Killer Cities and *Industrious Cities*? New Data and Evidence on 250 Years of Urban Growth

Marina Gindelsky (BEA and GWU) and Remi Jedwab (GWU)*

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Abstract

In the historical literature, cities of the Industrial Revolution are portrayed as having a demographic penalty: *killer cities* with high death rates and *industrious cities* with low birth rates. To econometrically test this, we construct a novel data set of almost 2,000 crude demographic rates for 142 large cities in 35 countries for 1700-1950. Mortality actually *decreased* faster than fertility during the Industrial Revolution era and rates of natural increase *rose* in the cities of industrializing countries, especially large cities. This implies a *declining*, not rising, demographic penalty thanks to the industrial Revolution. To explain the puzzle, we posit that negative health and industriousness effects of industrial urbanization might have been outweighed by positive effects of increased income and life expectancy.

JEL Codes: N90; N30; N10; R00; J10

Keywords: Urban Demographic Penalty; Killer Cities; Industrious Cities; Mortality; Fertility; Natural Increase; Industrial Revolution; Urban Growth

*Remi Jedwab: Associate Professor of Economics, Department of Economics, George Washington University, jedwab@gwu.edu. Marina Gindelsky: Bureau of Economic Analysis, and Adjunct Faculty, Department of Economics, George Washington University, marina.gindelsky@bea.gov. We would like to thank the editor, two anonymous referees, and seminar audiences and discussants at the ASSA Meetings, Bureau of Economic Analysis, George Washington University, Southern Economic Association Meetings, the Urban Economic Association Meetings, and Western Economic Association Meetings for helpful comments. We thank Thomas Howe, Vaibhav Jain, Joseph Kornegay, and Olivia Gonzalez for excellent research assistance. We thank the Institute for International Economic Policy for financial assistance.

Economic historians have left little doubt about the urban disamenities of the industrial revolution (Williamson, 1982; Wrigley and Schofield, 1989). Vivid depictions of "death sinks" in the *killer cities* of the 19th century, characterized urbanization as the source of poor health conditions and high mortality rates in the United Kingdom (UK) (Weber, 1899; Williamson, 1990; Landers, 1993), the United States (US) (Margo and Villaflor, 1987; Haines, 2001; Cain and Hong, 2009), and other parts of the world (Steckel, 2001; Kesztenbaum and Rosenthal, 2011).

Growth was accompanied by an increase in labor productivity and wages which were tied to an "industriousness" effect associated with a higher opportunity cost of time and lower birth rates (Weber, 1899; Haines, 1991; de Vries, 1994; Haines and Guest, 2010; Allen and Weisdorf, 2011; Allen, 2015). Workers might also have become more "industrious" by investing more time in acquiring human capital (Clark, 2005; Franck and Galor, 2015, 2017; de Pleijt et al., 2018).

Thus, *killer cities* characterized by high death rates were also *industrious cities* with low birth rates. As a result, fast-expanding cities had low rates of natural increase and experienced a demographic penalty which was compensated for by migration (Williamson, 1990; Brown, 1992).

While many analyzed the effects of urbanization in conjunction with the industrial revolution, a question remains: if cities grew rapidly during the industrial revolution, was urbanization really associated with a penalty? Globally, large cities grew 1% annually from 1700-1950 overall, but 2% annually from 1850-1950 (Chandler, 1987).[1] Migration alone, which accounted for half the growth in 19th century England (Williamson, 1990), cannot explain these high growth rates; natural increase must have played a role. A test of the killer and industrious cities theories would involve within-city comparisons pre-and post the Industrial Revolution.

However, pre-industrial cities were also "death sinks". Low incomes constrained nutrition and congestion aggravated the spread of disease (Coale and Watkins, 1986; Brown, 1992). Low life expectancy also meant fewer child-bearing years, such that birth rates were low. The European Marriage Pattern exacerbated that fact (Hajnal, 1983; Voigtländer and Voth, 2013). The average woman married later, due to a higher opportunity cost of female labor.

Therefore, could it be that urban mortality decreased faster than fertility, relatively, as cities industrialized and became larger? In other words, could it be that the demographic penalty was reduced during the Industrial Revolution era, making cities, especially larger cities, better places relative to the pre-Industrial era? To answer these questions, one must examine the effects of the Industrial Revolution on mortality and fertility for as large a sample as possible.

To understand whether cities (which already had high mortality rates before the Industrial Revolution) became "killer cities" as a result of industrialization, we will compare our evidence

[1] "Large cities" are here defined as those with over 200,000 in population in 1900.

for the 19th century to that of the pre-industrial period.[2] This is a significant challenge given data scarcity. Current evidence has been limited to studies focused on one city (e.g., Haines, 1980; Ferrie and Troesken, 2008; Haines and Guest, 2010; Kesztenbaum and Rostenthal, 2017) or else a panel of cities, but often in a single country and for a limited period of time (e.g., Haines and Steckel, 2000; Mokry and Grada, 1999; Beach and Hanlon, 2017) (see Hanlon and Heblich (2021) and Jedwab et al. (2020) for surveys of the literature on history and cities).[3] We complement the contributions of those studies by setting out to *econometrically* test two related hypotheses:

Hypothesis 1 (H1): City crude death rates increased, while city crude birth rates and city crude rates of natural increase decreased following the Industrial Revolution.

Hypothesis 2 (H2): City crude death rates *disproportionately* increased, while city crude birth rates and city crude rates of natural increase *disproportionately* decreased for *larger cities* following the Industrial Revolution.

To test these two hypotheses,[4] we construct a novel dataset which includes 1007 estimates of mortality (crude death rate = CDR), 865 estimates of fertility (crude birth rate = CBR), and 3,289 estimates of population size for historically important cities (those with over 200,000 inhabitants in 1900 (Chandler, 1987)) decadally from 1700-1950. This dataset covers 142 cities in 35 countries, providing 825 observations of the crude rate of natural increase (= CRNI) of the possible 3,692 city-decade observations, using over 300 sources, consisting of academic works (books, journal articles, etc.), statistical publications (e.g., censuses, statistical abstracts), and reports, newspaper articles, etc. We painstakingly compiled this dataset by searching through many historical volumes of published statistics (in their original languages) around the world. Given the demanding nature of finding the data, it is unsurprising that most studies either attempt to build a time series for only one city, or else examine a few cities within a country for a given era. However, it is only by studying the bigger picture that we can see bigger patterns.

To test H1, we estimate panel correlations between city demographic rates and the timing of the Industrial Revolution for each country, thus examining whether cities experienced an increased penalty following the Industrial Revolution: higher mortality and/or lower fertility. While we do not have an identification strategy for the timing of the Industrial Revolution, we add city fixed effects. We also perform a panel-event study based on the timing.

To test H2, we estimate panel correlations between city demographic rates and the timing

[2]A few studies instead compare the demographic transition of industrial Europe to present-day developing economies (Hanlon and Tian, 2015; Jedwab et al., 2017; Jedwab and Vollrath, 2019; Jedwab et al., 2021a).

[3]Haines and Steckel (2000) focus on military records for the U.S. for 1900-1910, Mokry and Grada (1999) focus on 1840-1850 Ireland, Beach and Hanlon (2017) focus on 1851-1860 Britain, and Tang (2017) focus on 1883-1899 Japan.

[4]To see the econometric formulation of H1 and H2, please see section 3.1.

of the Industrial Revolution which we interact with log city size, thus studying whether *larger* cities experienced an increased penalty following the Industrial Revolution. We add city fixed effects. In other regressions, country-year fixed effects control for time-varying factors at the country-level. We conduct this analysis for both industrial countries and industrial cities. We also perform a panel-event study based on the timing of the Industrial Revolution.

Overall, we find limited evidence of an increase in mortality and a decrease in fertility following the Industrial Revolution, whether across all cities – leading us to reject H1 – or for larger cities only – leading us to reject H2 –. In some cases, it seems that city mortality decreased relatively faster and city fertility decreased relatively slower following the Industrial Revolution.

Although it is difficult to isolate mechanisms for the heterogeneous demographic trends in a study of this size, we discuss the key drivers of the period. In line with the literature, we describe how industrialization was typically associated with negative *health effects* of pollution directly related to the sectors that grew with it - and congestion related to larger city sizes. Concurrently with the negative health effects, there was a positive *income effect* (i.e., real wages increased). Thus, people had access to better nutrition, housing, and health technology. Additionally, as the negative health effects became apparent, many (now richer) cities began investing heavily in public health improvements. Our econometric results suggest that, on average, the positive income effects of industrial urbanization may have outweighed its negative health effects.

We then rely on the existing literature to describe the possible effects of industrialization on fertility rates. As cities grew quickly, there was a fertility-reducing *industriousness effect*.[5] However, there were also additional opportunities for childbearing given the increase in life expectancy in cities. Our econometric results suggest that, on average, the *child-bearing year effect* must have actually dominated the industriousness effect in fast-growing industrial cities.[6]

Our analysis contributes to the extensive literature on mortality before, during, and after the industrial revolution. First, by documenting that the urban penalty may have decreased during the industrial era. Next, by building a large global database, which is a panel, we are providing researchers with tools to conduct their own analysis. By studying the changes in the demographic patterns of cities, we contribute to the literature regarding the heterogeneous demographic effects of city size. A large line of literature indeed documents how the fast growth of some cities had significant negative externalities (e.g., Mokyr, 1993; Ferrie and Troesken, 2008;

[5] Labor supply increased as wages and consumerism increased. Consumption rose in importance at the expense of family time and fertility. Industrialization then increased the demand for human capital, thus incentivizing both workers to spend more time developing skills – i.e., their career at the expense of a larger family – and families to have fewer, but more educated, children. Thus, workers became more skillful (the old meaning of "industrious").

[6] Our use of the word "industrious" differs from its use by de Vries (1994). He explains that demand factors (new goods) led workers to increase their labor supply at the expense of family time. However, supply factors such as new technologies brought by industrialization increased productivity and wages and the marginal cost of family time.

Kesztenbaum and Rosenthal, 2011; Heblich et al., 2021; Beach and Hanlon, 2017).

As mortality improves through increases in nutrition and health inputs, our data contributes to the literature on income growth and health innovations which led to these improvements (e.g., Fogel, 1986; Brown, 1992; Vögele, 1994; Troesken, 2001; Beach et al., 2016). We then contribute to the literature showing changes in city fertility (e.g., de Vries, 1994; Clark, 2005; Haines and Guest, 2010; Allen and Weisdorf, 2011; Clark and Cummins, 2015). Many studies separately analyze fertility and mortality. However, mortality affects fertility through behavioral responses to changes in child-bearing years and infant mortality. Also, most studies focus on a single country (or a single city) and a few periods at a time. Yet, our analysis has clear limitations. We do not have data on smaller cities whose trends are also of interest. This also affects our ability to examine patterns within-countries over time. Next, we do not instrument for the Industrial Revolution and city size, which limits the causal conclusions that can be derived from our work. Nor can we dive deep in order to tie the results to specific mechanisms.

The paper proceeds as follows. Section 1. describes the novel data set that we compiled. Section 2. presents a descriptive analysis, while Section 3 presents the results of our empirical analysis. Section 4 discusses the possible mechanisms behind our results. Section 5 concludes.

1. New Data on Killer Cities and Industrious Cities, 1700-1950

Sample Selection. Our data collection was centered on large cities for which historical data was more likely to be found. More precisely, we focus on the world's most populous cities at the turn of the 20th century. Our sample (1700-1950) consists of the 142 cities (in 35 countries) that had a population above 200,000 inhabitants in 1900 (Chandler, 1987). A majority of them are located in Europe, but a significant number are located in North America and Asia (see Web Appx. Fig. A.1). Since data on city mortality and fertility is not readily available with both breadth and depth, we collected it individually for each city-decade pair, using harmonized series where possible.[7]

Measures. For each city-decade observation in the full sample (142 cities x 26 decades = 3,692 obs.), we tried to obtain estimates of the *crude death rate* (CDR) (deaths per 1,000 inhabitants) and *crude birth rate* (CBR) (births per 1000 inhabitants) which we use to calculate the *crude rate of natural increase* (CRNI=CBR-CDR). The CRNI indicates how fast the city grows mechanically every year (abstracting from migration). One downside of CDR and CBR is that these measures do not account for the age composition of the population – unlike age-specific mortality and fertility rates. Also, CDR metrics do not reveal causes of mortality, unlike disease-specific mortality

[7] While studies such as Bairoch (1988) and Malanima and Volckart (2007) use 5,000 or 10,000 to define a locality as a city, we focus on "large cities" as these are the cities with the most significant economic and demographic changes throughout the period and the most complete time series. We do not focus on locations with less than 10,000 inhabitants (more in line with towns and villages), as these places are not central to our research question.

rates. The CDR is the mortality rate from *all* causes of death for *all* segments of the population. With a few exceptions, and since mortality is a function of poverty, child mortality and adult mortality are correlated with each other. The CBR then provides "a reasonable estimate of fertility because, while the age composition of countries can vary substantially, the proportion of women in the childbearing years (15-49) varies much less" (Kent and Haub, 1984).

Data & Sources. We obtain the CDR for 1,047 city-decade observations (27.3% of the sample) and the CBR for 865 observations (23.4%), and have both rates (and thus natural increase) for 825 observations (22.3%). Approximately three hundred sources were used to obtain the estimates. One half are publications by statistical offices in the respective countries (censuses, statistical abstracts, public health reports, etc.); one third are scholarly works (books, monographs, peer-reviewed articles, etc.); the remaining sources are comprised of independent reports, newspaper articles, and various other studies. Both scholarly works and the remaining sources tend to obtain their own estimates from official or semi-official publications.

