does not drive as many people into informal areas.

Rural productivity/amenity growth. In our baseline calibration, we assumed that the rural sector had a growth rate of 2.5%, which may be high if rural residents suffer from repeated climate shocks or conflict. However, whether natural and man-made disasters drive urbanization depend on where they mostly take place, and their respective effects on rural ad urban residents.[35] Results remain similar if we lower the rural growth rate by 1 percentage point, implying that rural areas are disproportionately affected by such shocks (row 20). Results also hold if we posit that urban areas are more affected (row 21; urban growth rates 1 percentage point lower) or that rural and urban areas are equally affected (row 22; all growth rates 1 percentage point lower).

Preferences. Our baseline value of the life expectancy preference parameter $\beta = 0.41$ was obtained using the results for Africa in Becker et al (2005). Their implied value from Latin America is $\beta = 1.56$ and from South Asia is $\beta = 1.70$. The lower value from Africa, implying less utility weight on life expectancy, is consistent with recent work by Jones (2016) on how people's preference for consumption relative to health falls as they become richer. When using $\beta = 1.56$ (row 23) or $\beta = 1.70$ (row 24), the preference for living in low-mortality locations is higher, and as such removing the UMT makes people less likely to live in cities. The effect of removing the UMT is to lower the urbanization rate by 20 percentage points, and the informal share by almost 15.

[35]While droughts reduce agricultural productivity (Barrios et al., 2006; Henderson et al., 2016a; Burgess et al., 2017), floodings reduce economic activity in cities (Kocornik-Mina et al., 2015). Heat waves then increase mortality in both rural and urban areas (Burgess et al., 2017). Likewise, conflict can be essentially "rural", thus driving rural-to-urban migration, or "urban" if the aim of battles is to capture cities, thus driving urban-to-rural migration.

3.8. Calibration for Historical Countries, 1800-1950

As a way of further validating our framework, we use it "out of sample" to predict the time path of urbanization and informal share for a set of 20 historical countries (19 European countries and the United States) beginning in 1800 (see Web Appendix Section 1.2 for details). These countries started from a similar initial level of urbanization, 12.6%, as our sample of poor countries. Based on our demographic data for 14 of them, they experienced similar declines in urban mortality as in our baseline sample (22.5 vs 25 per thousand). The significant *difference* for the historical countries is that their UMT took place over the course of 150 years (1800-1950), versus a few decades in the case of poor countries. In Table 6 we show the results of running our calibration, matching the average initial conditions of the 20 countries in 1800, and using their average observed demographic rates, but leaving all other parameters, including the elasticities calibrated using our baseline sample, shown in Table 2.[36]

Observed data. The first row shows the observed averages from the 20 countries. Based on the data compiled by Jedwab et al. (2015), their overall urbanization rate increased from 12.6% in 1800 to 37.9% and 57.9% in 1900 and 1950, respectively, whereas their total urban population was multiplied by 7.7 between 1800 and 1900 and 14.7 between 1800 and 1950. We do not know their informal share in either year, as such data does not exist. We thus assume that their initial slum share was 50% in 1800, to be consistent with the choice we made for our sample of developing countries in 1950. For the year 1900, we use the fact that for our four industrializing cities in the late 19th century (London in 1886, Manchester in 1894, New York in 1890-1895 and Paris in 1864, see Section 1.1.) the average slum share was 29.3%. We thus believe the average slum share could have been 30% in 1900. For the year 1950, we use the facts that: (i) 17.7% of people lived in "overcrowded" dwellings in London in 1921 according to the 1921 *Census*; (ii) the share of "insalubrious" housing units in Paris was 35% in the 1930s, half of which were "dangerous" to live in, according to *Annuaires Statistiques de la Ville de Paris*; and (iii) 21.2% of the U.S. urban population lived in "dilapidated" housing units and/or units without running water in 1950 according to the 1950 *U.S. Census*. We thus believe the average slum share could have been 15% in 1950.

Calibration. Row 2 shows the results of simulating the framework with the historical initial conditions, and assuming an exogenous fertility process the same as in our baseline calibration. 1900 urbanization in the simulation (40.8 percent) is close to urbanization in the data (37.9 percent). The predicted informal rate is 35.6%, close to the 30% value that we set from the available data. We do overstate the actual urban size by a significant amount (20.5 versus 7.7 in the data), which we can attribute to the exogenous fertility process as well as the fact that our simulation has no international out-migration, unlike the historical countries. By 1950, the simulation does a good job of matching the urbanization rate (58.4 percent versus 57.9 percent in the data), and the informal share (15.8 percent versus 15 percent in the data), but we do not want to overstate the

[36]More precisely, the initial crude death rates for the formal (35 per thousand), informal (42.5), and rural (25) fall gradually towards final values of 12.5, 20, and 10, respectively, with a half-life of 50 years. Crude birth rates in the formal (30), informal (35), and rural locations (37.5) fall towards long-run values of 12.5, 30, and 10, respectively, when we use the exogenous fertility assumption.

quality of that match, as the observed informal share is drawn from a handful of studies.

In row 3, we simulate again, this time allowing for an endogenous fertility response with the same parameters we set in our baseline sample. The simulation does a reasonable job of matching the observed urbanization rates in both 1900 and 1950, and we capture the declining informal share over time. With endogenous fertility, the implied urban sizes are more reasonable, predicting that urban population was 10.8 times larger in 1900 (versus 7.7 in the data), and 25.7 times larger in 1950 (versus 14.7 in the data). Again, without allowing for international out-migration, or a faster demographic transition, we continue to overstate population growth, but the composition of that population across locations appears reasonable.

Accelerating their UMT. In rows 4 and 5, we simulate again using the historical starting conditions, but impose a rapid UMT. We replicate the simulations in rows 2 and 3, changing *only* the speed of the UMT to match that of our baseline sample of developing countries. With exogenous fertility (row 4), by 1900 our historical sample would have been at 46.2 percent urban, and 50.1 percent informal, higher than the observed rates. As expected with lower mortality, the implied urban size would have been more than twice as large. By 1950, the urbanization rate would have been similar to that with a slow UMT, but the informal share would have been nearly twice as big. Urban size would have been close to three times larger. These results showing the importance of rapid mortality declines on urbanization are consistent with Hanlon (2016) who finds that coal pollution constrained city growth in Industrial Britain.

With endogenous fertility (row 5), a rapid UMT would have caused an even greater divergence from the observed outcomes, as the lower living standards led to higher fertility. One should not take the reported outcomes at face value; the simulated urban sizes reach improbably ratios. The simulations are useful, however, because they show that a fast UMT might push an economy into a vicious spiral. A rapid UMT is capable of producing rapid urbanization that is almost entirely informal, a significant departure from the slow UMT simulations in rows 2 or 3. Overall, the ability of the calibration to match the historical evidence provides reassurance that our framework is not limited to the specifics of the post-war UMT, and we believe the difference in results between the slow and rapid UMT shown in Table 6 shows that population growth rates have meaningful impacts on urbanization throughout time.

3.9. Simulating Policy Effects, 2005-2055

Baseline. Row 1 of Table 7 shows our starting point in 2005, with urbanization of 31.2% and an informal share of 62.2%. We normalize the size of the urban sector and of the informal sector to one in 2005. The second panel presents the simulated effects of various policy experiments, for which we use the parameters of Table 2, but update the demographic rates to match observed 2005 rates. We use the sample averages in the location-level data for the 20 poor countries (minus China, due to the one-child policy) for which we have demographic data in the 2000s. CBRs in informal locations and rural locations are set to 35, and formal locations to 20. CDRs are set to 10 in rural locations, and 7.5 in urban locations. Row 2 shows our baseline outcomes 50 years later in 2055, i.e. an urbanization rate of 49.8%. As a comparison, United Nations (2014) projects an

urbanization rate of 55%. The informal share of urban areas remains roughly the same as in 2005, at 60.8%. Welfare in 2055 is normalized to one for comparison to the alternatives below.[37]

Productivity growth. One strategy is to foster rapid productivity growth, either through industrial/green revolutions or climate change/conflict mitigation. To see these effects, we separately raise productivity/amenity growth by one percentage point in each sector. Raising rural growth to $G_r = 0.035$ (row 3) reduces urbanization to 37.6%, while welfare is now 25% higher. Compared to this, raising informal growth to 3.5% (row 4) increases welfare by 27%, even though urbanization would be 59.7% and the informal share 73.2% in this scenario. Welfare is higher in the informal case because we are raising growth in a location with a low congestion elasticity, and this allows a large group of people to move into that location to take advantage of the higher level of G_l. Raising G_f to 6% (row 5) for formal locations increases urbanization rates, but also lowers the informal share. Rows 6 and 7 increase formal growth to 8% and 10%, respectively, to explore the effects of rapid industrialization. In both cases, the urbanization rate rises and the informal share falls dramatically. The welfare gains appreciate quickly.