Historical data collection of this nature requires not only an exhaustive search of scholarly works and national statistical publications in their original forms (and languages), but also a careful evaluation of source veracity, accuracy, and completeness. Though diminishing over time, the widespread incompleteness of vital statistics either due to partial coverage or else under-registration of births and deaths presents a significant challenge to all who analyze demographic trends over time. In this regard, we stand on the shoulders of giants, for example Haines (1980); Troesken (2001); Ferrie and Troesken (2008); Haines and Guest (2010) who have documented some of these patterns for U.S. cities and 'have documented some of these patterns for UK cities. We also consulted many studies which discussed the extents of the resulting bias in different periods and offered corrections, particularly based on records of baptisms and burials (e.g., Shattuck, 1846; Newsholme and Stevenson, 1906; Wrigley and Schofield, 1989; Clark and Cummins, 2015). Wherever possible, we utilized series which had harmonized mortality and fertility statistics over time to increase our consistency and comparability.[8]

As many of these cities were in their infancy at the beginning of the period and boomed rapidly during the late 19th and early 20th centuries, there were few records kept below certain population/development levels. We have identified 124 observations (marked as "suspicious") which we consider to be less reliable based on our own reading but have been unable to find additional information for. In addition, the rates are sometimes based on where the death/birth itself occurs even if these are the deaths/births of people not living in the city.

[8]Examples include Duffy (1968) which has CDR for New York City (1804-1865) (Duffy, 1968); CBR and CDR for Philadelphia 1690-1860 (Klepp, 1989); CBR and CDR for Buenos Aires (1540-1930) (Moreno, 1939).

Population. We obtain population estimates for 3,305 city-decade observations (89.5% of the sample). These estimates primarily come from census estimates.[9] Though certainly boundaries have changed for cities over time, many boundary changes for the cities in our sample have taken place in the latter half of the twentieth century, rather than in our period of interest.

Sampling. Web Appx. Table A1 shows the number of available city-decade estimates for each country and four subperiods (before 1800, 1810-1840, 1850-1890, 1900-1950). This sample is dominated by the UK, U.S., Germany, Italy and France. We have more data from the second half of the 19th century, as confirmed by Web Appx. Fig. A.2a which shows the percentage share of observations among our full sample of 142 cities *for each decade*. As countries grew, their statistical capacity also developed alongside a growing interest in vital statistics.[10] We also have more data for death rates than birth rates. Deaths were more observable. Additionally, growing concern with causes of mortality meant that increasing attention was paid to deaths.[11]

2. Background: City Demography Rates 1700-1950

In this section, we study how CDRs, CBRs and CRNIs evolved before, during and after the onset of the Industrial Revolution globally (i.e., in our sample).

Timing of the Industrial Revolution (IR). We rely on various studies to obtain the approximate years the IR started for each country, for example 1760 for the UK, 1790 for the U.S., 1810 for France and Germany, and 1820 for Belgium.[12] For each city and each decade t, we then construct a dummy equal to one if the IR started in or before decade t. As can be seen in Figure 1, the share of the 142 cities in the full sample that belong to an industrializing country increased to more than one third in 1810, about 50% by 1850 and 80% in 1910 at the eve of World War I. We will thus choose to define the IR era as the period between 1810 and 1910 (incl.).

Figure 1 also shows the respective shares of the 142 cities that are in a country whose income level is at least equal to the income level of the UK in 1810, since the IR allowed the UK to pass important income thresholds which were only passed by other industrializing countries.[13]

Natural Increase and City Growth. Next, note that city population growth can be written as:

$$\triangle Upop_{(t-10,t)} = Uni_{(t-10,t)} * Upop_{t,10} + Mig_{(t-10,t)} + Urec_{(t-10,t)} \quad (1)$$

[9] They are compiled on Wikipedia, on pages such as https://en.wikipedia.org/wiki/Baltimore#Demographics (for Baltimore). One advantage of using estimates compiled here is that they are often compiled from primary sources (and therefore languages) in the original censuses and administrative records of each country.

[10] The first censuses of the UK, the U.S., Germany and France took place in 1801, 1790, 1895, and 1801, respectively.

[11] We obtain similar patterns if we weight each city by its population in the decade (Web Appx. Fig. A.2b).

[12] It is difficult to assign the start of the IR in each country to a specific decade, as it was gradual. There is also disagreement between scholars about which decade is correct for each country. We abstract from these issues since a difference of a few decades for a few countries should not impact the results. See the Web Appendix for the sources.

[13] Per capita GDP is expressed in constant international 2011 $ and comes from Bolt and van Zanden (2014).

where $\triangle Upop_{(t-10,t)}$ is the absolute growth of the city population between t-10 and t, $Uni_{(t-10,t)}$ is the city rate of natural increase between t-10 and t, $Upop_{t,10}$ is city population in t-10, $Mig_{(t-10,t)}$ is the net number of in-migrants between t-10 and t, and $Urec_{(t-10,t)}$ is the number of non-city residents reclassified as city residents between t-10 and t. Since municipal consolidation is a predominantly 20th century phenomenon, we abstract from reclassification. We then divide eq. (1) by population in t-10 and obtain that the growth rate in (t-10;t) is the sum of the rate of natural increase in (t-10;t) and the in-migration rate in (t-10;t):

$$\frac{\triangle Upop_{(t-10,t)}}{Upop_{t-10}} = Uni_{(t-10,t)} + \frac{Mig_{(t-10,t)}}{Upop_{t-10}} \tag{2}$$

For 913 observations with available data, when regressing the city's population growth rate between decade t-10 and decade t on the CRNI in (t-10;t) (we use the average of the CRNI in t-10 and t), we obtain a coefficient of 0.78***. By construction, the coefficient is equal to 1 in the very short-run, i.e. a child born in year t-10 increases population by 1 in year t-10. However, over a period of 10 years, between t-10 and t, migration creates a disconnect between natural increase and population growth. The fact that the coefficient remains high indicates that natural increase was, at least in the medium-run, a strong mechanical determinant of city growth.

CDRs. Figure 2a shows the CDRs (N = 1,007 city-decade observations), as well as the average CDR for each decade (using city populations as weights). The dashed vertical lines show the years used for the IR era analysis, i.e. 1810 and 1910. From this figure, we can observe that: (i) Death rates were already high in the 18th century, before industrialization began globally; (ii) Death rates decreased in the 19th century (the era of the Industrial Revolution), contrary to expectations of an increase in mortality due to harmful health effects; and (iii) Death rates kept decreasing until 1950, at which time they stabilized at around 10-15, slightly above today's levels.

CBRs. Figure 2b shows the CBRs (N = 865) and the population-weighted average CBR for each decade. Birth rates remained high until the mid-19th century, after which they started to fall.

CRNIs. In Figure 3a, we analyze the CRNI (= CBR - CDR; N = 825). We see that death rates were greater than or equal to birth rates until the turn of the 19th century, after which death rates fell faster than birth rates, thus allowing the CRNI to increase and become positive. **City Size.** Figure 3b shows the mean population size of the 142 "large cities" from 1700 to 1950. City sizes dramatically increased in the 19th century. Together, Figure 3a and Figure 3b show that death rates decreased as city sizes increased during the Industrial Revolution era. Birth rates also decreased but slower than death rates. Thus, CRNI *increased* in cities as city sizes increased.

Urban Sector. Lastly, we collected information on the birth and death rates for the whole urban sector (when available).[14] In general, demographic data at the city level is more readily available than for the whole urban sector during the period. Governments were more likely to distinguish rural areas and individual cities, rather than focusing on the urban sector in census, health, or vital statistics reports. The corresponding urban-area estimates are available for only 58.6% (of 1,007) and 54.80% (of 865) of city-decade observations with an estimate of the CDR and CBR, respectively. The missing observations are disproportionately found in earlier decades. If we focus on the urban CDR and CBR for at least 5 countries for 1790-1950 for which we have complete panel data, the coefficient of correlation we obtain between the decadal averages using our city-level data and decadal averages for the urban sector only is 0.94 and 0.76, respectively (N = 17). Interestingly, larger cities started with higher CDRs in 1790 than the whole urban sector (which also includes smaller cities) (Web Appx. Fig. A.3).[15] However, during the Industrial Revolution era, the gap closed between large cities and the overall urban sector, i.e. other cities.

To summarize, our descriptive results suggest that rates of natural increase may have increased, not decreased, as city size increased during the Industrial Revolution era.

3. Results: The Industrial Revolution & City Demographic Rates

We now document econometrically whether (i) *Hypothesis 1 (H1):* Cities saw an increase in CDR and a decrease in CBR during the Industrial Revolution, thus implying a declining CRNI (i.e., a demographic penalty); (ii) *Hypothesis 2 (H2):* It was particularly the case for larger cities.

3.1. The Industrial Revolution Era and City Demographic Rates

Model and Results for H1. For city c and decade t, we estimate the following model:

$$\text{Demo. Rate}_{c,t} = \alpha + \beta * \mathbb{1}(t = [1810, 1910]) + \gamma * \mathbb{1}(t = [1920, 1950]) + \kappa_c + \mu_{c,t} \tag{3}$$

where Demo. Rate$_{c,t}$ is the city's demographic rate in decade t – the CDR, the CBR, and the CRNI. β measures how the demographic rate changed during the Industrial Revolution era ([1810, 1910]) (relative to before). We cannot reject H1 if β is significantly positive for the CDR and significantly negative for the CBR and CRNI. City fixed effects then capture the effects of time-invariant factors specific to each city.[16] Lastly, we cluster standard errors at the city level.

Since there are only three coefficients of interest, we do not present the results in table form. We find that β is equal to -12.46***, -7.65*** and 4.26 for the CDR (N = 1,007), CBR (865) and CRNI (825), respectively. Thus, during the IR era (relative to the pre-industrial era), death rates

[14] As explained in footnote 7, the “urban sector” typically includes all localities above 5,000 or 10,000 inhabitants. However, the exact definition used for each estimate likely varies across countries and years.

[15] If the urban sector includes localities above 5,000 or 10,000 inhabitants and large cities exceed 200,000 inhabitants in our analysis, smaller cities should include cities between 5,000 or 10,000 and 200,000.

[16] By construction, we cannot add year fixed effects for this regression.

decreased faster than birth rates, and there was a (not significant) increase in the rates of natural increase. Based on this, we reject H1, thus implying a lack of IR-related demographic penalty. Finally, these correlations are large. Indeed, the mean CDR, CBR and CRNI in the sample is 22.2, 28.0 and 6.4, respectively. Note that summary statistics can be found in Web Appx. Table A2.

Model and Results for H2. For city c and decade t, we estimate the following model:

$$\begin{aligned}\text{Demo. Rate}_{c,t} = \alpha + \delta * \text{Log Pop. Size}_{c,t} + \theta * \text{Log Pop. Size}_{c,t} * \mathbb{1}(t = [1810, 1910]) \\ + \varphi * \text{Log Pop. Size}_{c,t} * \mathbb{1}(t = [1920, 1950]) + \kappa_c + \lambda_t + \mu_{c,t}\end{aligned} \tag{4}$$

where Log Pop. Size $_{c,t}$ is the log of the city's population size in decade t. This equation is different from equation (3) in that we now also include (log) city size and its interactions with the two period dummies. Since we now include year fixed effects, the two period dummies are automatically dropped. Lastly, we cluster standard errors at the city level.

θ measures how the demographic rate of larger cities differentially changed during the Industrial Revolution (IR) era ([1810, 1910]) (relative to before). We cannot reject H2 if θ is significantly positive for the CDR and significantly negative for the CBR and CRNI.

Col. (1) of Table 1 shows the results for specification (4). In cols. (2)-(3), we additionally control for time-varying factors at the country level, by either including country fixed effects interacted with the year and its square (col. (2)), or country-year fixed effects (col. (3)).

For the CDR (Panel A), we obtain a positive correlation between mortality and city size, consistent with larger cities being lethal pre-IR. However, θ – the coefficient of the interaction with the IR era dummy (underlined in the left panel of the table) – is either nil or negative. Thus, mortality either remained the same or actually decreased during the IR, inconsistent with H2.

For the CBR (Panel B), we either obtain a negative correlation or a positive correlation between fertility and city size. More importantly, θ is either positive or close to 0. Thus, fertility either remained similar or actually increased during the IR, also inconsistent with H2.

The CRNI is our main outcome since it directly measures any demographic penalty. As seen in Panel C, we obtain a strongly negative correlation between natural increase and city size, consistent with larger cities exhibiting a clear penalty pre-IR. However, θ is either nil or positive. Thus, natural increase either remained the same or actually increased during the IR, inconsistent with H2. The correlation obtained when including country-year fixed effects is even significant (col. (3); 1.04**), which may imply a *decline* in the penalty for larger cities (apparently driven by the decline of mortality in larger cities during the IR). However, there is still a penalty overall as the estimated total effect for 1810-1910 (δ + θ) remains negative (see fourth row of Panel C).

How large are the obtained correlations? Between 1810 and 1910, city population sizes were multiplied by 5.3 on average (Figure 3b). A coefficient of 1.04 implies that a 530% increase in city size during the IR is (relatively) associated with a 2 point increase in the CRNI.[17] During the same period, the CRNI increased from about 4 to 8, hence by +4 (Figure 3a; per 1,000). The estimated correlation is thus large. Alternatively, a one standard deviation increase in city size during the IR is (relatively) associated with a 0.86 standard deviation increase in the CRNI.

Decade-Specific Correlations. Instead of studying the coefficient of log city population for the IR era as a whole, we can estimate a coefficient of log city population for each decade. More precisely, for city c and decade t, we estimate the following model:

$$\text{Demo. Rate}_{c,t} = \alpha + \delta * \text{Log Pop. Size}_{c,t} + \sum_{s=1710}^{1950} \theta_t * \text{Log Pop. Size}_{c,t} * \mathbb{1}(t=s) + \kappa_c + \lambda_t + \mu_{c,t}. \quad (5)$$

The θ_t measure how the demographic rate of larger cities differentially changed in each decade (the omitted decade is 1700). We then plot in Figures 4a and 4b two-decade moving averages of the decadal θ_t coefficients when the dependent variable is the CDR, the CBR or the CRNI. We use two-decade moving averages of the coefficients as decade-specific coefficients are mechanically more sensitive to the lack of data in specific decades, and noise more generally, than coefficients for the full IR era period. As seen in Figure 4a, the correlation between the CDR and city size has been decreasing, and become negative, during the IR era. Next, the figure also shows that the negative correlation between the CBR and city size has been increasing after 1810. Finally, Figure 4b shows that the negative correlation between the CRNI and city size has also been dramatically increasing post-1810. Therefore, the disappearance of the demographic penalty for larger cities has been gradual. By 1950, we even see a slight inversion of the CRNI-city size relationship.

To conclude, we can reject both H1 and H2 when using the global timing of the IR.

3.2. Industrial Revolution Countries and City Demographic Rates

We know the approximate decade the IR started for each country, for example 1760 for the UK, 1790 for the U.S., 1810 for France and Germany, and 1820 for Belgium. We can thus use this data to further test H1 and H2 depending on the onset of the IR in each country.

Model and Results for H1. For city c and decade t, we first estimate the following model:

$$\text{Demo. Rate}_{c,t} = \alpha + \beta * \mathbb{1}(\text{Indu. Revo.}_{c,t} = 1) + \delta * \text{Log Pop. Size}_{c,t} + \kappa_c + \lambda_t + \mu_{c,t} \quad (6)$$

where Indu. Revo.$_{c,t}$ is a dummy equal to one if the city's country has started industrializing. β measures how a city's demographic rate changed after a country started industrializing (relative to before and other cities in other countries, in a difference-in-difference spirit). We cannot reject H1 if β is significantly positive for the CDR and significantly negative for the CBR and

[17] Given the linear-log model, to obtain 2 we multiply 1.04 by log([100 + p]/100) with p = 530.

CRNI. Unlike for eq. (3), we can include year fixed effects as the IR dummy is time-varying. Given the city fixed effects, we then focus on within-city variation in industrialization.[18]

Results are reported in rows 1 of cols. (1)-(3) in Table 2. In cols. (4)-(6), the IR dummy is a dummy for whether the country's income level is at least equal to the income level of the UK in 1810. Finally, for each IR dummy, the three columns correspond to: (i) the baseline specification; (ii) the specification with country trends (i.e., country fixed effects interacted with the year and its square); and (iii) the specification with country-year fixed effects.

For the CDR (Panel A), we find lower, not higher, death rates, inconsistent with H1. We find a decrease in mortality of about 2.69-6.23 ($\approx$ 0.3-0.6% per year), which is large compared to a mean of 22.2. Alternatively, CDRs decreased by about 13 from 31.7 in 1810 to 18.7 in 1910.

For the CBR (Panel B), we find higher, not lower, birth rates, also inconsistent with H1. We find an increase of about 0.38-2.01 ($\approx$ 0.04-0.2% per year), which is not large compared to a mean of 28.0. However, CBRs decreased on average by about 10 from 35.7 in 1810 to 26.1 in 1910. Therefore, industrialization was associated with a *slower* decrease in birth rates overall.

For the CRNI (Panel C), we find much higher, not lower, rates of natural increase, inconsistent with H1. We find an increase of about 3.30-6.18 ($\approx$ 0.3-0.6% per year), which is very large given a mean of 6.4. CRNIs also only increased by about 4 on average, from 4.0 in 1810 to 8.2 in 1910.

Model and Results for H2. For city c and decade t, we estimate the following model which replicates model (6) except we also include the interaction of log city size and the IR dummy:

$$\begin{aligned}\text{Demo. Rate}_{c,t} &= \alpha + \beta * \mathbb{1}(\text{Indu. Revo.}_{c,t} = 1) + \delta * \text{Log Pop. Size}_{c,t} \\ &+ \theta * \text{Log Pop. Size}_{c,t} * \mathbb{1}(\text{Indu. Revo.}_{c,t} = 1) + \kappa_c + \lambda_t + \mu_{c,t}. \end{aligned} \tag{7}$$

θ measures how the demographic rate of larger cities differentially changed after a country began industrializing (relative to before and other cities). We cannot reject H2 if θ is significantly positive for the CDR and significantly negative for the CBR and CRNI.

Results are reported in rows 2 of cols. (1)-(3) in Table 2. In cols. (4)-(6), the IR dummy is based on the UK's income level in 1810. For each IR dummy, we then consider three different specifications: (i) baseline; (ii) with country trends; and (iii) with country-year fixed effects.

For the CDR (Panel A), we obtain a positive correlation between mortality and city size. Larger cities were lethal pre-IR. However, θ – the coefficient of the interaction with the IR dummy (underlined in the left panel of the table) – is either nil or negative. Thus, mortality either remained the same or actually decreased during industrialization, inconsistent with H2.

[18]Information on the timing of the IR at a city-level is unreliable. However, there was often substantial within-city variation in pollution (Heblich et al., 2021) and in investments in infrastructure (Colten, 2006; Beach et al., 2018) which led to differential impacts on mortality whose neighborhood-level effects can still be seen today.

For the CBR (Panel B), we often obtain a negative correlation between fertility and city size. Thus, it appears that larger cities indeed had lower birth rates pre-IR. However, θ – the coefficient of the interaction – is either positive or close to 0. Thus, fertility either remained similar or actually increased during industrialization, also inconsistent with H2.

Finally, we obtain a clear negative correlation between natural increase and city size (Panel C), consistent with larger cities exhibiting a demographic penalty pre-IR. However, θ is either nil or positive. Thus, natural increase either remained the same or actually increased during the IR, inconsistent with H2. Interestingly, the coefficient of the IR dummy is negative whereas it was positive in row 1 when the interaction was not included. Hence, the increase in CRNIs observed across *all* cities in row 1 was driven by larger cities. In other words, the increase in CRNI in larger cities was such that any penalty for smaller cities was too minor to affect aggregate trends.

To conclude, it appears that we can reject both H1 and H2 when using the country-specific timing of the IR. In the next section, we use the same information on the timing of the IR as well as information on the nature of the industrialization at a city level to further test H1 and H2.

3.3. Industrial Cities and City Demographic Rates

Industrial Cities: We classify the 142 cities into *industrial* during most of the Industrial Revolution era vs. *not industrial* during most of the era, relying on spatial analysis in Rubenstein (2020). Among industrial cities, we know whether they are *major industrial centers* belonging to an industrial basin or *minor industrial centers* that do not belong to an industrial basin. For example, Liverpool, Manchester, Newcastle and Sheffield in the UK, Boston, New York, Philadelphia and Pittsburgh in the U.S. and Lille and Roubaix in France are major manufacturing centers. Cardiff, Kansas City, Minneapolis, Paris and St. Louis are minor manufacturing centers. Belfast, Bordeaux, Bristol, Marseille and Portsmouth are not manufacturing centers.

Model and Results for H1. For city c and decade t, we first estimate the following model:

$$\begin{aligned}\text{Demo. Rate}_{c,t} &= \alpha + \beta * \mathbb{1}(\text{Indu. Revo.}_{c,t} = 1) + \delta * \text{Log Pop. Size}_{c,t} \\ &+ \pi * \mathbb{1}(\text{Indu. Revo.}_{c,t} = 1) * \mathbb{1}(\text{Indu. City}_c = 1) + \kappa_c + \lambda_t + \mu_{c,t} \qquad (8)\end{aligned}$$

where Indu. Revo.$_{c,t}$ is a dummy equal to one if the country the city is located in has begun industrializing and Indu. City$_c$ is a dummy if the city was a major or minor industrial city. β measures how a non-industrial city's demographic rate changed after a country began industrializing. $\beta + \pi$ measures how an industrial city's demographic rate changed post-industrialization (π measures the differential evolution for industrial cities relative to non-industrial cities). We cannot reject H1 for industrial cities if $\beta + \pi$ is significantly positive for the CDR and significantly negative for the CBR and CRNI. However, the IR may affect both industrial *and* non-industrial cities; for example, profits generated in industrial cities may be reinvested in non-industrial cities or prices of industrial goods may decrease for *all* cities in industrial countries. Hence, a proper test of H1 should not solely consider industrial cities, as it misses the effects of the IR for non-industrial cities. As such, we believe the analysis of the previous section where we do not distinguish industrial and non-industrial cities is more correct.

Results are reported in rows 1 of cols. (1)-(3) in Table 3. In cols. (4)-(6), the Industrial City dummy is a dummy for whether the city was a major industrial center. Finally, for each industrial city dummy, the three columns correspond to: (i) the baseline specification; (ii) the specification with country trends; and (iii) the specification with country-year fixed effects.

For the CDR (row 1 of Panel A), "IR + IR*Indu. City" ($\beta+\pi$) shows lower, not higher, death rates for industrial cities, inconsistent with H1. The decrease in mortality is 3.75-7.98 ($\approx$ 0.4-0.8% per year), which is large compared to a mean of 22.2. With country-year fixed effects (cols. (3) and (6)), "IR*Industrial City" (π) suggests higher mortality rates for industrial cities *relative to* non-industrial cities *within* the same country for the same year. However, this is essentially because non-industrial cities in industrial countries see their mortality rates decrease even more. Indeed, in the country trends specification (where industrial cities are implicitly also compared to other cities in *other* countries, since country-year fixed effects are not included), we observe declining CDRs for industrial cities as suggested by "IR + IR*Indu. City" ($\beta + \pi$).

For the CBR (row 1 of Panel B), we find higher or similar birth rates for industrial cities (cols. (1)-(3); see "IR + IR*Indu. City"), also inconsistent with H1. However, for major industrial cities, we indeed see lower birth rates (cols. (4)-(6); see "IR + IR*Indu. City"), which could be consistent with H1. However, to assess whether there is a demographic penalty, one must simultaneously consider the CBR and the CDR, hence the CRNI.

For the CRNI (row 1 of Panel C), we find higher, not lower, rates of natural increase for industrial cities (see the row "IR + IR*Indu. City"), inconsistent with H1. The increase in natural increase is 5.03-8.31 ($\approx$ 0.5-0.8% per year), which is very large compared to a mean of 6.4. Next, with country-year fixed effects and col. (6) (not col. (3)), "IR*Industrial City" (π) suggests lower rates of natural increase for industrial cities relative to non-industrial cities *within* the same country for the same year. However, this is again because non-industrial cities in industrial countries see their CRNI increase even more than for industrial cities as suggested by the country trends specification. Therefore, even for industrial cities, evidence contradicts H1.

Model and Results for H2. For city c and decade t, we estimate the following model which replicates model (8) except we also include the interaction of log city size and the IR dummy and the triple interaction of log city size, the IR dummy and the Industrial City dummy:

$$\begin{aligned}\text{Demo. Rate}_{c,t} = \alpha + \beta * \mathbb{1}(\text{Indu. Revo.}_{c,t} = 1) + \pi * \mathbb{1}(\text{Indu. Revo.}_{c,t} = 1) * \mathbb{1}(\text{Indu. City}_c = 1) \\ + \delta * \text{Log Pop. Size}_{c,t} + \theta * \text{Log Pop. Size}_{c,t} * \mathbb{1}(\text{Indu. Revo.}_{c,t} = 1) \\ + \xi * \text{Log Pop. Size}_{c,t} * \mathbb{1}(\text{Indu. Revo.}_{c,t} = 1) * \mathbb{1}(\text{Indu. City}_c = 1) + \kappa_c + \lambda_t + \mu_{c,t}. \quad (9)\end{aligned}$$

θ measures how the demographic rate of larger non-industrial cities differentially changed after a country began industrialization. $\theta + \xi$ measures how the demographic rate of larger industrial cities differentially changed after a country began industrialization (ξ captures the differential evolution between the two types of cities). We cannot reject H2 for industrial cities if $\theta + \xi$ is significantly positive for the CDR and significantly negative for the CBR and CRNI. However, the IR may have differential effects on both large industrial cities *and* large non-industrial cities. Hence, a proper test of H2 should not consider large industrial cities only, as it misses any effects on large non-industrial cities. Thus, the analysis of the previous section is more correct.

Results are reported in rows 2 of cols. (1)-(3) in Table 3. Cols. (4)-(6) use the major industrial city dummy. For each industrial city dummy, the three columns correspond to the following specifications: (i) baseline; (ii) with country trends; and (iii) with country-year fixed effects.

For the CDR (row 2 of Panel A), $(\theta + \xi)$ is negative, not positive (see "Log City Pop.*IR + Log City Pop.*IR*Indu. City"). Thus, regardless of the Indu. City definition, mortality (relatively) decreased, not increased, for larger industrial cities during the IR, inconsistent with H2.

For the CBR (row 2 of Panel B), $(\theta + \xi)$ is either positive (which would be inconsistent with H2) or negative (consistent with H2). However, to assess whether the demographic penalty was indeed aggravated with the IR, we need to study natural increase (since CRNI = CBR - CDR).