Lower formal elasticity. An alternative policy is trying to lower the cost of population growth in locations with high wage/amenity growth (i.e. formal locations) by improving urban planning, relaxing land-use regulations, building infrastructure, facilitating the growth of secondary cities, and/or creating well-planned cities ex nihilo. In row 8, we examine the effect of lowering the formal elasticity of 1.29 to the value we use for rural locations (1.20). This raises the urbanization rate slightly to 50.9%, while lowering the informal share slightly to 57.0%, and welfare is 3% higher. In row 9, we lower the formal elasticity to 0.90, which is close to 0.83, the minimal individual formal elasticity found for the 43 countries. This is equivalent to assigning the elasticity of the "best" country in our sample to the full sample. The informal share decreases to 40.1% and welfare is 24% higher. A more dramatic change is seen in row 10, where we lower the formal elasticity by about 50% to equal the informal elasticity (0.64). The urbanization rate rises to 65.5%, the informal share falls to 21.3%, and welfare increases by 73%. Row 11 drops the formal elasticity further to $\epsilon_f = 0.43$, one third of the calibrated value of 1.29. Here, the same pattern of results holds. The welfare effect is now similar to the effect of raising the formal growth rate to 10%.

Higher informal congestion. Policies may alternatively be aimed at reducing the attraction of informal locations. This could take the form of enforcing property rights within these locations (or regulations in their sectors), or physically destroying these locations (i.e. clearing slums). In row 12 we simulate these policies by raising the informal elasticity to the level of the formal elasticity, $\epsilon_l = 1.29$. 1.29 is also close to 1.22, the maximal individual informal elasticity found for the 43 countries. This is thus equivalent to assigning the informal elasticity of the "worst" country in our sample to the full sample. This lowers the informal share to 41.1%. However, welfare is lower, at only 82% of the baseline, because the policy raises the average elasticity of welfare with respect to population. Informal areas, while they have low productivity growth, provide an outlet for population growth that alleviates congestion effects in the aggregate.

[37] We find similar results if we replicate the entire analysis using endogenous fertility (not shown).

Migration restrictions. Another policy approach, such as with China's hukou system, is to limit in-migration to cities. We evaluate the effect of such policies by adding a migration restriction to our framework that generates a wedge in welfare growth between locations. Let the value λ_{ur} measure the wedge between welfare growth in rural and urban areas. If $\lambda_{ur} = -0.01$, for example, this means that migration restrictions keeping rural residents from leaving lead to 1% slower growth in welfare in rural locations compared to urban ones. For our simulation, we set $\lambda_{ur} = -0.01$ in row 13. These kinds of migration restrictions limit urbanization to 37.6%. However, welfare is only 91% of the baseline. The migration restrictions lower welfare by forcing a large portion of the population to stay in high-congestion locations.[38] In row 14, we flip the migration restrictions, imposing limits on the movement of urban people into rural areas. This may reflect either an explicit urban-biased policy, or the fact that with the UMT an increasing share of urban residents are urban-born, and urban-born individuals may acquire from birth a preference for urban living. Setting $\lambda_{ur} = 0.01$, which implies faster welfare growth in rural areas, this raises urbanization rates to 61.6%, and informal areas are larger. Similar to the conclusions of Au and Henderson (2006) and Desmet and Rossi-Hansberg (2014), migration restrictions are counter-productive.

Family planning. Most low-income countries still have CBRs of about 40 per thousand. In row 15 we impose zero population growth by setting the CBR and CDR to be equal in each location. This results in urbanization of only 40.2% by 2055. The informal share of urban areas drops to 37.9%. Lowering population growth slows down the growth of the low-congestion informal locations, resulting in lower urbanization and informal shares. However, zero population growth is an extreme policy. In row 16 we instead explore a policy of voluntary family planning (FP) that would contribute to CBRs decreasing to 20, similar to those achieved in Hong Kong, Singapore, South Korea, or China before the involuntary one-child policy was introduced in 1979. 20 is also the average formal CBR that we obtained for 7 poor mega-cities today (see section 1.2.). Urbanization would only be 44.0% in 2055, while the informal share would fall to 48.8%. Welfare would be 85% higher. In rows 17 and 18, we show separately the effects of FP in informal and rural areas, respectively. Informal FP lowers urbanization and informal shares relative to the baseline scenario, and raises welfare by 19%. Rural FP has larger effects, lowering urbanization to 45.4% and informalization to 52.0%, while raising welfare by 58%. The larger effect of rural FP is due to the relatively large size of the rural population. However, rural FP may be costlier to implement than urban FP due to the rural population being more scattered spatially.

4. Conclusion

Using a novel dataset of location-level demographics over time, we document that poor countries urbanized at the same time as the urban mortality transition (UMT) following WW2, which lowered their urban mortality rates to rich-country levels. To assess the quantitative importance of the UMT, we develop a framework involving location choice that has heterogeneity in congestion

[38] We obtain similar results if we extend the framework to see how slum-constraining policies impact poor mega-city growth when there are cross-location congestion effects (not shown, but available upon request).

costs and demographics across locations. It shows that population growth affects the distribution of population across locations. Calibrating this framework to a sample of poor countries, we find that the UMT may have doubled their urbanization rate as well as the size of their slums between 1950 and 2015. One-third of these effects could be traced to direct preferences for living in locations with lower mortality rates, while the remaining two-thirds are accounted for by faster population growth pushing people into informal locations. The calibration allows us to assess various policies, and we find that industrialization, urban infrastructure and institutions, and family planning could help improve the urbanization process in poor countries. Going forward, it would be fruitful to expand the framework to incorporate heterogenous products by location, international trade, and/or uncertainty to investigate their interaction with population growth and urbanization.

REFERENCES

Acemoglu, Daron and Simon Johnson, "Disease and Development: The Effect of Life Expectancy on Economic Growth," *Journal of Political Economy*, December 2007, *115* (6), 925–985.

Ades, Alberto F and Edward L Glaeser, "Trade and Circuses: Explaining Urban Giants," *The Quarterly Journal of Economics*, February 1995, *110* (1), 195–227.

Akbar, Prottoy and Gilles Duranton, "Estimating the Costs of Traffic Congestion in Bogota," Mimeo 2016.

__ , Victor Couture, Gilles Duranton, Ejaz Ghani, and Adam Storeygard, "Accessibility and mobility in urban India," 2017. Mimeo.

Albouy, David, "Are Big Cities Bad Places to Live? Estimating Quality of Life across Metropolitan Areas," NBER Working Papers 14472, National Bureau of Economic Research November 2008.

__ and Bryan Stuart, "Urban Population and Amenities: The Neoclassical Model of Location," NBER Working Papers 19919, National Bureau of Economic Research, Inc February 2014.

__ and Gabriel Ehrlich, "Housing Productivity and the Social Cost of Land-Use Restrictions," NBER Working Papers 18110, National Bureau of Economic Research, Inc 2012.

Allen, Robert C., Jean-Pascal Bassino, Debin Ma, Christine Mollâ-Murata, and Jan Luiten Van Zanden, "Wages, Prices, and Living Standards in China, 1738-1925: in Comparison with Europe, Japan, and India," *Economic History Review*, 2011, *64* (s1), 8–38.

Alvarez-Cuadrado, Francisco and Markus Poschke, "Structural Change Out of Agriculture: Labor Push versus Labor Pull," *American Economic Journal: Macroeconomics*, July 2011, *3* (3), 127–58.

Ambrus, Attila, Erica Field, and Robert Gonzalez, "Loss in the Time of Cholera: Long-run Impact of a Disease Epidemic on the Urban Landscape," 2015.

Ashraf, Nava, Edward L. Glaeser, and Giacomo A. M. Ponzetto, "Infrastructure, Incentives, and Institutions," *American Economic Review*, May 2016, *106* (5), 77–82.

Ashraf, Quamrul and Oded Galor, "Dynamics and Stagnation in the Malthusian Epoch," *American Economic Review*, August 2011, *101* (5), 2003–41.

__ , David Weil, and Joshua Wilde, "The Effect of Fertility Reduction on Economic Growth," *Population and Development Review*, 2013, *39* (1), 97–130.

Au, Chun-Chung and J. Vernon Henderson, "Are Chinese Cities Too Small?," *Review of Economic Studies*, 2006, *73* (3), 549–576.

Barrios, Salvador, Luisito Bertinelli, and Eric Strobl, "Climatic Change and Rural-Urban Migration: The Case of Sub-Saharan Africa," *Journal of Urban Economics*, November 2006, *60* (3), 357–371.

Barro, Robert J and Gary S Becker, "Fertility Choice in a Model of Economic Growth," *Econometrica*, March 1989, *57* (2), 481–501.

Beach, Brian and Walker Hanlon, "Coal Smoke and Mortality in an Early Industrial Economy," *The Economic Journal, Forthcoming*, 2017.

Becker, Gary S., "An Economic Analysis of Fertility," in "Demographic and Economic Change in Developed Countries" NBER Chapters December 1960, pp. 209–240.

__ , Edward L. Glaeser, and Kevin M. Murphy, "Population and Economic Growth," *American Economic Review*, September 1999, *89* (2), 145–149.

Becker, Gary S, Kevin M Murphy, and Robert Tamura, "Human Capital, Fertility, and Economic Growth," *Journal of Political Economy*, October 1990, *98* (5), S12–37.

Becker, Gary S., Tomas J. Philipson, and Rodrigo R. Soares, "The Quantity and Quality of Life and the Evolution of World Inequality," *American Economic Review*, March 2005, *95* (1), 277–291.

Bleakley, Hoyt, "Disease and Development: Evidence from Hookworm Eradication in the American South," *Quarterly Journal of Economics*, 02 2007, *122* (1), 73–117.

__ , "Malaria Eradication in the Americas: A Retrospective Analysis of Childhood Exposure," *American Economic Journal: Applied Economics*, April 2010, *2* (2), 1–45.

Block, Steven, "The Decline and Rise of Agricultural Productivity in Sub-Saharan Africa Since 1961," NBER Working Papers 16481, National Bureau of Economic Research 2010.