In row 2 of Panel C, $(\theta + \xi)$ is positive in cols. (1)-(2) and (4)-(5), suggesting a higher CRNI, i.e. a demographic amelioration, for larger industrial cities during the IR, invalidating H2. It is then only slightly negative and insignificant in cols. (3) and (6). This also leads us to reject H2.

3.4. Discussion on Issues of Internal and External Validity

The estimated correlations are not causal, and possibly impacted by measurement error. Here, we provide a discussion of these issues and present a few robustness checks.

Causality. Our main results are shown in Table 2 wherein we: (i) test H1 by examining the correlation between the demographic rates and the IR dummy based on the onset of the IR in each country (row 1); (ii) test H2 by examining the correlation between the demographic rates and the interaction of log city size and the IR country (row 2). We do not find significant negative correlations for the CRNI, suggesting a lack of demographic penalty, whether for all cities or larger cities. Were these coefficients downward biased and under-estimated, the true effects would be even less negative, which would reinforce our conclusions. However, if our coefficients are upward biased then an increased demographic penalty is possible, but we do not capture it.

City fixed effects account for time-invariant factors at the city level. In some specifications, we also account for time-varying effects at the country level. However, there could still be reverse causality and omitted variable bias. Regarding the former, mortality (fertility) in t reduces (increases) city size in t relative to t-10. Thus, we can use *log city size* in t-10 as our variable of interest. Alternatively, we can control for the *log change in city size* between t-10 and t.

Next, omitted-variable bias (OVB) affects both city size and mortality, for example if cities in IR countries grow by attracting polluting sectors whose presence in the cities raises mortality. However, our regressions where we examine the interacted effect of size and industrialization aim to capture that specific effect, so it is by construction not an OVB (we also control for industrialization directly). However, if cities, especially larger cities, in IR countries have other (unobserved) characteristics that improve their net wages or quality-of-life over time (e.g., relative to the countryside), they will become more attractive and grow faster. These factors may also differentially affect mortality across cities over time. There is no way to know whether this would lead to a (inconsequential) downward or (consequential) upward bias for CRNIs. If in-migrants are negatively selected, for example if they have a lower health capital than current residents, then CDRs may increase and CRNIs decrease, thus causing a downward bias. But if the factors improves quality-of-life in the cities, it will reduce CDRs and raise CRNIs, thus leading to an upward bias for natural increase. Past patterns in fertility also affect current city size and mortality via age composition effects affecting the workforce and the overall population. The best we can do is control for past changes in log population, the CDR and the CBR.

In Table A3, we perform these tests for col. (2) of row 1 in Table 2 (adding country-specific trends); only showing the coefficient of interest allowing us to test H1, i.e. the coefficient of the IR country dummy.[19] In the new table, column (1) replicates the baseline results. In column (2), we use log city size defined in t-10. In column (3), we include the changes in log city size, the CDR and the CBR between t-s and t, with decade s being the previous decade with available data in the sample. While the point estimates vary for the CDR (row 1) and the CBR (row 2), they remain strongly positive and significant for the CRNI (row 3), which is inconsistent with H1.

Table A4 shows the same tests for col. (2) (adding country-specific trends) and col. (3) (country-year fixed effects) of row 2 in Table 2, only showing the coefficient of interest allowing us to test H2, i.e. the coefficient of the interaction between log city size and the IR country

[19]We ignore the third specification which includes country-year fixed effects. Indeed, the coefficient of the IR country dummy is by construction not estimated when adding country-year fixed effects.

dummy. The coefficient remains negative or is close to nil for the CDR (panels A-B). For the CBR (Panels C-D), it remains positive or is close to nil. In no case did mortality (fertility) significantly increase (decrease) for larger cities during the IR. Finally, the coefficient is positive or close to nil for the CRNI (panels E-F). In no case did natural increase decrease for larger cities during the IR.

Finally, one OVB that is worth discussing in more detail is the possibility that exogenous increases in educational attainment simultaneously led to the onset of industrialization (if skilled labor was a necessary input), reduced mortality (if education facilitated the diffusion of health innovations) and lowered fertility (if education encouraged fertility control). The country-year fixed effects do not control for time-varying factors at the city level. However, while such a bias could lead us to under-estimate to what extent large, industrial cities were killer cities, it also leads us to over-estimate to what extent they were low-fertility industrious cities. As such, the impact of this OVB on natural increase – i.e., demographic penalty – is ambiguous.

Measurement Error (ME): Population. Classical ME in city size biases the effects towards 0. However, we care about city size only when focusing on the interacted effect of log city size and the IR country dummy (while simultaneously controlling for log city size). If city size is mismeasured, both city size and its interaction with the IR dummy are mismeasured, likely to the same extent. The differential effect should be little affected. We also have city, year, and country-year fixed effects in some specifications, which should capture various types of ME.

In addition, city size is likely well-estimated, especially as cities were still small then. Most population estimates also come from censuses. Furthermore, we know the years in which a census took place for each country. In our sample of 825 observations with information on the CRNI, the median, 75th percentile, and mean value of the number of years between our years of study and the census years is only 1, 3, and 6, respectively. In col. (5) of Table A3 (for H1) and Table A4 (H2), we show that the CRNI results hold when excluding 20 interpolated observations as well as observations (strictly) more than three years away from a census year.

Measurement Error (ME): Demographic Rates. ME was presumably highest in the time before vital statistics were reliably measured (mid-late 19th century), when such rates were derived from estimates of baptisms and burials (Teitelbaum, 1984). However, for this period, we use estimates compiled by economic historians, who have implemented corrections based on information about epidemics, age structure, and migratory patterns. Once the "era of statistical enthusiasm" began in the 1830s, there was a substantial surge of interest in reliable vital statistics, stemming from concerns over community health (Rosen, 1958). We use vital statistics reports for the later 19th century (and onward) where they exist.

Mortality rates are considered to be better measured than fertility rates, since death registration was likely more complete (Teitelbaum, 1984; Hirscheld, 1941). One possibility for excessively high mortality rates is whether they are measured in an epidemic year, and thus we often use decadal averages in these cases. Even where birth rates were incorrectly measured, there is both evidence of over-registration and underregistration in cities. Non-city residents may have traveled to cities to give birth, while stillbirths and short-lived births may not have been counted at all. Thus, it would be difficult to sign the bias and we can suppose that the ME is classical conditional on year, city and country-year fixed effects.

Classical ME in the demographic rates lowers precision, which is not an issue for us since the coefficients do not have the expected signs that would be consistent with H1 and H2 (or are close to 0). Alternatively, we drop suspicious observations or outlying observations, i.e. observations whose change in the rate relative to the previous decade is more than the 95th percentile value in the sample, in case such switch changes capture methodological changes. As seen in col. (6) of Table A3 (for H1) and Table A4 (H2), the CRNI results hold when doing so.

Correlated ME. The ME in the demographic rates could be correlated with the ME in city size. Indeed, the CDR, CBR and CRNI is the number of deaths, births, and (births-deaths) per 1,000 inhabitants. City size is thus their denominator. If city size is misestimated, then the rate should be as well. However, the sources used for the demographic rates (which are always directly reported as rates) and the sources used for city size are different. Furthermore, this issue only matters when testing H2 and this should similarly affect the coefficients of both city size and city size*the IR dummy, hence *not* the differential effect between the two. Lastly, if city size is under-(over-)estimated, the CRNI is over-(under-)estimated. Either way, this would make us under-estimate the level effects of both city size and city size*the IR dummy. Thus, the level effect of city size*the IR dummy would be even more positive.

Sampling. Our panel is unbalanced. To minimize compositional biases coming from cities entering the sample for one or two decades only, we limit the analysis to cities that appear in five different decades or more. As seen in col. (7) of Table A3 (H1) and Table A4 (H2), results hold when doing so. Results also hold if we use populations as weights (col. (8)) or restrict the sample to 825 observations for which we have data on both the CBR and the CDR (col. (9)).

External Validity: Why might our results contradict the results of some other studies? First of all, our panel database allows us to include city fixed effects. Second, we also use demographic data for the pre-industrial era, which allows us to study how the urban penalty *changed*, instead of documenting how large industrial cities had high mortality rates.

Third, non-econometric studies have focused on more extreme examples of killer cities, whereas our sample aims to include a large number of cities. Mortality did increase in Manchester between 1830 and 1850 and in Liverpool between 1840 and 1860 (Web Appx. Fig. A.4a). However, mortality decreased after that, and by 1890, mortality was as low as it was circa 1830-1840. After 1890, mortality kept decreasing. Likewise, in the U.S. (Web Appx. Fig. A.4b), mortality did increase in New York from 1810 to 1850 and in Boston from 1820 to 1890 but decreased after that. By 1900, both had lower mortality rates. Overall, for the whole period 1760-1910 for the UK and the whole period 1790-1910 for the U.S., death rates decreased across all cities (black connected line). Now, if we show the aggregate evolution using the population of each in decade t as weights (grey connected line), we see the increase in the CDR observed for UK cities c. 1850 was clearly not as large as in Manchester and Liverpool, two cities that were on average about 9 and 12 times smaller than London for the period 1760-1910.

3.5. Panel-Event Study

The previous difference-in-difference (DiD) analyses estimate one effect for the whole IR period of the country. We now adopt a panel-event study framework where we estimate the effect in decades around the time a country "switches" to the IR (decade "0"). More precisely, for H1, we modify baseline panel specification (6) but we now estimate a coefficient of the IR country dummy in the 5 decades before the switch and the 5 decades after it.[20] Indeed, since we have 26 decades from 1700 to 1950 and the UK switches as early as 1760, the number of "pre" decades is 5 for the UK. We thus also focus on 5 "post" decades. However, since the maximum number of "post" decades is 19, we aggregate all the decades from +6 to +19 in a "60+" years category. In the end, we obtain 5 "pre" coefficients and 6 "post" coefficients. Lastly, for both the pre and post periods, we use two-decade moving averages of the coefficients as decade-specific coefficients are sensitive to the lack of data in specific decades, and noise more generally, than coefficients for the full IR period. We also report the simple mean of the coefficients so as to better understand where the DiD estimates from Table 2 col. (1) come from.

As can be seen for H1 in Figures 5a, 5c and 5e, parallel trends are somewhat confirmed before a country industrializes. Yet, it appears that death rates (Figure 5a) decreased and birth rates (Figure 5c) and rates of natural increase (Figure 5e) increased around the time the IR started in a country. As seen, the effects are not instantaneous. For example, the CRNI keeps increasing for at least 50 years (see Figure 5e). The "60+" effect (i.e., the average of all the effects after 60 years) is then not different from the "50" effect, thus suggesting stability in the effects after 50 years.

For H2, we modify baseline panel specification (7) but we now estimate a coefficient of the IR country dummy*log city size in the 5 decades before and the 5 decades after it as well as the 60+ period. As can be seen in Figure 5b, it seems that larger cities saw their death rates decrease once

[20] Since we estimate many coefficients instead of just one, we rely on the simple model without country trends.

industrialization began. Patterns are less clear for birth rates (5d). However, Figure 5f suggests higher rates of natural increase for larger cities after a country begins industrialization.

4. Discussion on the Mechanisms

Why did the demographic penalty decrease, and not increase, during the Industrial Revolution, whether for all cities (H1) or larger cities (H2)? In this section, we attempt to place our empirical findings into an appropriate historical context and discuss the underlying mechanisms.

4.1. Discussion on the Industrial Revolution and City Mortality

Most specifications suggest that mortality decreased with the IR. Why would this be? In pre-industrial times populations were plagued by epidemics (Brown, 1992) and famines (Coale and Watkins, 1986). Together, these shocks led to a so-called "waste of life", where "burials exceeded baptisms by more than 65 percent" in mid-18th century London (Landers, 1993). As the 19th century started, urban residents of industrializing countries encountered additional problems (or "disamenities") predominantly severe pollution and negative externalities of congestion (Williamson, 1982; Heblich et al., 2021). The question is to what extent urbanization became a greater problem during the IR. Likewise, standards of living dramatically improved during the period. We ask to what extent rising income levels mitigated, or more than compensated for, the negative health effects associated with industrialization, especially in larger cities.

4.1.1. Negative Health Effects Leading to Higher City Mortality

Industrialization can directly impact health. Health effects from increased city size due to the IR are usually described as various forms of density-driven pollution and congestion effects.

Air Pollution. Pollution had an impact on health throughout the period through the air (respiratory illnesses) and water (digestive illnesses). This is not hard to imagine when picturing the smoke and industrial waste of the "dark satanic mills" of the 1840s in the UK (Williamson, 1982). Indeed, while coal was already in use to heat homes in the 17th century (Brimblecombe and Ogden, 1977), its use became much more widespread as incomes grew and coal fell in price (Clark and Jacks, 2007). This problem was exacerbated by building density which trapped smoke (Brimblecombe, 1987). Although industrialization began a bit later in the U.S., UK and U.S. cities experienced very similar problems with pollution in the 19th century as it became symbolic of the "urban poor" (Stradling and Thorsheim, 1999; Heblich et al., 2021; Beach and Hanlon, 2017).

Water Pollution. Another source of city mortality stemmed from contaminated water. In Chicago, the leading causes of death in 1880 for children were diarrheal diseases (e.g., typhoid, cholera, dysentery), in addition to the respiratory diseases (Ferrie and Troesken, 2008). The link between contaminated drinking water and waterborne diseases was not well understood, and outbreaks of typhoid and cholera were frequent (Antman, 2020). Instead, illnesses were thought to be caused by "miasmas" (dirty air) and waste was therefore dumped into bodies of water (Mokyr, 1993). London's water supply did deteriorate in the 1820s until the point where the Thames was "rapidly becoming an open sewer" (Melosi, 2008). The necessity of sewers whose waste did not empty into large bodies of water was eventually discovered (Cutler et al., 2006).

Congestion Effects. Density impacted mortality through the rapid spread of disease (Haines, 2001). More generally, no matter the origin of the disease (polluted air, sewage-tainted water, or a virus), density was the factor that caused mortality rates to multiply.

4.1.2. Positive Effects Leading to Lower Mortality.

Cities grew in size because standards of living improved, thus attracting migrants, even despite the negative health effects just discussed. Our empirical findings suggest that the positive income effects of industrialization might have outweighed the negative health effects.

Standards of Living. There is significant evidence on the increase in incomes during the Industrial Revolution era. First, we use the Maddison Project database of Bolt et al. (2018) which shows per capita GDP (constant 2011 international dollars) for a large number of country-decade observations. Bolt et al. (2018) uses \$700 ($\approx$ \$2 a day) as the income level needed for the average inhabitant to be above the subsistence threshold required to survive.

If we assume high levels of inequality, for example the fact that 40% of income went to the top 5%[21], most individuals had an income that was 60% of the income level indicated by per capita GDP. Thus, \$700 required per capita GDP to be above \$1200 for most people to subsist. Around 1700, among 5 early industrializers – Belgium, France, Germany, the UK, the U.S. –, only Belgium and then the UK had an income level above that. In the five countries income barely increased during the second half of the 18th century (during which the first industrializer – the UK – overtook Belgium and the U.S. passed the subsistence threshold) but income increased dramatically from 1810-1910 (during which time France and Germany both passed the threshold) (see Web Appx. Fig. A.5a). Between the decade each country began industrialization and 1910, its income level grew 3.1-4.3 times. Since income inequality was overall constant during that period (Roser and Ortiz-Ospina, 2020), it must be that average individuals saw their income increase to more than three times the subsistence threshold.

We obtain similar patterns if we study urbanization rates instead. To do so, we use the database of Jedwab and Vollrath (2015), who show that income and urbanization levels were historically very strongly correlated.[22] Web Appx. Fig. A.5b shows very similar patterns as for

[21] "How has inequality in the UK changed over the very long run?" (https://ourworldindata.org/income-inequality

[22] Jedwab and Vollrath (2015) compile estimates from Bairoch (1988), Malanima and Volckart (2007) and other sources. In order to ensure consistency, Jedwab and Vollrath (2015) were careful to use across all sources urbanization

income, with the UK overtaking Belgium after starting its industrialization process in the second half of the 18th century, and urbanization increasing dramatically from 1810-1910. On average, urbanization rates grew by 4.9, higher than what we found for incomes.

We then study the relationship between industrialization and income more formally. More precisely, we rely on the data of Bolt et al. (2018) for the 35 countries in our demographic sample (N = 651 country-decade observations with GDP data during the 1700-1950 period).[23] We use a panel-event study framework to examine how log per capita GDP changes around the time a country "switches" to the IR (decade "0"). For countries c and decade t, the model is:

$$\text{Log per Cap. GDP}_{c,t} = \alpha + \sum_{s=-50}^{60+} \theta_t * \mathbb{1}(\text{Indu.Revo}_{c,t=s}) + \kappa_c + \lambda_t + \mu_{c,t}. \tag{10}$$

As before, we include 5 pre-IR decades and 5 post-IR decades as well as a post-IR dummy capturing all decades after the 6th decade. Standard errors are clustered at the country level.

Web Appx. Fig. A.6 reports the results (as well as the means of the pre- and post- coefficients). As seen, incomes are stable before the onset of the IR in a country. After 50 years, per capita GDP has increased by about 30% (relative to "-10"). In the long run (see "60+"), we obtain about 50% (Ibid.). We cannot claim causality. Yet, these are relatively large effects potentially, and industrializing countries likely easily passed the $1200 threshold.

Wage and price data are almost non-existent at the city level during the period. However, an available data set is the *Consumer price indices, nominal / real wages and welfare ratios of building craftsmen and labourers, 1260-1913* by Robert Allen, consistent with Allen's work in a series of works Allen (1990, 2007, 2011) documenting real wages, prices, consumption baskets and more for various cities. One of the reported metrics is welfare ratios for both unskilled workers ("laborer") and skilled workers ("craftsmen"). Welfare ratios typically measure the ratio of the wage to the price of a typical subsistence basket of goods (including food) and services (including housing). The data set includes information for 20 cities from 1260 to 1913. However, we focus on six cities that are in our sample of 142 large cities and with welfare ratio data for both unskilled and skilled workers throughout the period 1700-1910. Figure A.7 shows the evolution of these welfare ratios (using the average for each decade) for the six cities as well as the decade the city began industrialization: London (Panel A; 1800), Paris (Panel B; 1810), Antwerp (Panel C; 1830), Leipzig (Panel D; 1840), Amsterdam (Panel E; 1850) and Madrid (Panel F; 1890).

Welfare ratios of unskilled workers were close to 1 when cities started industrializing. Thus, workers in pre-industrial cities lived close to the subsistence level. After the process started,

rates based on cities of above 5,000 inhabitants (consistent with Paul Bairoch's work).

[23] We average their yearly data at the decadal level to minimize the influence of short-term income fluctuations.

welfare ratios increased, on average by +1 by 1910 (net incomes doubled). For skilled workers, their initial level was on average close to 1.5. By 1910, their net income had doubled. Overall, increases in urban incomes were just as significant for unskilled workers as for skilled workers. Since the incomes of both unskilled and skilled workers increased, and the population size of cities too, cities' total income must have dramatically increased, also allowing them to make large-scale health-related investments characterized by large fixed costs.

Nutritional Improvements. The increase in incomes should have led to improved nutrition and reduced mortality rates (Teitelbaum, 1984; Brown, 1992; Vögele, 1994; Steckel, 2001). This improvement was initially seen in declines in infant mortality (Fogel, 1986). However, the effects of improved nutrition, as evidenced by increased heights, may have been realized a few decades later. As Fogel (1986) notes, "when the final heights are used to explain differences in adult mortality rates, they reveal the effect, not of adult levels of nutrition on adult mortality rates, but of nutritional levels during infancy, childhood, and adolescence on adult mortality rates."

Public Health Investments - Sanitation Infrastructure. As incomes rose and the public became aware of the importance of clean air and water, calls began to mount for public health improvements to address these problems. New York, for example, spent several years on the construction of the Croton Aqueduct, completed in 1842 (Haines, 2001).

Cities began building sewer systems. In addition to the famous Haussman Parisian sewers (Kesztenbaum and Rostenthal, 2017), cities like Boston invested in piped water and sewerage systems in the 19th century, significantly reducing their mortality (Alsan and Goldin, 2019).

There is no doubt that such public health improvement projects significantly attenuated the rise in mortality from crowding. However, a necessary condition for large-scale improvements was sufficient income. As Beach et al. (2018) note, "in 1890, the median waterworks cost over $700,000 dollars, comparable in cost to a $7,000,000 project for a modern city. Since these projects were financed at the local level, investment likely depended on the political will of local residents." The sewerage project which affected 15 municipalities in Massachusetts cost $300,000 in 1910 (Alsan and Goldin, 2019). Accordingly, we note that incomes increased significantly as a result of the Industrial Revolution, helping to fund projects via taxes (Gaspari and Woolf, 1985; Mokyr, 1993; Allen, 2007; Clark and Jacks, 2007).

Access to Health Care. The increase in incomes also permitted better access to health care, which was helpful as medicine moved forward (Condran and Cheney, 1982; Melosi, 1980). However, access to health care did not play a significant role in mortality reduction until well into the twentieth century in the U.S. (Catillon et al., 2018). Similarly, Cutler and Miller (2005) suggest that the very effective public health innovations of the time in the U.S. may have "crowded out costly private preventative measures." There was a steady shift in the late nineteenth century, wherein "people in sickness and distress increasingly resorted to physicians, entered hospitals rather than be cared for at home, and bought patent medicines" (Starr, 1977). However, this shift occurred late in the century, and likely helped to accelerate the fall in mortality.

Education. As discussed above, exogenous increases in educational attainment could have led to both industrialization and mortality decreases. However, although we may think of educational attainment as necessary for modern growth, this was not necessarily the case in the 19th century. Evidence suggests that the initially relatively low level of human capital in Western Europe was not a constraint on industrialization, while the higher level observed in Scandinavia did not go hand in hand with higher growth rates (Squicciarini and Voigtlander, 2015). Using data for France, Squicciarini and Voigtlander (2015) find that educational attainment in the upper tail may have raised firm productivity and innovation, fostering growth, unlike the average level of educational attainment. Similarly, Becker et al. (2011) look at Prussian data and suggest that education may have played a role in accelerating growth in some industries (such as metal) but not in others (such as textiles) where child labor played a larger role. In other parts of the world, missionaries who promoted education may have had an impact on incomes (Caicedo, 2019), but not in all contexts (Jedwab et al., 2019, 2021b). It thus appears the role of education in the IR was fairly nuanced, possibly constraining the examined channel.

Summary. On average and for our global sample, the positive income effects described above may have eventually outweighed the negative health effects, particularly in larger cities.

4.2. Discussion on City Population Sizes and Fertility

Urban birth rates decreased overall starting in the 19th century (Figures 2b). Our econometric findings suggest that birth rates were relatively higher in industrializing countries. As such, it must be that birth rates decreased relatively slower in the cities of industrializing countries. Why might this be? We can consider some evidence on fertility rates. The primary channels through which city size had an effect on fertility were labor supply/human capital ("industriousness" effect) and increased life expectancy ("child-bearing years" effect).

Industriousness Effect. de Vries (1994) characterizes the "industrious revolution" as an effect from the mid-17th to the early 19th century when the supply of labor increased along with the demand for goods. He describes how one can see the Industrious Revolution "in the more extensive market-oriented labor of women and children, and finally, in the pace or intensity of work." We might speculate that if both male and female labor force supply was increasing, fertility would decrease. Allen and Weisdorf (2011) look specifically at cities (1750-1818) and find support for consumerism driving increased labor supply. However, the labor supply of children is relevant when studying fertility. As pointed out by Guest and Tolnay (1983), "during the initial stages of the industrial revolution, children continued to occupy an economic niche... especially in textile operations." Thus, there was an incentive for high fertility rates. However, in the latter half of the century, the labor supply of children fell and school attendance rose (Guest and Tolnay, 1983), contributing to a further decrease in fertility. This effect is also found by Franck and Galor (2015), who show that the increased demand for human capital deriving from industrialization led to parental investment in children's human capital (measured by literacy rates). As this investment was relatively expensive, the result was a decline in fertility.

This ties into a "quantity-quality tradeoff" argument. If children contributed to household earnings, it made sense to keep birth rates high. Increased factory production increased the demand for child labor (Becker et al., 2011). However, there were efforts to curtail child labor and increase educational enrollment in the mid-and-late 19th century as well (see for example the series of Factory Acts and Education Acts in the UK). As schooling was also somewhat costly (Guest and Tolnay, 1983), if children attended school rather than working, the child-bearing incentive was reversed. As living standards rose (which first occurred in cities), education became more affordable (Becker et al., 2011). However, Weber (1899) pointed out that fertility patterns in cities were not representative of the country as a whole. Moreover, Clark and Cummins (2015) use wills across England for 1500-1914 to show that in England, fertility of poorer families increased, while fertility of rich families decreased "some time between 1640 and 1851." Importantly, as there were many more poor families than rich families, urban fertility did not decrease quickly.

Child-Bearing Years Effect. CBRs decreased, but not until the late nineteenth century. One reason for this delayed fertility transition might be the increase in life expectancy discussed above. As women lived longer, there was an increase in the number of child-bearing years.

For example, the average life expectancy for large towns in Britain remains constant at about 33 until the 1860s and increases to 39 by the end of the 19th century (Davenport, 2020)[table 3]. Even in cities traditionally thought of "killer cities" such as Liverpool and Manchester, life expectancy increased by 3 years and 6 years respectively by the end of the century. Additionally, these gains were not only experienced by men. Female life expectancy in French cities also increased, rising from about 30 in 1850 to 43 in 1900 for Paris. Thus, on average, the number of child-bearing years for Parisian women increased by at least 5 years.

If we consider these patterns together, we can rely on Mokyr and Voth (2009) who say that there were significant reductions in the fertility of most countries, but only after the 1880s. Thus, for most of the 19th century and in industrializing countries, the positive child-bearing year effect coming from decreasing CDRs must have more fully offset the industriousness effect.

Ultimately, both mortality and fertility fell, but mortality faster than fertility, leading to higher rates of natural increase, including in larger cities. While we might have expected health and industriousness effects to have constrained natural increase, the income and child-bearing years effect may have been altogether, and on net, stronger for most of the period.

5. Conclusion

This paper set out to investigate whether there really was a true demographic penalty, as characterized by high death rates and low birth rates, associated with urbanization during the Industrial Revolution, whether for all cities or larger cities only. By constructing a novel data set of almost 2,000 crude demographic rates for 142 large cities in 35 countries for 1700-1950, we provided econometric evidence that in fact, city mortality decreased faster than city fertility during the Industrial Revolution era and therefore, natural increase was positive for cities.

The demographic penalty of higher mortality tied to "killer city" health effects of pollution and congestion appears to have been, on average, counteracted by the positive income effects of improved nutrition, improvements in public health technology and medical advances.