Bolt, Jutta and Jan Luiten van Zanden, "The Maddison Project: collaborative research on historical national accounts," *Economic History Review*, 2014, *67* (3), 627–651.

British Medical Journal, *Public Health and Poor-Law Medical Services* 1887.

Buera, Francisco J. and Joseph P. Kaboski, "The Rise of the Service Economy," *American Economic Review*, October 2012, *102* (6), 2540–69.

Burgess, Robin, Olivier Deschenes, Dave Donaldson, and Michael Greenstone, "The Unequal Effects of Weather and Climate Change: Evidence from Mortality in India," 2017. Mimeo.

Caldera, Aida and sa Johansson, "The price responsiveness of housing supply in OECD countries," *Journal of Housing Economics*, 2013, *22* (3), 231–249.

Census Office, *Report of the Social Statistics of Cities of the United States: Eleventh Census 1890* 1895.

Cervellati, Matteo and Uwe Sunde, "Human Capital Formation, Life Expectancy, and the Process of Development," *American Economic Review*, 2005, *95* (5), 1653–1672.

__ and __ , "The Economic and Demographic Transition, Mortality, and Comparative Development," *American Economic Journal: Macroeconomics*, July 2015, *7* (3), 189–225.

Chandler, Tertius, *Four Thousand Years of Urban Growth: An Historical Census* 1987.

Chauvin, Juan Pablo, Edward Glaeser, Yueran Ma, and Kristina Tobio, "What is different about urbanization in rich and poor countries? Cities in Brazil, China, India and the United States," *Journal of Urban Economics*, 2016, pp. –.

Chen, Chaoran, Diego Restuccia, and Raul Santaeulalia-Llopis, "Land Markets, Resource Allocation, and Agricultural Productivity," Technical Report 2017.

Clark, Gregory and Neil Cummins, "Urbanization, Mortality, and Fertility in Malthusian England," *American Economic Review*, May 2009, *99* (2), 242–47.

Combes, Pierre-Philippe and Laurent Gobillon, "The Empirics of Agglomeration Economies," in "in," Vol. 5, Elsevier, 2015, chapter Chapter 5, pp. 247–348.

__ , Sylvie Demurger, and Shi Li, "Productivity gains from agglomeration and migration in Chinese cities over 2002-2013," Technical Report 2017.

Costa, Dora and Matthew E. Kahn, "Public Health and Mortality: What Can We. Learn from the Past?," in David Card Alan Auerbach and John Quigley, eds., *Poverty, the Distribution of Income, and Public Policy*, Russell Sage volume in honor of Eugene Smolensky, 2006.

Cutler, David M., Wei Huang, and Adriana Lleras-Muney, "Economic Conditions and Mortality: Evidence from 200 Years of Data," Working Paper 22690, National Bureau of Economic Research September 2016.

Davis, James C. and J. Vernon Henderson, "Evidence on the Political Economy of the Urbanization Process," *Journal of Urban Economics*, January 2003, *53* (1), 98–125.

Davis, Kingsley, "The Amazing Decline of Mortality in Underdeveloped Areas," *American Economic Review Papers and Proceedings*, May 1956, *46*, 305–18.

Demographia, *World Urban Areas (500,000+): Population, Density.* 2014.

Desmet, Klaus and Esteban Rossi-Hansberg, "Urban Accounting and Welfare," *American Economic Review*, October 2013, *103* (6), 2296–2327.

__ and __ , "Analyzing Urban Systems : Have Megacities Become too Large?," Policy Research Working Paper Series 6872, The World Bank May 2014.

__ and J Vernon Henderson, "The Geography of Development within Countries," CEPR Discussion Papers 10150, C.E.P.R. Discussion Papers September 2014.

__ , Avner Greif, and Stephen Parente, "Spatial Competition, Innovation and Institutions: The Industrial Revolution and the Great Divergence," Mimeo 2015.

Diamond, Rebecca, "The Determinants and Welfare Implications of US Workers' Diverging Location Choices by Skill: 1980-2000," *American Economic Review*, March 2016, *106* (3), 479–524.

Dincecco, Mark and Massimiliano Gaetano Onorato, "Military conflict and the rise of urban Europe," *Journal of Economic Growth*, September 2016, *21* (3), 259–282.

Doepke, Matthias, "Child mortality and fertility decline: Does the Barro-Becker model fit the facts?," *Journal of Population Economics*, 06 2005, *18* (2), 337–366.

__ and Fabrizio Zilibotti, "The Macroeconomics of Child Labor Regulation," *American Economic Review*, December 2005, *95* (5), 1492–1524.

__ , Moshe Hazan, and Yishay D. Maoz, "The Baby Boom and World War II: A Macroeconomic Analysis," *The Review of Economic Studies*, 2015, *82* (3), 1031.

Duarte, Margarida and Diego Restuccia, "The Role of the Structural Transformation in Aggregate Productivity," *The Quarterly Journal of Economics*, 2010, *125* (1), 129–173.

Duranton, Gilles, "The Colombian Urban System: Agglomeration, Urban Costs, and Growth," 2014. Working paper.

__ , "Growing through cities in developing countries," Policy Research Working Paper Series 6818, The World Bank March 2014.

__ , "Agglomeration Effects In Colombia," *Journal of Regional Science*, 03 2016, *56* (2), 210–238.

__ and Diego Puga, "Micro-foundations of urban agglomeration economies," in J. V. Henderson and J. F. Thisse, eds., *Handbook of Regional and Urban Economics*, Vol. 4, Elsevier, 2004, chapter 48, pp. 2063–2117.

Fay, Marianne and Charlotte Opal, "Urbanization without growth : a not-so-uncommon phenomenon," Policy Research Working Paper 2412, The World Bank August 2000.

Fink, Günther, Isabel Günther, and Kenneth Hill, *Urban Mortality Transitions: The Role of Slums*, Cham: Springer International Publishing,

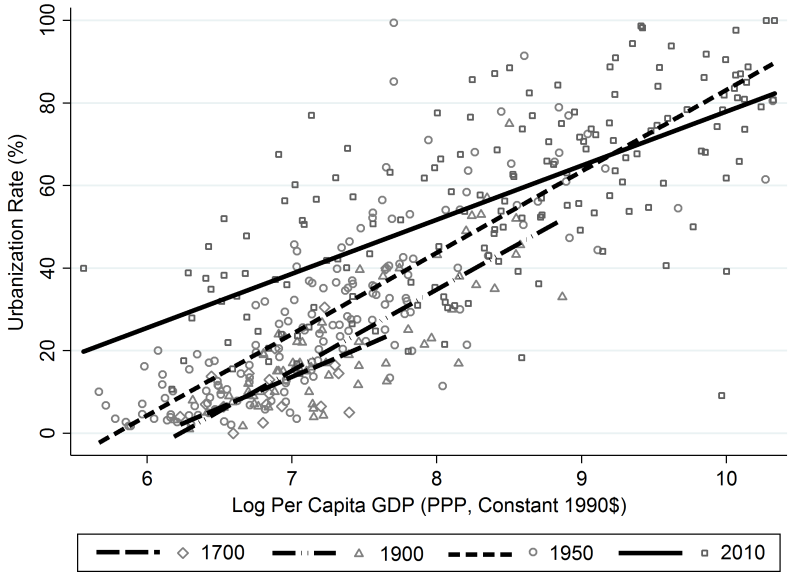
Fox, Sean, "The Political Economy of Slums: Theory and Evidence from Sub-Saharan Africa," *World Development*, 2014, *54* (C), 191–203.