The demographic penalty of lower fertility tied to "industrious cities" was present in the long-run, but initially outweighed by the positive effects of increased nutrition and life expectancy. Results suggest city birth rates decreased relatively slower in industrializing countries, possibly due to a positive child-bearing effect (due to increased life expectancy). Eventually, as schooling increased (i.e., child labor force participation decreased), and infant mortality fell, "industrious" residents of large cities likely began decreasing their fertility, focusing on quality over quantity.

Together, the results for mortality and fertility suggest that the demographic penalty of lower natural increase traditionally believed to be strong during the Industrial Revolution era was actually declining. Our analysis represents a significant starting point; nevertheless, a significant amount of further work remains on estimating causal effects of the Industrial Revolution and city size and isolating the contributions of the mechanisms relative to one another over time.

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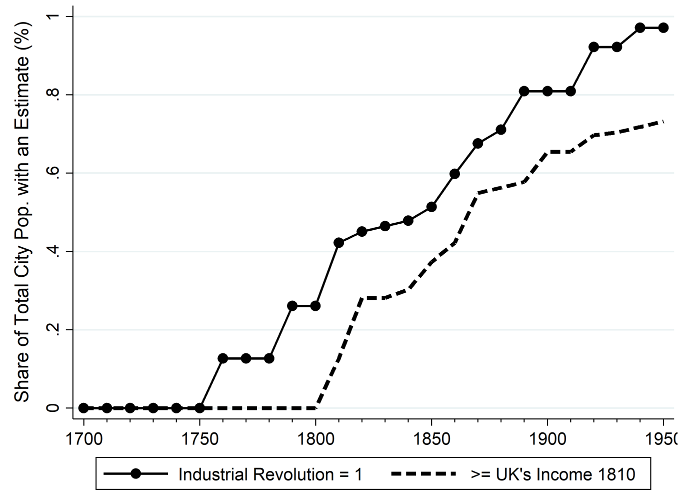
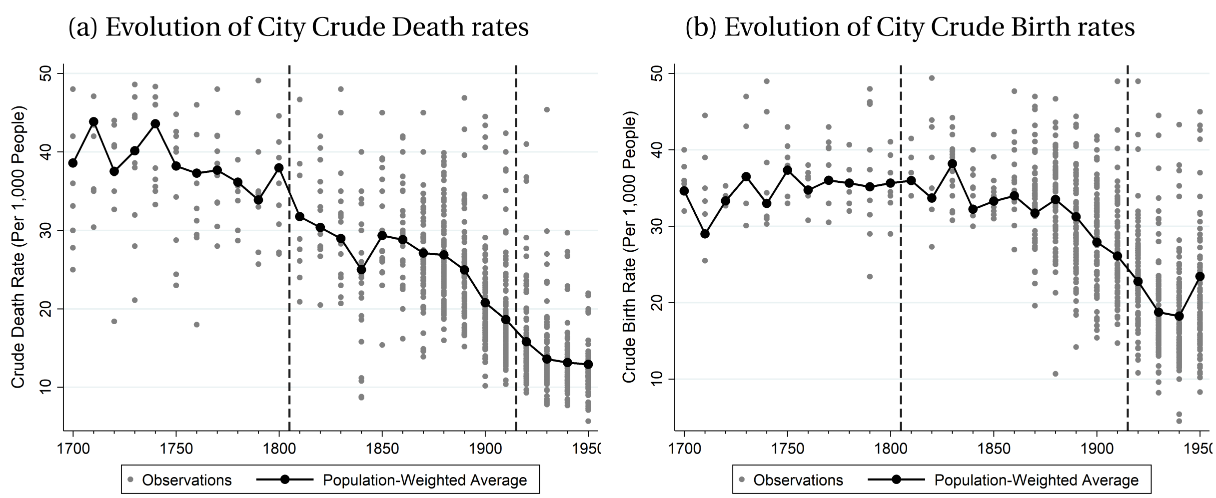
Figure 1: Diffusion of the Industrial Revolution among the 142 Cities



Notes: This figure shows for each decade the respective percentage shares of the 142 cities that are located in a country in which the (first) Industrial Revolution has already begun or a country in which mean per capita GDP (in 1990 Geary-Khamis dollars, which is equivalent to PPP and constant international 1990 $) in the decade is higher or equal than the level of per capita GDP of the UK in 1810. See the Web Data Appendix for the sources used to obtain the starting year of the Industrial Revolution in each country and each country's per capita GDP in each decade.

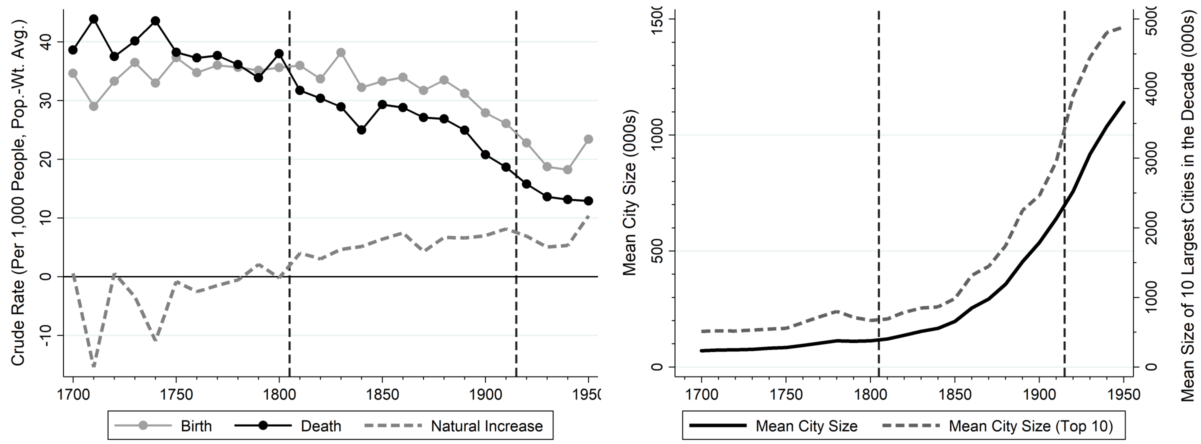
Figure 2: Evolution of City Crude Death and Birth Rates 1700-1950



Notes: Subfigure 2a shows the crude death rate (per 1,000 people) for 1,007 city-decade observations. Subfigure 2b shows the crude birth rate (per 1,000 people) for 865 city-decade observations. For both subfigures, we do not show the outlying observations with a rate above 50. The figures also show the average rates for each decade when weighting each city-decade observation by its population in that decade ("population-weighted average")). The dashed vertical lines denote the selected period for the Industrial Revolution era ([1810-1910]).

Figure 3: Evolution of City Demographic Rates and City Size 1700-1950

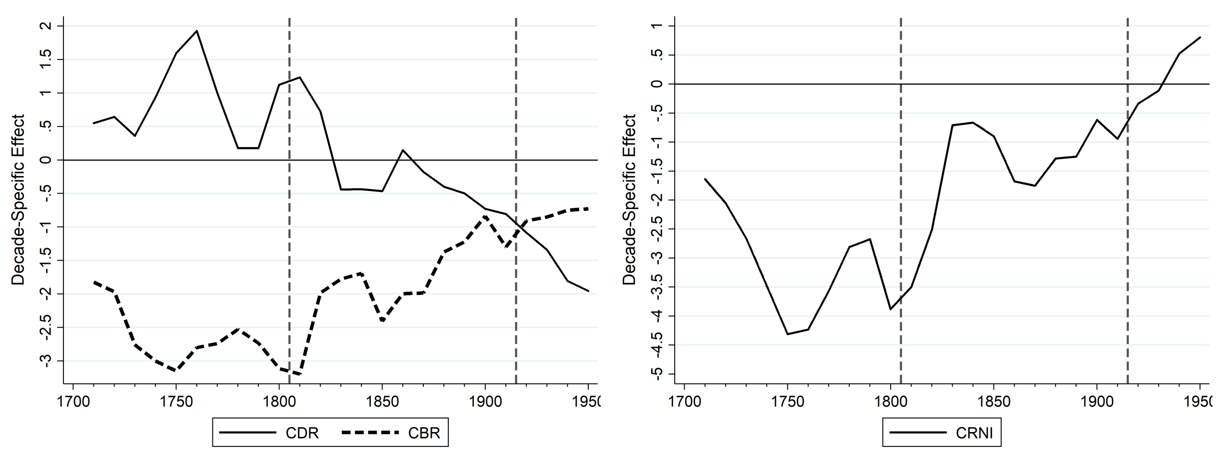
(a) Evolution of City Demographic rates (b) Evolution of City Population Size



Notes: Subfigure 3a shows the average crude rates of death, birth and natural increase (per 1,000 people) when weighting each city-decade observation by its population in that decade (data for 1,007, 865 and 825 city-decade observations respectively). Subfigure 3b shows the average population size of the 142 cities in each decade ("mean city size") and the average population size of the 10 largest cities in each decade ("top 10"). The dashed vertical lines denote the selected period for the Industrial Revolution era ([1810-1910]).

Figure 4: Decade-Specific Effects of City Size on Birth and Death Rates 1700-1950

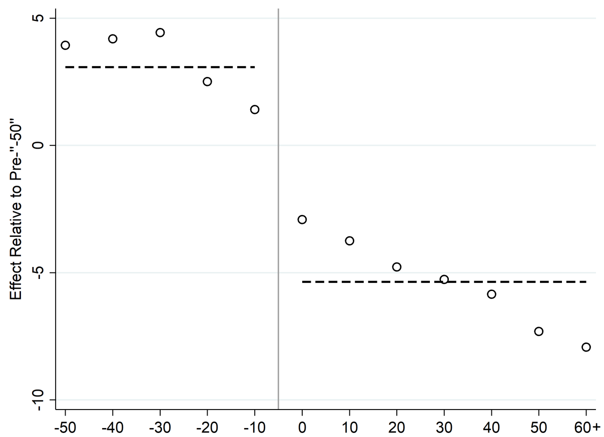
(a) Decade-Specific Effects on CDRs and CBRs (b) Decade-Specific Effects on CRNIs



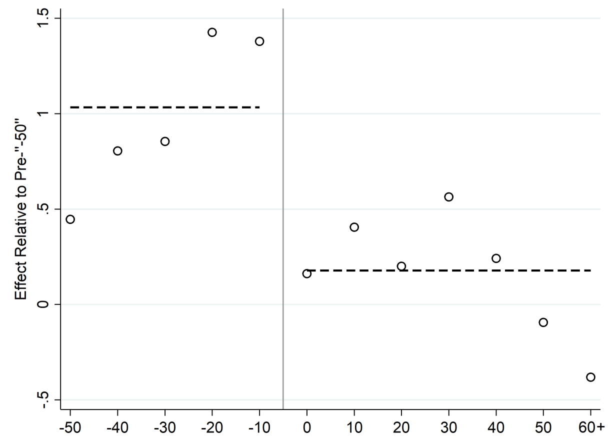
Notes: Subfigure 4a and Subfigure 4b show the decade-specific effects of log city size on the crude death rate (CDR) and the crude birth rate (CBR) and the crude rate of natural increase (CRNI), respectively. We use the specification with only city and year fixed effects (N = 1,007, 865 and 825). We use two-decade moving averages of the coefficients as decade-specific coefficients are more sensitive to the lack of data in specific decades, and noise more generally, than coefficients for the full period or the Industrial Revolution era period. The dashed vertical lines denote the selected period for the Industrial Revolution era ([1810-1910]).

Figure 5: Industrial Revolution and City Demographic Rates, Panel-Event Study

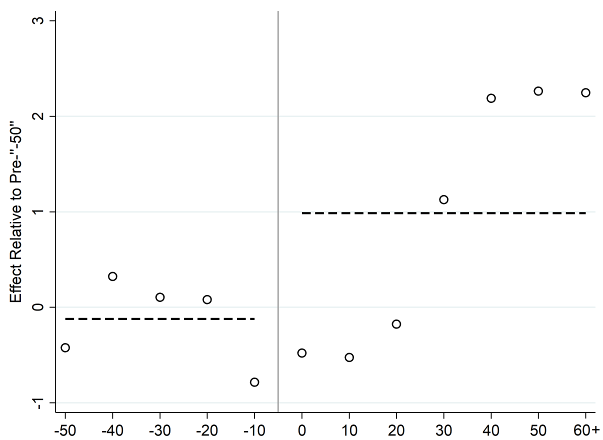
(a) H1: Effects of Indu. Revo. on CDRs



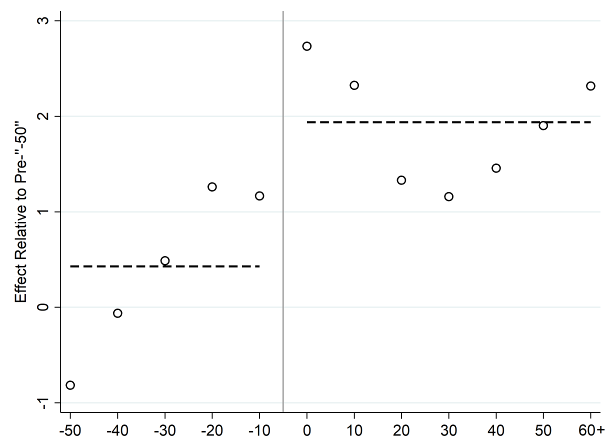
(b) H2: Effects of Indu.Revo.*Log City Size on CDRs



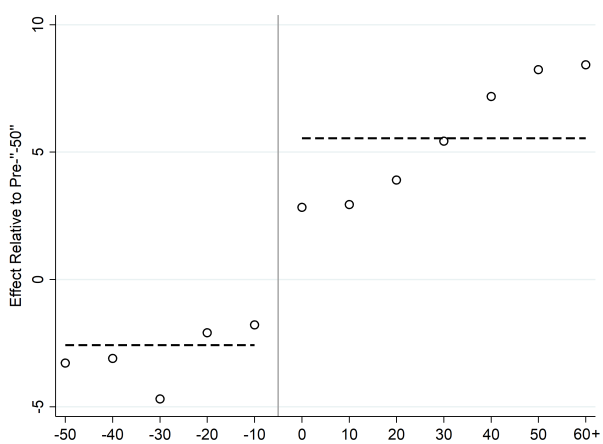
(c) H1: Effects of Indu. Revo. on CBRs



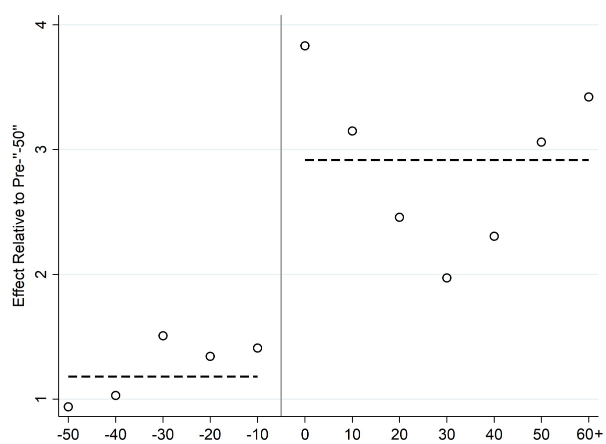
(d) H2: Effects of Indu.Revo.*Log City Size on CBRs



(e) H1: Effects of Indu. Revo. on CRNIs



(f) H2: Effects of Indu.Revo.*Log City Size on CRNIs



Notes: The left panel show the timing of the effects of the IR country dummy on the crude death rate (CDR), the crude birth rate (CBR) and the crude rate of natural increase (CRNI) (to test H1). The right panel show the timing of the effects of the IR country dummy*log city size on the demographic rates (H2). See text for details. We use two-decade moving averages of the coefficients as decade-specific coefficients are more sensitive to the lack of data in specific decades, and noise more generally, than coefficients for the full IR period.

Table 1: CITY SIZE, INDUSTRIAL REVOLUTION ERA, AND CITY DEMOGRAPHIC RATES

	(1)	(2)	(3)
Panel A:	**Dep. Var: Crude Death Rate in City c and Year t (N = 1,007)**		
Log City Pop. c,t	0.94	1.54	1.59
	[0.97]	[1.02]	[1.18]
Log City Pop. c,t x $\mathbb{1}(t=[1810,1910])$ (θ)	-1.16	0.07	-0.92*
	[1.00]	[0.97]	[0.47]
Log City Pop. c,t x $\mathbb{1}(t=[1920,1950])$	-2.34***	-1.44*	-2.38***
	[0.85]	[0.76]	[0.62]
Log City Pop + Log City Pop 1810-1910 $(\delta+\theta)$	-0.22	1.61	0.67
	[0.86]	[1.17]	[1.36]
Log City Pop + Log City Pop 1920-1950	-1.41*	0.1	-0.79
	[0.74]	[1.05]	[1.34]
Panel B:	**Dep. Var: Crude Birth Rate in City c and Year t (N = 865)**		
Log City Pop. c,t	-1.86***	1.03	-2.10*
	[0.55]	[1.69]	[1.21]
Log City Pop. c,t x $\mathbb{1}(t=[1810,1910])$ (θ)	0.65	-0.15	0.33
	[0.47]	[0.58]	[0.51]
Log City Pop. c,t x $\mathbb{1}(t=[1920,1950])$	1.30*	-0.06	-0.07
	[0.78]	[0.59]	[0.43]
Log City Pop + Log City Pop 1810-1910 $(\delta+\theta)$	-1.22*	0.88	-1.77
	[0.71]	[1.91]	[1.57]
Log City Pop + Log City Pop 1920-1950	-0.56	0.97	-2.17
	[0.94]	[1.81]	[1.49]
Panel C:	**Dep. Var: Crude Rate of Natural Increase in City c and Year t (N = 825)**		
Log City Pop. c,t	-2.59**	-1.53	-2.88
	[1.16]	[2.23]	[1.83]
Log City Pop. c,t x $\mathbb{1}(t=[1810,1910])$ (θ)	1.72	0.07	1.04**
	[1.18]	[1.35]	[0.46]
Log City Pop. c,t x $\mathbb{1}(t=[1920,1950])$	3.12***	1.12	1.87***
	[1.13]	[1.10]	[0.48]
Log City Pop + Log City Pop 1810-1910 $(\delta+\theta)$	-0.87	-1.46	-1.84
	[1.31]	[2.70]	[2.14]
Log City Pop + Log City Pop 1920-1950	0.54	-0.41	-1.01
	[1.42]	[2.46]	[2.08]
Year FE (N = 142), City FE (N = 26)	Yes	Yes	Yes
Country (N = 35)-Specific Trends	No	Yes	No
Country-Year FE	No	No	Yes

Notes: The table shows the effect of interacting log city pop. size in decade t with a dummy if decade t belongs to the period 1810-1910 (incl.) on the crude death rate (CDR), the crude birth rate (CBR) and the crude rate of natural increase (CRNI) in decade t, respectively. Col. (2): We interact the country FE with the decade and its square. The full sample includes 142 cities x 26 decades = 3,692 obs. However, the CDR, the CBR and the CRNI are available for 1,007, 865 and 825 obs. only. Robust SEs clustered at the city level. * significant at 10%; ** 5%; *** 1%.

Table 2: INDUSTRIAL REVOLUTION COUNTRIES, CITY SIZE AND DEMOGRAPHIC RATES

Indu. Revo. Dummy:	$\mathbb{1}$(**Industrial Revolution = 1**)			$\mathbb{1}$(**$\geq$ UK's Income 1810**)		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A:	**Dep. Var: Crude Death Rate in City c and Year t (N = 1,007)**					
1. Indu. Revo. c,t (IR) (β)	-6.23***	-4.28***		-4.59***	-2.69**	
	[1.33]	[1.41]		[1.43]	[1.28]	
Log City Pop. c,t	0.48	0.93	0.56	0.43	1.04	0.56
	[0.83]	[0.96]	[1.34]	[0.80]	[1.01]	[1.34]
2. Indu. Revo. c,t (IR)	9.79	-3.14		-4.14	2.11	
	[10.41]	[9.56]		[10.15]	[8.24]	
Log City Pop. c,t	0.98	1.01	1.26	0.44	1.31	1.49
	[1.00]	[1.13]	[1.20]	[0.92]	[0.92]	[1.14]
Log City Pop. x IR (θ)	-1.33	-0.10	-1.03**	-0.04	-0.39	-1.46***
	[0.88]	[0.80]	[0.49]	[0.83]	[0.66]	[0.40]
Sum for Log City Pop.	-0.35	0.91	0.23	0.41	0.92	0.03
	[0.71]	[0.98]	[1.32]	[0.81]	[1.11]	[1.29]
Panel B:	**Dep. Var: Crude Birth Rate in City c and Year t (N = 865)**					
1. Indu. Revo. c,t (IR) (β)	0.48	1.44		0.38	2.01	
	[1.55]	[1.90]		[1.72]	[1.74]	
Log City Pop. c,t	-1.57***	1.09	-2.05	-1.57***	1.02	-2.05
	[0.58]	[1.87]	[1.35]	[0.58]	[1.81]	[1.35]
2. Indu. Revo. c,t (IR)	-20.67**	-9.48		-6.71	-3.42	
	[9.12]	[11.76]		[7.22]	[6.96]	
Log City Pop. c,t	-2.10***	0.24	-1.96	-1.68***	0.73	-2.32*
	[0.60]	[1.92]	[1.42]	[0.59]	[1.76]	[1.37]
Log City Pop. x IR (θ)	1.77**	0.94	-0.16	0.56	0.44	0.54
	[0.78]	[1.07]	[0.93]	[0.62]	[0.60]	[0.42]
Sum for Log City Pop.	-0.33	1.18	-2.11	-1.12	1.17	-1.78
	[0.86]	[1.90]	[1.40]	[0.81]	[1.88]	[1.51]
Panel C:	**Dep. Var: Crude Rate of Natural Increase in City c and Year t (N = 825)**					
1. Indu. Revo.) c,t (IR) (β)	6.18***	5.82**		3.41**	3.30*	
	[1.76]	[2.24]		[1.39]	[1.92]	
Log City Pop. c,t	-2.12*	-0.50	-1.96	-1.92*	-0.90	-1.96
	[1.13]	[2.38]	[1.97]	[1.13]	[2.50]	[1.97]
2. Indu. Revo. c,t (IR)	-29.63*	-3.05		-1.19	-3.35	
	[15.00]	[8.60]		[14.77]	[12.50]	
Log City Pop. c,t	-3.01**	-1.19	-1.92	-1.99	-1.24	-2.84
	[1.25]	[2.00]	[1.80]	[1.21]	[2.30]	[1.94]
Log City Pop. x IR (θ)	2.98**	0.76	-0.06	0.37	0.55	1.77***
	[1.23]	[0.76]	[0.43]	[1.19]	[1.00]	[0.35]
Sum for Log City Pop.	-0.03	-0.43	-1.98	-1.62	-0.70	-1.06
	[1.07]	[2.46]	[2.07]	[1.26]	[2.70]	[2.04]
Year (142) FE, City (26) FE	Yes	Yes	Yes	Yes	Yes	Yes
Country (N = 35) Trends	No	Yes	No	No	Yes	No
Country-Year FE	No	No	Yes	No	No	Yes

Notes: The full sample includes 142 cities x 26 decades = 3,692 obs. However, the crude death rate, the crude birth rate and the crude rate of natural increase are available for 1,007, 865 and 825 obs. only. Robust SEs clustered at the city level. * significant at 10%; ** 5%; *** 1%.

Table 3: INDUSTRIAL REVOLUTION CITIES, CITY SIZE AND DEMOGRAPHIC RATES 1/2

Industrial City Var.:	$\mathbb{1}$(Industrial Basin = 1)			$\mathbb{1}$(Major Industrial Basin = 1)		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A:	**Dep. Var: Crude Death Rate in City c and Year t (N = 1,007)**					
1. Indu. Revo. c, t (IR) (β)	-5.43**	-7.50***		-5.44***	-2.95*	
	[2.07]	[2.86]		[1.54]	[1.64]	
IR*Industrial City c (π)	-0.98	3.76	7.80	-2.54	-2.98	5.85***
	[2.18]	[3.23]	[5.67]	[2.25]	[2.39]	[0.40]
Log City Pop. c, t	0.52	0.92	0.49	0.51	0.85	0.51
	[0.85]	[0.94]	[1.32]	[0.77]	[0.97]	[1.33]
IR + IR*Indu. City (β+π)	-6.41***	-3.75**	_	-7.98***	-5.93***	_
	[1.45]	[1.60]	_	[1.98]	[2.02]	_
2. Indu. Revo. c, t (IR)	43.00**	-1.42		27.90**	-9.64	
	[19.81]	[13.83]		[12.37]	[10.98]	
IR*Industrial City c	-35.30*	-0.69	16.60	-22.09**	9.76	22.34*
	[18.51]	[11.40]	[17.76]	[10.94]	[8.73]	[12.62]
Log City Pop c, t	1.07	1.07	1.30	1.20	1.00	0.98
	[1.02]	[1.13]	[1.15]	[0.89]	[1.03]	[1.19]
Log City Pop*IR (θ)	-3.83**	-0.49	-0.66	-2.60**	0.52	0.28
	[1.59]	[1.15]	[1.24]	[1.01]	[0.92]	[1.03]
Log City Pop*IR*Indu. City (ξ)	2.64*	0.35	-0.58	1.39*	-1.06	-1.34
	[1.46]	[0.93]	[1.23]	[0.84]	[0.75]	[0.99]
Log City Pop*IR*Indu. City	-1.18	-0.14	-1.24***	-1.22	-0.55	-1.07**
+ Log City Pop*IR ($\theta + \xi$)	[0.88]	[0.75]	[0.44]	[0.76]	[0.66]	[0.48]
Panel B:	**Dep. Var: Crude Birth Rate in City c and Year t (N = 865)**					
1. Indu. Revo. c, t (IR) (β)	2.68	0.38		0.96	4.27*	
	[1.96]	[3.99]		[1.81]	[2.57]	
IR*Industrial City c (π)	-2.73	1.20	0.78	-1.30	-5.48*	-8.64***
	[2.09]	[4.47]	[8.50]	[2.42]	[3.10]	[2.97]
Log City Pop. c, t	-1.45**	1.08	-2.07	-1.58***	0.97	-1.38
	[0.62]	[1.87]	[1.36]	[0.60]	[1.82]	[1.26]
IR + IR*Indu. City (β+π)	-0.05	1.58	_	-0.33	-1.21	_
	[1.74]	[2.08]	_	[2.10]	[2.18]	_
2. Indu. Revo. c, t (IR)	-9.01	-20.84		-13.42	-42.70**	
	[17.75]	[17.94]		[12.34]	[18.73]	
IR*Industrial City c	-12.83	12.13	18.40	-11.08	47.02***	26.85
	[18.65]	[19.22]	[21.70]	[14.05]	[16.98]	[18.02]
Log City Pop. c, t	-1.97***	0.18	-2.10	-2.07***	0.03	-1.44
	[0.63]	[1.95]	[1.41]	[0.58]	[1.55]	[1.12]
Log City Pop*IR (θ)	0.78	-0.87	-1.30	0.84	-4.15***	-2.72*
	[1.45]	[1.63]	[1.68]	[1.08]	[1.26]	[1.39]
Log City Pop*IR*Indu. City (ξ)	1.04	1.76	1.10	1.25	3.69**	1.85
	[1.44]	[1.52]	[1.67]	[0.99]	[1.48]	[1.62]
Log City Pop*IR*Indu. City	1.82**	0.89	-0.21	2.09**	-0.46	-0.87
+ Log City Pop*IR ($\theta + \xi$)	[0.81]	[1.07]	[0.86]	[1.01]	[0.60]	[0.54]
Year (142) FE, City (26) FE	Yes	Yes	Yes	Yes	Yes	Yes
Country (N = 35) Trends	No	Yes	No	No	Yes	No
Country-Year FE	No	No	Yes	No	No	Yes