__ and Tom Goodfellow, *Cities and Development* 2016.
Fuglie, Keith O., "Total Factor Productivity in the Global Agricultural Economy: Evidence from FAO Data," in "Shifting Patterns of Agricultural Production and Productivity Worldwide" 2010.
Galley, C, *The Demography of Early Modern Towns: York in the Sixteenth and Seventeenth Centuries* 1998.
Galor, Oded, *Unified Growth Theory*, Princeton, NJ: Princeton University Press, 2011.
__ , "The Demographic Transition: Causes and Consequences," *Cliometrica, Journal of Historical Economics and Econometric History*, January 2012, *6* (1), 1–28.
__ and Andrew Mountford, "Trading Population for Productivity: Theory and Evidence," *Review of Economic Studies*, 2008, *75* (4), 1143–1179.
__ and David Weil, "From Malthusian Stagnation to Modern Growth," *American Economic Review*, May 1999, *89* (2), 150–154.
__ and __ , "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond," *American Economic Review*, 2000, *90* (4), 806–828.
Garenne, Michel, "Will Urban and Rural Mortality Converge in Africa?," in Michel Oris Diego Ramiro Fariñas, ed., *New Approaches to Death in Cities during the Health Transition*, Russell Sage volume in honor of Eugene Smolensky, 2016.
Glaeser, Edward and J. Vernon Henderson, "Urban economics for the developing World: An introduction," *Journal of Urban Economics*, 2017, pp. –.
Glaeser, Edward L., "A World of Cities: The Causes and Consequences of Urbanization in Poorer Countries," *Journal of the European Economic Association*, 2014, *12* (5), 1154–1199.
__ , Hedi D. Kallal, Jose A. Scheinkman, and Andrei Shleifer, "Growth in Cities," *Journal of Political Economy*, December 1992, *100* (6), 1126–52.
__ , Joseph Gyourko, and Raven E. Saks, "Urban growth and housing supply," *Journal of Economic Geography*, January 2006, *6* (1), 71–89.
Gollin, Douglas and Richard Rogerson, "Productivity, transport costs and subsistence agriculture," *Journal of Development Economics*, 2014, *107*, 38 – 48.
__ , David Lagakos, and Michael E. Waugh, "The Agricultural Productivity Gap," *The Quarterly Journal of Economics*, 2013.
__ , Remi Jedwab, and Dietrich Vollrath, "Urbanization with and without industrialization," *Journal of Economic Growth*, 2015, *21* (1), 35–70.
__ , Stephen L. Parente, and Richard Rogerson, "The Role of Agriculture in Development," *American Economic Review*, May 2002, *92* (2), 160–164.
__ , __ , and __ , "The food problem and the evolution of international income levels," *Journal of Monetary Economics*, May 2007, *54* (4), 1230–1255.
Gould, W.T.S., *Population and Development* 2015.
Guillot, Michel, "The Momentum of Mortality Change," *Population Studies*, 2005, *59* (3).
Gyourko, Joseph, "Housing Supply," *Annual Review of Economics*, 2009, *1* (1), 295–318.
__ , Albert Saiz, and Anita Summers, "A New Measure of the Local Regulatory Environment for Housing Markets: The Wharton Residential Land Use Regulatory Index," *Urban Studies*, 2008, *45* (3), 693–729.
Haines, Michael R., *Social Science History*, 2004, *28* (2), 249–270.
__ , *The Population of the United States, 1790-1920* 2008.
Hanlon, W. Walker, "Coal Smoke and the Costs of the Industrial Revolution," Working Paper 22921, National Bureau of Economic Research December 2016.
__ and Yuan Tian, "Killer Cities: Past and Present," *American Economic Review*, May 2015, *105* (5), 570–75.
Hansen, Gary D. and Edward C. Prescott, "Malthus to Solow," *American Economic Review*, September 2002, *92* (4), 1205–1217.
Harari, Mariaflavia, "Cities in Bad Shape," 2016. Unpublished.
Henderson, J. Vernon, "The Size and Types of Cities," *American Economic Review*, 1974, *64* (4), 640–656.
__ , "Cities and Development," *Journal of Regional Science*, 2010, *50* (1), 515–540.
__ , Adam Storeygard, and Uwe Deichmann, "Has climate change driven urbanization in Africa?," *Journal of Development Economics*, 2016, pp. –.
__ , Tanner Regan, and Anthony J. Venables, "Building the City: Sunk Capital, Sequencing and Institutional Frictions," SERC Discussion Papers 0196 April 2016.
Herrendorf, Berthold, Richard Rogerson, and kos Valentinyi, "Growth and Structural Transformation," in "Handbook of Economic Growth," Vol. 2 of *Handbook of Economic Growth*, Elsevier, 2014, chapter 6, pp. 855–941.
Heuveline, Patrick, "The Global and Regional Impact of Mortality and Fertility Transitions, 1950-2000," *Population and Development Review*, 1999, *25* (4), 681–702.
Jacobs, Jane, *The Economy of Cities* 1969.
Jedwab, Remi, Luc Christiaensen, and Marina Gindelsky, "Demography, urbanization and development:

Rural push, urban pull and … urban push?," *Journal of Urban Economics*, 2015, pp. –.
Jones, Charles I., "Life and Growth," *Journal of Political Economy*, 2016, *124* (2), 539–578.
Jones, Larry E., Alice Schoonbroodt, and Michele Tertilt, "Fertility Theories: Can They Explain the Negative Fertility-Income Relationship?," in "Demography and the Economy" NBER Chapters, National Bureau of Economic Research, Inc, December 2010, pp. 43–100.
__ and Michele Tertilt, "An Economic History of Fertility in the U.S.: 1826-1960," NBER Working Papers 12796, National Bureau of Economic Research, Inc December 2006.
Kalemli-Ozcan, Sebnem, " Does the Mortality Decline Promote Economic Growth?," *Journal of Economic Growth*, December 2002, *7* (4), 411–39.
Kocornik-Mina, Adriana, Thomas K.J. McDermott, Guy Michaels, and Ferdinand Rauch, "Flooded Cities," CEP Discussion Papers dp1398, Centre for Economic Performance, LSE December 2015.
Lagakos, David and Michael E. Waugh, "Selection, Agriculture, and Cross-Country Productivity Differences," *American Economic Review*, April 2013, *103* (2), 948–80.
__ , Mushfiq Mobarak, and Michael E. Waugh, "The Welfare Effects of Encouraging Rural-Urban Migration," 2017. Unpublished manuscript.
Lall, Somik V., Hyoung Gun Wang, and Daniel Da Mata, "Do Urban Land Regulations Influence Slum Formation? Evidence From Brazilian Cities," Technical Report 2007.
Landers, J, *Death and the Metropolis: Studies in the Demographic History of London* 1993.
Lee, Ronald, "Population Dynamics of Humans and Other Animals," *Demography*, 1987, *24* (4), 443–465.
__ , "Population dynamics: Equilibrium, disequilibrium, and consequences of fluctuations," in "Handbook of Population and Family Economics," Vol. 1, Elsevier, 1997.
Leukhina, Oksana M. and Stephen J. Turnovsky, "Population Size Effects in the Structural Development of England," *American Economic Journal: Macroeconomics*, July 2016, *8* (3), 195–229.
Lucas, Robert E., "On the mechanics of economic development," *Journal of Monetary Economics*, July 1988, *22* (1), 3–42.
__ , "Life Earnings and Rural-Urban Migration," *Journal of Political Economy*, 2004, *112* (S1), S29–S59.
Maddison, Angus, *Statistics on World Population, GDP and Per Capita GDP, 1-2008 AD* 2008.
Malpezzi, Stephen and Stephen K. Mayo, "Getting Housing Incentives Right: A Case Study of the Effects of Regulation, Taxes, and Subsidies on Housing Supply in Malaysia," *Land Economics*, 1997, *73* (3), 372–391.
Manuelli, Rodolfo E. and Ananth Seshadri, "Explaining International Fertility Differences," *The Quarterly Journal of Economics*, May 2009, *124* (2), 771–807.
Marghany, M. and J. V. Genderen, "Three-dimensional slum urban reconstruction in Envisat and Google Earth Egypt," *IOP Conference Series: Earth and Environmental Science*, 2014, *18* (1), 012166.
Matsuyama, Kiminori, "Agricultural Productivity, Comparative Advantage, and Economic Growth," *Journal of Economic Theory*, December 1992, *58* (2), 317–334.
May, John F., *World Population Policies: Their Origin, Evolution, and Impact* 2012.
Maystadt, Jean-Francois and Gilles Duranton, "The development push of refugees: Evidence from Tanzania:," Technical Report 2014.
McMillan, Margaret, Dani Rodrik, and Inigo Verduzco-Gallo, "Globalization, Structural Change, and Productivity Growth, with an Update on Africa," *World Development*, 2014, *63*, 11 – 32.
Michaels, Guy, Ferdinand Rauch, and Stephen J. Redding, "Urbanization and Structural Transformation," *The Quarterly Journal of Economics*, 2012, *127* (2), 535–586.
New York Department of Health, *Picture of Public Health in New York City* 1897.
Njoh, Ambe, "Colonization and Sanitation in Urban Africa: A Logistics Analysis of the Availability of Central Sewerage Systems," *Habitat International*, 2013, *38*, 207 – 213.
__ and Fenda Akiwumi, "The Impact of Colonization on Access to Improved Water and Sanitation Facilities in African cities," *Cities*, 2011, *28* (5), 452 – 460.
Njoh, Ambe J., *Urban Planning and Public Health in Africa Historical, Theoretical and Practical Dimensions of a Continent's Water and Sanitation Problematic* 2016.
Özmucur, Süleyman and Şevket Pamuk, "Real Wages and Standards of Living in the Ottoman Empire, 1489-1914," *Journal of Economic History*, June 2002, *62* (2), 293–321.
Perlman, Janice E., "The Metamorphosis of Marginality: Four Generations in the Favelas of Rio de Janeiro," *The Annals of the American Academy of Political and Social Science*, 2006, *606*, 154–177.
Preston, Samuel H., "The Changing Relation between Mortality and Level of Economic Development," *Population Studies*, July 1975, *29*, 231–48.
Restuccia, Diego and Raul Santaeulalia-Llopis, "Land Misallocation and Productivity," Working Paper 23128, National Bureau of Economic Research February 2017.
__ , Dennis Tao Yang, and Xiaodong Zhu, "Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis," *Journal of Monetary Economics*, March 2008, *55* (2), 234–250.
Roback, Jennifer, "Wages, Rents, and the Quality of Life," *Journal of Political Economy*, December 1982, *90*

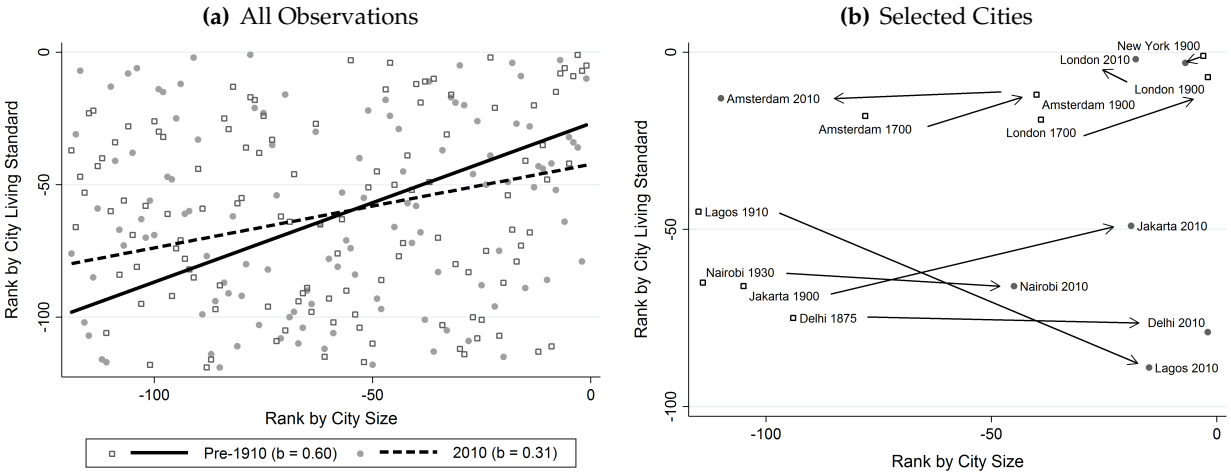
(6), 1257–78.
Rodrik, Dani, "Unconditional Convergence in Manufacturing," *The Quarterly Journal of Economics*, 2013, *128* (1), 165–204.
Romer, Paul M, "Increasing Returns and Long-run Growth," *Journal of Political Economy*, October 1986, *94* (5), 1002–37.
Rosen, Sherwin, "Wagebased Indexes of Urban Quality of Life," in Peter Miezkowski and Mahlon Straszheim, eds., *Current Issues in Urban Economics*, Johns Hopkins, 1979.
Rosenthal, Stuart S. and Stephen L. Ross, *Change and Persistence in the Economic Status of Neighborhoods and Cities*, Vol. 5 of *Handbook of Regional and Urban Economics*, Elsevier,
Saiz, Albert, "The Geographic Determinants of Housing Supply," *The Quarterly Journal of Economics*, 2010, *125* (3), 1253–1296.
Soares, Rodrigo R., "Mortality Reductions, Educational Attainment, and Fertility Choice," *American Economic Review*, June 2005, *95* (3), 580–601.
Steckel, Richard H. and Roderick Floud, *Health and Welfare during Industrialization* 1997.
Stolnitz, George J., "A Century of International Mortality Trends: I.," *Population Studies*, July 1955, *9*, 24–55.
The Lancet, *The Quaterly Report of the Medical Office of Health* 1894.
Timaeus, John Cleland Abdhalah K Ziraba Ian M and Alex Ezeh, "Declining Adult Mortality in Nairobi Slums is due to Fall in HIV/AIDS Related Mortality," Technical Report 2013.
Tombe, Trevor, "The Missing Food Problem: Trade, Agriculture, and International Productivity Differences," *American Economic Journal: Macroeconomics*, July 2015, *7* (3), 226–58.
UN-Habitat, *Global Urban Indicators* 1998.
_ , *The Challenge of Slums* 2003.
_ , *Slums of the World: The face of urban poverty in the new millennium?* 2003.
_ , *State of the World's Cities Report* 2012.
United Nations, *World Urbanization Prospects* 2014.
Vacher, Léon, *Etude médicale et statistique sur la mortalité, à Paris, Londres, Vienne et New-York en 1965* 1866.
Valentinyi, Akos and Berthold Herrendorf, "Measuring Factor Income Shares at the Sector Level," *Review of Economic Dynamics*, October 2008, *11* (4), 820–835.
Vogl, Tom S., "Differential Fertility, Human Capital, and Development," *The Review of Economic Studies*, 2016, *83* (1), 365.
Voigtländer, Nico and Hans-Joachim Voth, "The Three Horsemen of Riches: Plague, War, and Urbanization in Early Modern Europe," *Review of Economic Studies*, 2013, *80* (2), 774–811.
Vollrath, Dietrich, "The Agricultural Basis of Comparative Development," *Journal of Economic Growth*, December 2011, *16* (4), 343–370.
Weil, David N., "Accounting for The Effect of Health on Economic Growth," *The Quarterly Journal of Economics*, 08 2007, *122* (3), 1265–1306.
_ , "Endemic Diseases and African Economic Growth: Challenges and Policy Responses," *Journal of African Economies*, November 2010, *19*, 81–109.
Weir, David, "A Historical Perspective on the Economic Consequences of Population Growth.," in "Consequences of rapid population growth in developing countries," Taylor & Francis, 1991.
Williamson, Jeffrey, *Coping with City Growth During the British Industrial Revolution* 1990.
Woods, Robert, "Urban-Rural Mortality Differentials: An Unresolved Debate," *Population and Development Review*, 2003, *29* (1), 29–46.
World Bank, *World Development Indicators* 2017.
Young, Alwyn, "The Gift of the Dying: The Tragedy of Aids and the Welfare of Future African Generations," *The Quarterly Journal of Economics*, 2005, *120* (2), 423–466.
_ , "Inequality, the Urban-Rural Gap, and Migration," *The Quarterly Journal of Economics*, 2013, *128* (4), 1727–1785.
Young, Andrew T., "One of the things we know that ain't so: Is US labor's share relatively stable?," *Journal of Macroeconomics*, March 2010, *32* (1), 90–102.
Zuleta, Hernando, Andres Felipe Garcia Suaza, and Andrew Young, "Factor shares at the sector level, Colombia 1990-2005," Documentos de Trabajo 006120, Universidad del Rosario November 2009.

Figure 1: **URBANIZATION AND ECONOMIC DEVELOPMENT ACROSS TIME, 1700-2010**



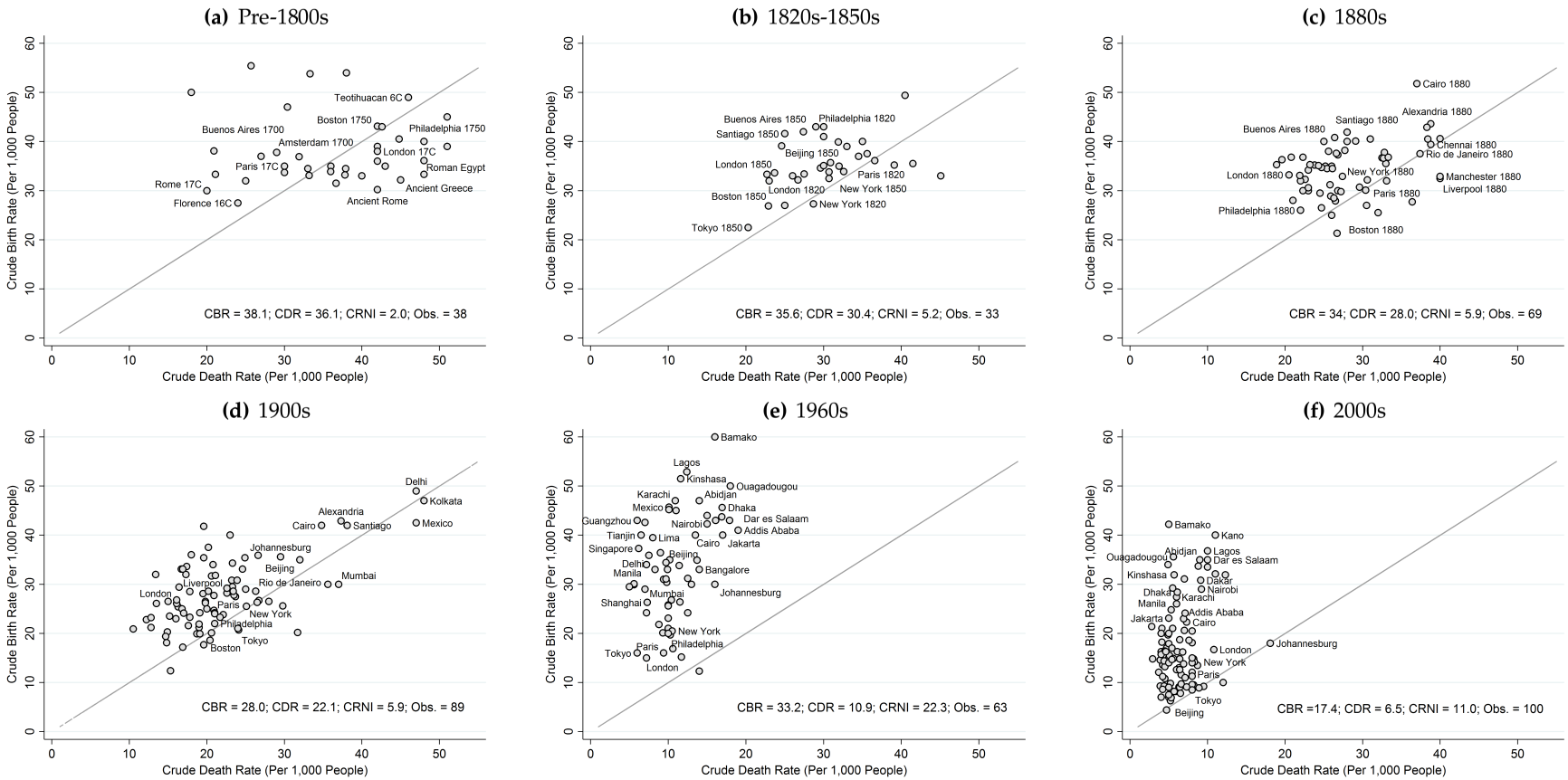
Notes: This figure shows for selected years the relationship between urbanization and economic development. For development, we use log GDP per capita (PPP, constant 1990 dollars) from Bolt and van Zanden (2014), who update Maddison (2008). We base our sample of the 159 countries available from these sources (99% of the world population in 2010). To the information on GDP per capita we add observations on urbanization rates circa 1700, 1900, 1950 and 2010. The sources for the urbanization rates are detailed in Web Appendix Section 1.1. The availability of urbanization and GDP data leaves us with 406 observations. The distribution of observations across time is for 1700 (18 observations), 1900 (70), 1950 (159), and 2010 (159).

Figure 2: **CITY LIVING STANDARD VERSUS CITY SIZE RANK, HISTORICALLY (PRE-1910) AND IN 2010**



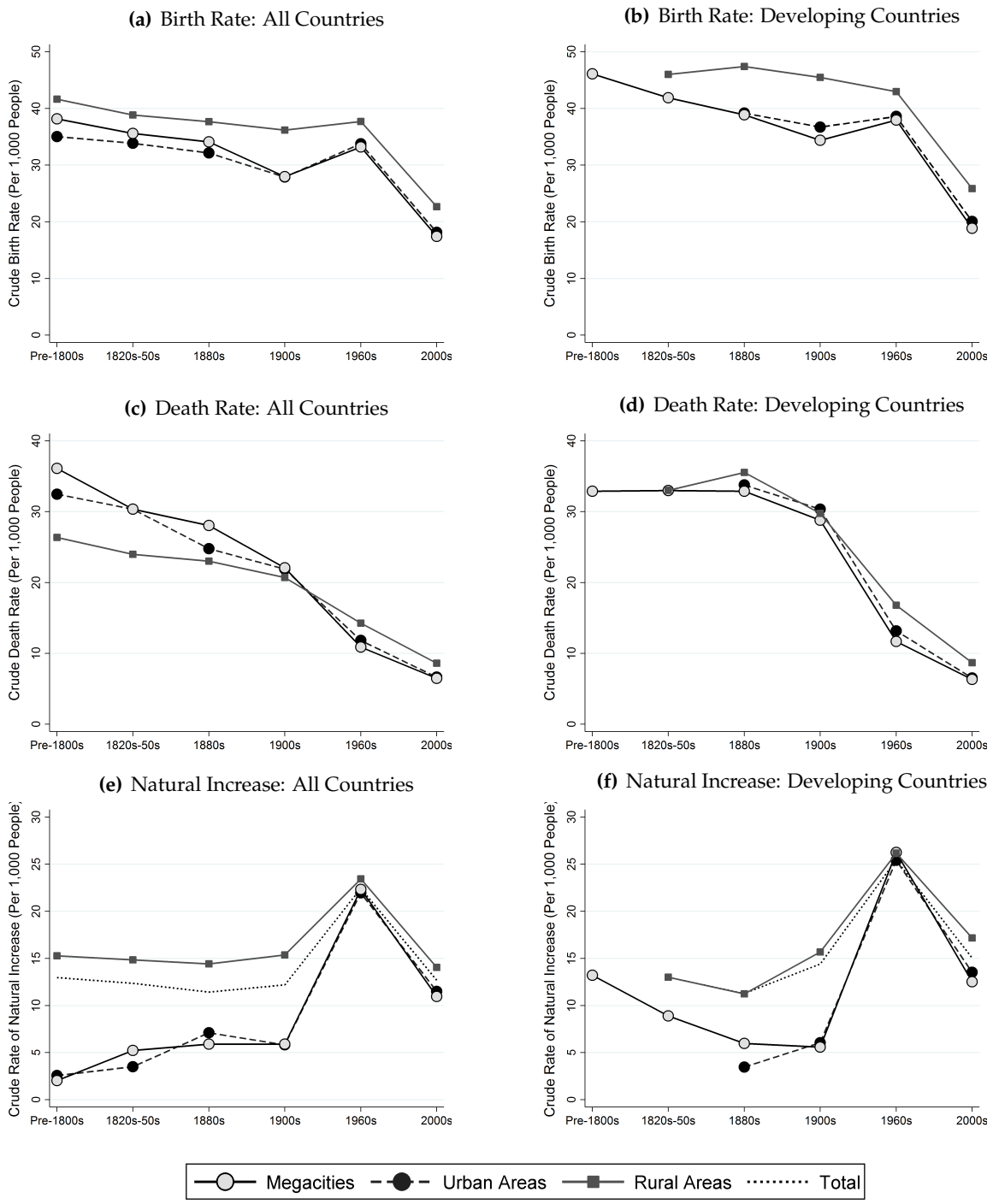
Notes: The left panel displays the relationship between city living standards and city population size for 119 city-year observations of more than 100,000 inhabitants pre-1910 (multiple observations for a same city) and 119 cities of more than 500,000 inhabitants in 2010. For each period, we rank the cities by living standards and population size and show the correlation between the two (linear fit estimated using as weights the population of each city-year). City living standards are proxied by city development indexes in 1998-2012 ("2010" in the figure) and welfare ratios for the pre-1910 period ("pre-1910"). The right panel shows the observations for selected cities in rich and poor countries today, with arrows indicating the evolution of their ranks over time. The sources for the city development index in 2010 and the welfare ratios for the pre-1910 period (estimated for a "bare bones" consumption basket) are detailed in Web Appendix Section 1.1. We obtain the size of each city from Chandler (1987) and United Nations (2014).

Figure 3: **CRUDE BIRTH AND DEATH RATES OF THE WORLD'S LARGEST CITIES, FROM ANTIQUITY TO DATE**



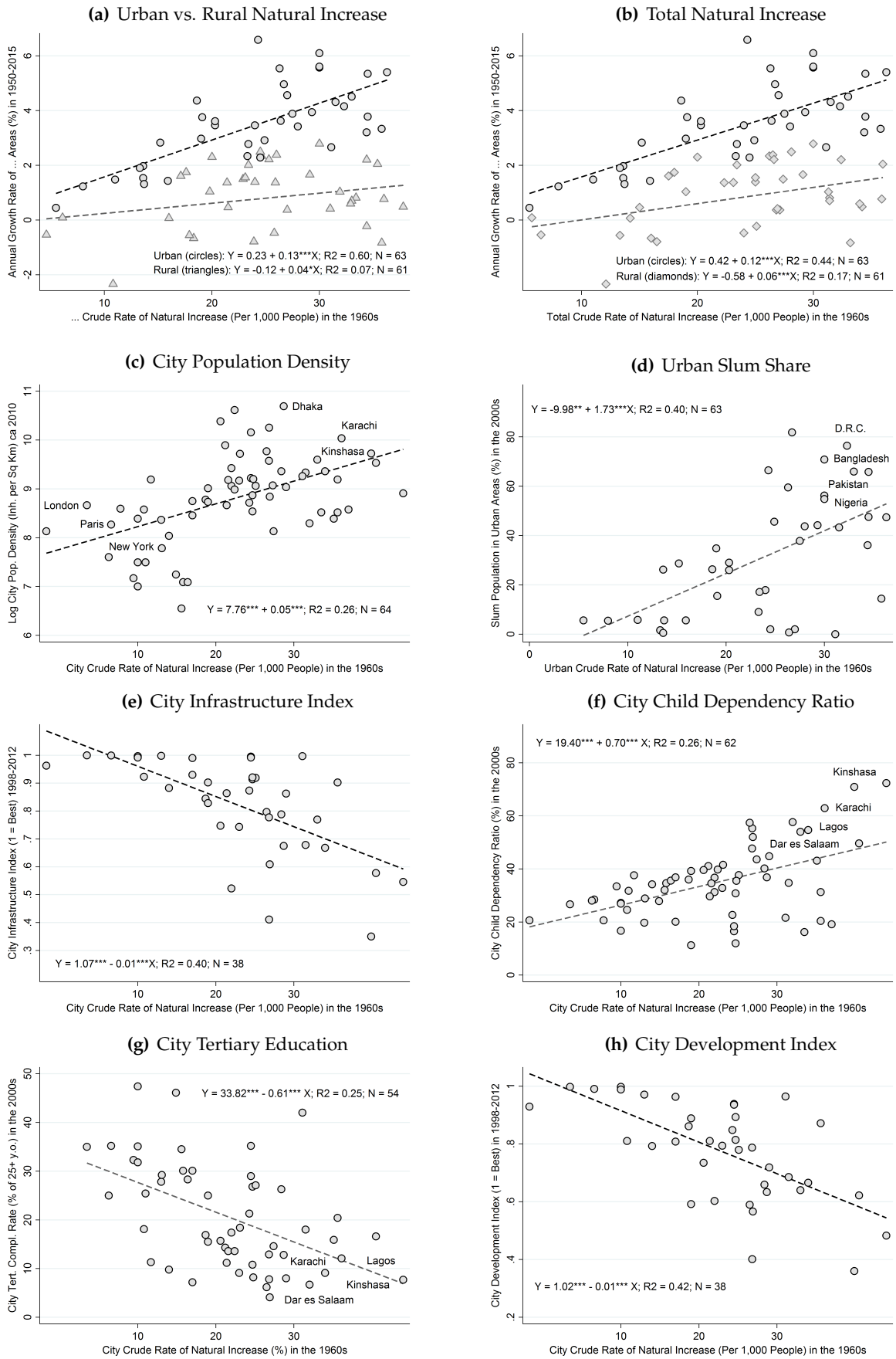
Notes: This figure shows the crude birth rates and the crude death rates for 392 city-period observations: 38 cities in the 1800s or before (Panel A), 33 cities in the 1820s or the 1850s (Panel B), 69 cities in the 1880s (Panel C), 89 cities in the 1900s (Panel D), 63 cities in the 1960s (Panel E), and 100 cities in the 2000s (Panel F). The cities in the 1900s and before (Panels A-D) were selected because they were among the 100 top cities in 1900. The cities in the 1960s-2000s (Panels E-F) were selected because they will be among the 100 top cities in 2030 according to United Nations (2014). The number of observations (Obs.), mean crude birth rates (CBR), death rates (CDR) and rates of natural increase (CRNI) are shown. See Web Appendix Section 1.1 for data sources.

Figure 4: **HISTORICAL DEMOGRAPHY ACROSS LOCATIONS**



Notes: The left panel (*All Observations*) shows the unweighted mean crude rates of birth (Panel A), death (Panel B) and natural increase (Panel C) for the 392 *Megacities* as well as for the *Urban Areas*, the *Rural Areas*, and the whole area (*Total*) of the same countries as the mega-cities in the 1800s or before (N = 38), the 1820s-1850s (33), the 1880s (69), the 1900s (89), the 1960s (63), and the 2000s (100). The sample is the same as in Figure 3. The right panel shows the same evolutions for the subsample of 167 observations in *Developing Countries Only* – based on their 2015 GDP per capita, i.e. the countries whose income level is below the income of Slovakia, the last country to have become a developed country according to the International Monetary Fund – (N = 8 in the 1800s or before, 5 in the 1820s-1850s, 13 in the 1880s, 22 in the 1900s, 42 in the 1960s, and 77 in the 2000s). See Web Appendix Section 1.1 for data sources.

Figure 5: URBAN NATURAL INCREASE AND CHARACTERISTICS OF URBAN AREAS



Notes: See text for details on the data sources and the figures.

Table 1: **WORLD'S LARGEST MEGACITIES (MILLIONS), 1700-2015**

Rank	1700		1900		1950		2015		(△% 2015-2030)
1	Istanbul	0.7	London	6.5	New York	12.3	Tokyo	38.0	(-0.1)
2	Tokyo	0.7	New York	4.2	Tokyo	11.3	Delhi	25.7	(2.3)
3	Beijing	0.7	Paris	3.3	London	8.4	Shanghai	23.7	(1.8)
4	London	0.6	Berlin	2.7	Paris	6.3	Sao Paulo	21.1	(0.7)
5	Paris	0.5	Chicago	1.7	Moscow	5.4	Mumbai	21.0	(1.9)
6	Ahmedabad	0.4	Vienna	1.7	Buenos Aires	5.1	Mexico	21.0	(0.9)
7	Osaka	0.4	Tokyo	1.5	Chicago	5	Beijing	20.4	(2.1)
8	Isfahan	0.4	St. Petersburg	1.4	Kolkata	4.5	Osaka	20.2	(-0.1)
9	Kyoto	0.4	Manchester	1.4	Shanghai	4.3	Cairo	18.8	(1.8)
10	Hangzhou	0.3	Philadelphia	1.4	Osaka	4.1	New York	18.6	(0.5)
11	Amsterdam	0.2	Birmingham	1.2	Los Angeles	4	Dhaka	17.6	(3.0)
12	Naples	0.2	Moscow	1.1	Berlin	3.3	Karachi	16.6	(2.7)
13	Guangzhou	0.2	Beijing	1.1	Philadelphia	3.1	Buenos Aires	15.2	(0.7)
14	Aurangabad	0.2	Kolkata	1.1	Rio	3	Kolkata	14.9	(1.7)
15	Lisbon	0.2	Boston	1.1	StPetersburg	2.9	Istanbul	14.2	(1.1)
16	Cairo	0.2	Glasgow	1	Mexico	2.9	Chongqing	13.3	(1.8)
17	Xian	0.2	Osaka	1	Mumbai	2.9	Lagos	13.1	(4.2)
18	Seoul	0.2	Liverpool	0.9	Detroit	2.8	Manila	12.9	(1.8)
19	Dacca	0.2	Istanbul	0.9	Boston	2.6	Rio	12.9	(0.6)
20	Ayutthaya	0.2	Hamburg	0.9	Cairo	2.5	Guangzhou	12.5	(2.3)
21	Venice	0.1	Buenos Aires	0.8	Tianjin	2.5	Los Angeles	12.3	(0.5)
22	Suzhou	0.1	Budapest	0.8	Manchester	2.4	Moscow	12.2	(0.0)
23	Nanking	0.1	Mumbai	0.8	Sao Paulo	2.3	Kinshasa	11.6	(3.7)
24	Rome	0.1	Ruhr	0.8	Birmingham	2.2	Tianjin	11.2	(1.8)
25	Smyrna	0.1	Rio	0.7	Shenyang	2.1	Paris	10.8	(0.6)
26	Srinagar	0.1	Warsaw	0.7	Roma	1.9	Shenzhen	10.7	(1.1)
27	Palermo	0.1	Tientsin	0.7	Milano	1.9	Jakarta	10.3	(2.0)
28	Moscow	0.1	Shanghai	0.6	San Francisco	1.9	London	10.3	(0.7)
29	Milan	0.1	Newcastle	0.6	Barcelona	1.8	Bangalore	10.1	(2.6)
30	Madrid	0.1	St.Louis	0.6	Glasgow	1.8	Lima	9.9	(1.4)

Notes: The table shows the population (millions) of the world's largest urban agglomerations in 1700, 1900, 1950 and 2015. (△% 2015-30) is the projected annual growth rate (%) of the urban agglomeration between 2015 and 2030 according to United Nations (2014). The main sources of the data are Chandler (1987) and United Nations (2014).

Table 2: **CALIBRATION PARAMETER VALUES**

Parameter	Value	Source
Set externally:		
Urbanization rate (%) in 1950	9.1	Sample average
Informal share of urban areas (%) in 1950	50.0	See text for details
Initial population size in 1950	1.0	Normalization
Pre-UMT formal CDR (per 000)	40	Location-level data, 1900s
Pre-UMT informal CDR (per 000)	40	Location-level data, 1900s
Post-UMT formal CDR (per 000)	15	Location-level data, 2000s
Post-UMT informal CDR (per 000)	15	Location-level data, 2000s
UMT half-life	3	Location-level data, 1960s
Initial rural CDR (per 000)	20	Location-level data, 1960s
Initial rural CBR (per 000)	43	Location-level data, 1960s
Initial informal CBR (per 000)	43	Location-level data, 1960s
Initial formal CBR (per 000)	38	Location-level data, 1960s
Informal prod./amenity growth (G_l)	0.03	See text for details
Rural prod./amenity growth (G_r)	0.03	See text for details
Formal prod./amenity growth (G_f)	0.05	See text for details
Preference parameters (β)	0.41	From Becker et al (2005)
Rural congestion elasticity (ϵ_r)	1.20	See text for details
Targeted:		
Formal congestion elasticity (ϵ_f)	1.29	Urbanization rate in 2005 (mean 31.2%)
Informal congestion elasticity (ϵ_l)	0.64	Informal share in 2005 (mean 62.2%)

Notes: The table shows the parameter values used in the baseline simulation of the model. *Location-level data* refers to the data presented in section 1.2.. *Sample average* refers to the sample of 43 "poor" countries in 1950-2005.

Table 3: **CALIBRATED OUTCOMES AT DIFFERENT DEATH RATES, 1950-2005**

	Urbanization Rate (%)		Urban Size		Informal Share (%)		Informal Size		Welfare
	1950	2005	1950	2005	1950	2005	1950	2005	2005
Observed data:									
1. With UMT:	9.1	31.2	1.0	14.8	n/a	62.2	1.0	17.3	n/a
Calibrated model:									
2. With UMT	9.1	31.2	1.0	16.8	50.0	62.2	1.0	20.8	1.00
3. Without UMT	9.1	21.8	1.0	9.7	50.0	53.7	1.0	10.4	1.09
4. With UMT, $\beta = 0$	9.1	23.2	1.0	12.3	50.0	57.6	1.0	14.2	0.89
5. With UMT, $\epsilon_i = \bar{\epsilon} = 1.03$	9.1	24.9	1.0	13.2	50.0	21.6	1.0	5.7	1.16
6. Without UMT, constant fertility	9.1	19.8	1.0	6.3	50.0	46.4	1.0	5.8	1.59
7. Without UMT, endogenous fertility	9.1	19.4	1.0	5.8	50.0	44.9	1.0	5.2	1.71

Notes: Row 1: Observed data. Row 2: Baseline model. The urban CDR falls from 40 (per thousand) to 15 exponentially, with a half-life of 3 years. The CBRs follow the observed path in the data. Row 3: We hold the urban CDR constant at 40 over the entire period, and also have CBRs follow the observed path. Row 4: We allow the UMT to occur, but shut down the preference of individuals for lower CDRs. Row 5: We allow the UMT to occur, and individuals to have a preference for lower CDRs, but set the congestion elasticity in each location to be equal to 1.03. Row 6: We hold the urban CDR at 40, but also hold the CBR in each location at the 1950 level. Row 7: We hold urban CDRs at 40, but have the CBR determined endogenously by changes in the CDRs and wages (see Web Appendix Section 3 for details of this model).

Table 4: **USING ALTERNATIVE SOURCES FOR THE ELASTICITIES, 1950-2005**

	Elasticities (ϵ_i):			Difference in 2005 in Actual vs. no-UMT		Welfare Ratio
	Rural	Formal	Informal	Urb. Rate	Inf. Share	
Chosen Set of Elasticities:	(1)	(2)	(3)	(4)	(5)	(6)
1. Baseline	1.20	1.29	0.64	-9.4	-8.5	1.09
Calibrating to each individual country:						
2. Mean elasticities	1.20	1.76	0.69	-7.7	-8.3	1.09
3. Median elasticities	1.20	1.41	0.65	-9.0	-8.6	1.09
Alternative rural elasticity, calibrating formal and informal elasticities:						
4. Rural elasticity from factor shares and housing	0.76	1.06	0.45	-11.5	-12.1	1.03
Alternatives for all elasticities:						
5. All elasticities from factor shares, housing, agglom.	0.76	0.96	0.43	-12.9	-12.2	1.02
6. Increase informal elasticity by 0.20:	0.76	0.96	0.63	-7.5	-5.3	1.06

Notes: This table shows the results when using alternative location-specific elasticities. Columns (1)-(3) show the elasticities (see text for details). Columns (4) and (5) show the difference between the actual and no-UMT values of the urbanization rate and informal share. The welfare ratio, in column (6), is the calibrated welfare without the UMT relative to with the UMT. It is a unique value to each row, and cannot be compared across rows.

Table 5: **SENSITIVITY CHECKS ON CALIBRATION, 1950-2005**

	Number of Countries	Difference in 2005 in Actual vs. no-UMT: Urb. Rate	Inf. Share	Welfare Ratio	Elasticities (ϵ_i): Formal	Informal
Scenario	(1)	(2)	(3)	(4)	(5)	(6)
1. Baseline	43	-9.4	-8.5	1.09	1.293	0.640
Panel A: Sample Changes:						
2. 1950 Urbanization Rate $\leq$ 30%	52	-10.8	-8.4	1.08	1.126	0.599
3. 1950 Urbanization Rate $\leq$ 40%	62	-12.1	-8.4	1.07	1.020	0.562
4. 1950 Urbanization Rate $\leq$ 50%	66	-12.6	-8.4	1.06	0.980	0.545
5. Imputed Slum Share if Missing	51	-9.3	-7.8	1.09	1.206	0.653
6. Imputed Slum Share for All Countries	51	-8.8	-6.4	1.10	1.133	0.691
7. $\Delta CDR_{1950,1980} \leq -7$ (median)	57	-12.3	-8.3	1.06	0.998	0.556
8. $\Delta CDR_{1950,1980} \leq -12$ (25th pctile)	26	-12.7	-8.1	1.06	0.952	0.543
9. $\Delta CDR_{1950,1980} \leq -16$ (10th pctile)	9	-13.6	-8.4	1.05	0.908	0.511
Panel B: Parameter Changes:						
10. Initial Informal Share (s_l) 40%	43	-9.6	-10.2	1.08	1.393	0.595
11. Initial Informal Share (s_l) 60%	43	-9.3	-6.8	1.09	1.188	0.682
12. 1950 Urban CDR = 35	43	-8.4	-7.3	1.06	1.274	0.625
13. 1950 Urban CDR = 30	43	-7.1	-6.0	1.04	1.251	0.606
14. 1950 Formal/Informal CDR = 30/40	43	-8.6	-9.7	1.06	1.251	0.640
15. 1950 Rural CDR = 40	43	-12.2	-28.4	2.20	1.188	0.538
16. Informal Growth Rate $G_l = 0.035$	43	-8.0	-5.1	1.12	1.293	0.816
17. Informal Growth Rate $G_l = 0.045$	43	-7.0	-2.7	1.14	1.293	0.991
18. Formal Growth Rate $G_f = 0.03$	43	-10.4	-4.1	1.06	0.872	0.640
19. Formal Growth Rate $G_f = 0.04$	43	-9.8	-6.7	1.08	1.083	0.640
20. Rural Growth Rate -1 Pct. Point	43	-7.6	-6.5	1.13	1.503	0.816
21. All Urban Growth Rates -1 Pct. Point	43	-11.6	-12.0	1.04	1.083	0.465
22. All Growth Rates -1 Pct. Point	43	-9.4	-8.5	1.09	1.293	0.640
23. Mortality Preference $\beta = 1.56$	43	-18.6	-13.3	0.91	1.690	0.966
24. Mortality Preference $\beta = 1.70$	43	-19.2	-13.6	0.90	1.738	1.005

Notes: This table shows the results of various sensitivity checks (see text for details). Columns (2) and (3) show the difference between the actual and no-UMT values of the urbanization rate and informal share. The welfare ratio, in column (4), is the calibrated welfare without the UMT relative to with the UMT. It is a unique value to each row, and cannot be compared across rows. The formal and informal elasticities, in columns (5) and (6), show the values of ϵ_f and ϵ_l calibrated so that the model matches the actual values for the urbanization and informal shares in 2005.

Table 6: **HISTORICAL OUTCOMES USING THE CALIBRATED MODEL, 1800-1950**

	1800:			1900:			1950:		
Scenario	Urb. Rate	Inf. Rate	Urb. Size	Urb. Rate	Inf. Rate	Urb. Size	Urb. Rate	Inf. Rate	Urb. Size
1. *Observed data:* Slow UMT	12.6	50.0	1.0	37.9	30.0	7.7	57.9	15.0	14.7
2. Calibrated model, exogenous fert.	12.6	50.0	1.0	40.8	35.6	20.5	58.4	15.8	37.9
3. Calibrated model, endogenous fert.	12.6	50.0	1.0	38.1	25.1	10.8	57.8	11.7	25.7
4. Calibrated model, exog. fert., fast UMT	12.6	50.0	1.0	46.2	50.1	49.9	61.2	29.1	98.5
5. Calibrated model, endog. fert., fast UMT	12.6	50.0	1.0	64.3	78.2	383	91.7	91.9	18887

Notes: Row 1 shows the average urbanization rate and informal share, as well as the relative size of the total urban population, for a set of 20 historical countries. Row 2 shows the results of simulating our model, using the parameters of Table 2, except for setting the initial urbanization rate to match the data in 1800, setting the initial demographic rates to match averages from the 18 historical countries, and setting the half-life of the UMT to be 50 years. Row 3 replicates Row 2, but replaces the exogenous fertility process with an endogenous fertility process (see Web Appendix Section 3). In Rows 4 and 5, we set the half-life of the UMT to be 3 years (matching the "fast" UMT in our baseline).

Table 7: **LONG-RUN OUTCOMES UNDER DIFFERENT POLICIES, 2055**

	Urb. Rate	Urb. Size	Inf. Rate	Inf. Size	Welf.
1. Initial values (in 2005):	31.2	1.0	62.2	1.0	n/a
After 50 years (2055):					
2. Baseline (CDR_r = 10; CDR_l = CDR_f = 7.5; CBR_r = CBR_l = 35, CBR_f = 20; $G_r = G_l = 0.025$; $G_f = 0.05$; $\epsilon_r = 1.20$; $\epsilon_l = 0.64$; $\epsilon_f = 1.29$)	49.8	5.1	60.8	4.8	1.00
Productivity changes:					
3. Higher rural growth rate ($G_r = 0.035$)	37.6	3.8	56.5	3.4	1.25
4. Higher informal growth rate ($G_l = 0.035$)	59.7	6.2	73.2	7.1	1.27
5. Higher formal growth rate ($G_f = 0.06$)	53.1	5.3	49.6	4.1	1.11
6. Higher formal growth rate ($G_f = 0.08$)	62.6	6.0	26.5	2.5	1.53
7. Higher formal growth rate ($G_f = 0.10$)	74.9	6.7	9.9	1.0	2.60
Changes in net congestion costs:					
8. Lower formal elasticity ($\epsilon_f = \epsilon_r = 1.20$)	50.9	5.2	57.0	4.6	1.03
9. Lower formal elasticity ($\epsilon_f = 0.90$)	56.4	5.5	40.1	3.5	1.24
10. Lower formal elasticity ($\epsilon_f = \epsilon_l = 0.64$)	65.5	6.1	21.3	2.0	1.73
11. Lower formal elasticity ($\epsilon_f = 1.29 \div 3 = 0.43$)	75.2	6.6	9.5	1.0	2.73
12. Higher informal elasticity ($\epsilon_f = \epsilon_l = 1.29$)	39.5	4.0	41.1	2.5	0.82
Changes in migration costs:					
13. Rural-to-urban migration restriction ($\lambda_{cr} = -0.01$)	37.6	3.8	56.5	3.4	0.91
14. Urban-to-rural migration restriction ($\lambda_{cr} = 0.01$)	61.6	6.3	63.9	6.2	1.10
Population growth changes:					
15. Zero population growth (CDR = CBR)	40.2	1.3	37.9	0.8	3.21
16. Family planning (CBR = 20)	44.0	2.4	48.8	1.8	1.85
17. Informal family planning (CBR_l = 20)	48.1	4.1	57.5	3.7	1.19
18. Rural family planning (CBR_r = 20)	45.4	2.9	52.0	2.4	1.58

Notes: Simulated outcomes 50 years later, in 2055, using different policy interventions. Each simulation uses the parameters of Table 2, except that CDRs and CBRs are set to observed rates in 2005. Welfare is the equivalent variation in net wage necessary for the baseline economy (row 1) to match welfare in the given scenario.