CONTINUED ON THE NEXT PAGE

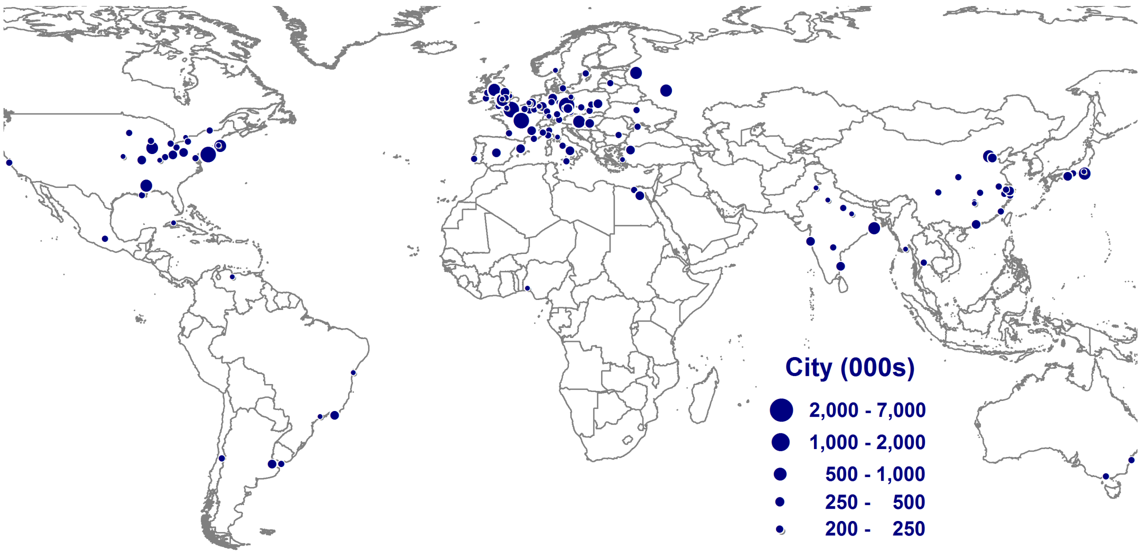
Table 3: CITY SIZE, INDUSTRIAL REVOLUTION CITIES AND DEMOGRAPHIC RATES 2/2

Industrial City Var.:	**$\mathbb{1}$(Industrial Basin = 1)**			**$\mathbb{1}$(Major Industrial Basin = 1)**		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel C:	**Dep. Var: Crude Rate of Natural Increase in City c and Year t (N = 865)**					
1. Indu. Revo. c,t (IR) (β)	8.07***	2.96		5.08**	6.60***	
	[2.41]	[3.78]		[2.05]	[2.25]	
IR*Industrial City c (π)	-2.35	3.26	6.97***	3.23	-1.57	-8.65***
	[2.58]	[3.99]	[1.57]	[3.43]	[4.84]	[0.46]
Log City Pop. c,t	-2.01*	-0.54	-1.98	-2.12**	-0.56	-1.82
	[1.15]	[2.38]	[1.97]	[1.00]	[2.41]	[1.98]
IR + IR*Indu. City (β+π)	5.72***	6.21**	-	8.31***	5.03	-
	[1.92]	[2.41]	-	[3.04]	[4.07]	-
2. Indu. Revo. c,t (IR)	-60.45***	-21.16		-40.97**	-28.31	
	[21.58]	[24.02]		[16.03]	[20.95]	
IR*Industrial City c	33.12	19.84	44.04	8.74	31.31	9.50
	[21.82]	[24.16]	[30.27]	[17.31]	[19.13]	[23.37]
Log City Pop c,t	-2.94**	-1.25	-2.05	-3.21***	-1.66	-1.97
	[1.24]	[2.04]	[1.85]	[1.00]	[2.02]	[1.91]
Log City Pop*IR (θ)	5.49***	2.00	2.32	3.74***	2.80	1.10
	[1.73]	[1.84]	[2.19]	[1.28]	[1.73]	[1.77]
Log City Pop*IR*Indu. City (ξ)	-2.72	-1.35	-2.68	-0.22	-2.64*	-1.44
	[1.71]	[1.85]	[2.19]	[1.43]	[1.59]	[1.84]
Log City Pop*IR*Indu. City	2.77**	0.65	-0.35	3.52**	0.16	-0.35
+ Log City Pop*IR ($\theta+\xi$)	[1.26]	[0.81]	[0.38]	[1.40]	[0.92]	[0.36]
Year (142) FE, City (26) FE	Yes	Yes	Yes	Yes	Yes	Yes
Country (N = 35) Trends	No	Yes	No	No	Yes	No
Country-Year FE	No	No	Yes	No	No	Yes

Notes: The full sample includes 142 cities x 26 decades = 3,692 obs. However, the crude death rate, the crude birth rate and the crude rate of natural increase are available for 1,007, 865 and 825 obs. only. Robust SEs clustered at the city level. * significant at 10%; ** 5%; *** 1%.

A Web Appendix Figures and Tables (Not for Publication)

Figure A.1: Largest Cities of the World circa 1900

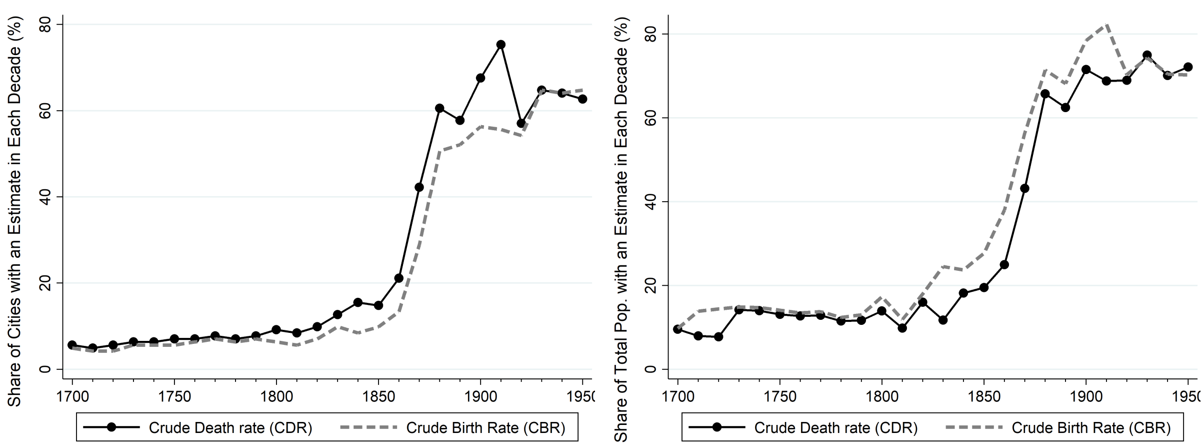


Notes: This figure shows 142 cities above 200,000 inhabitants in 1900 according to (Chandler, 1987). London is the largest city in 1900 with 6,480,000 inh., and Foshan is the smallest city with 200,000 inh.

Figure A.2: For Each Decade, Share of Sample with a Demographic Rate Observation 1700-1950

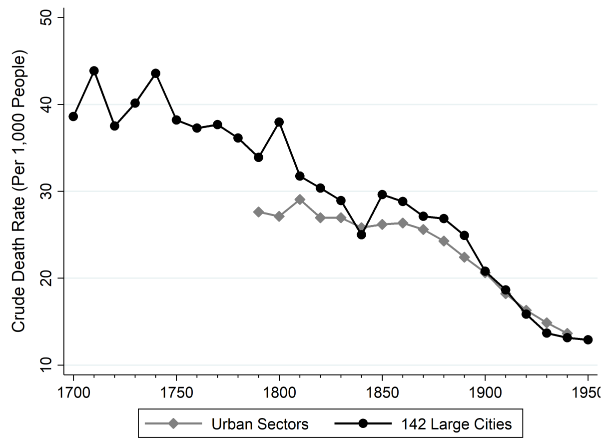
(a) For Each Decade, Share with an Estimate

(b) For Each Decade, Share of Pop. with an Est.



Notes: Subfigure A.2.a shows for each decade one by one the percentage share of the full sample of 142 cities with an available observation for the crude birth rate and an available observation for the crude death rate (per 1,000 people). Subfigure A.2.b describes the same patterns when weighting the cities by their population in each decade, which allows us to show the percentage share of the total city population in each decade with an available observation for the crude birth rate and an available observation for the crude death rate (per 1,000 people). See text for details.

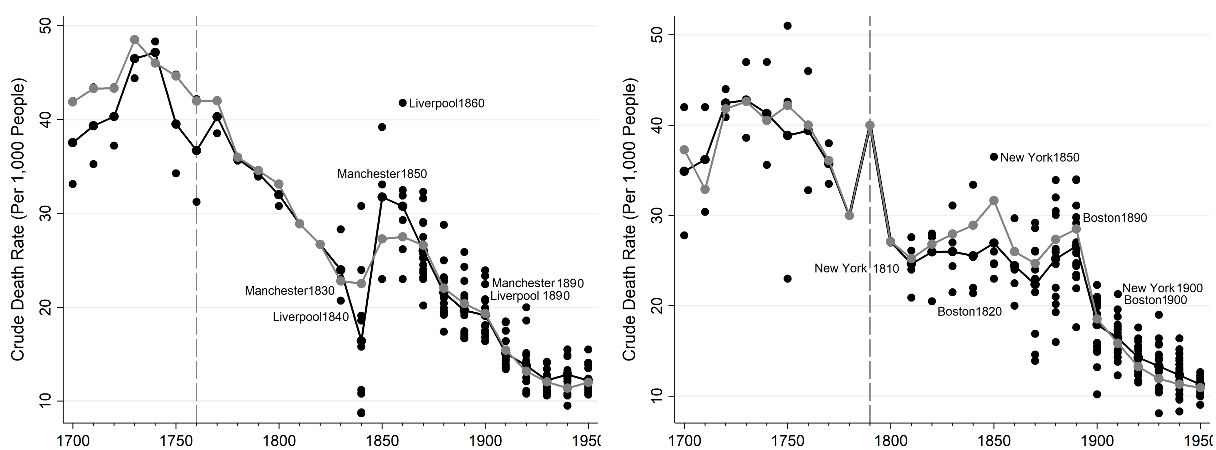
Figure A.3: Evolution of Crude Death Rates for Cities and Urban Sectors, 1700-1950



Notes: This figure shows for 1,007 city-decade observations the average crude death rate for each decade when weighting each city-decade observation by its population in that decade. It also shows for 162 country-decade observations the average crude death rate for each decade when weighting each country-decade observation by its population in that decade. We only show the urban sector evolution from 1790 onwards because we have fewer than 5 country observations for each decade before. We then use a two-decade moving average to reduce noise coming from the fact that we have few countries and their composition changes frequently for earlier decades.

Figure A.4: Crude Death Rates for UK and U.S. Cities, 1700-1950

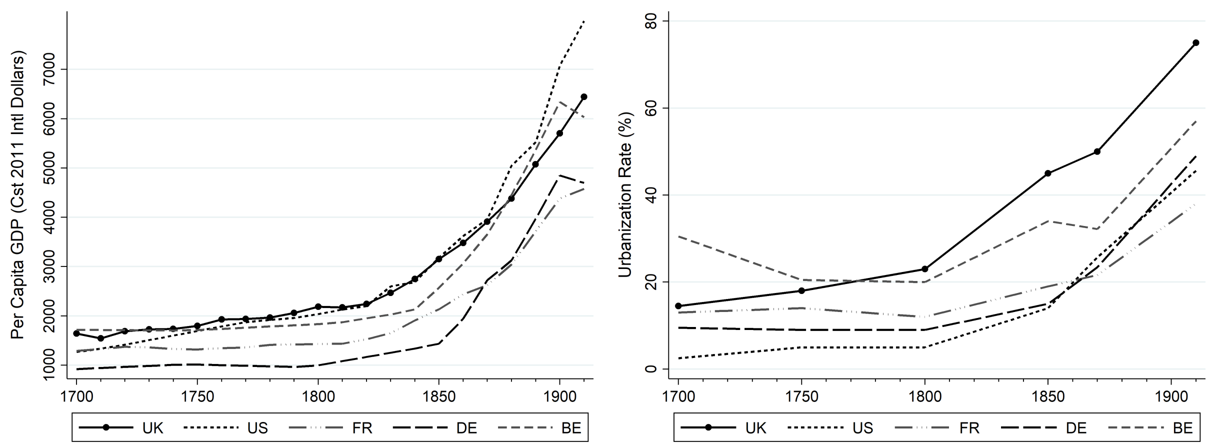
(a) UK Cities (b) U.S. Cities



Notes: Subfigure A.4a shows the crude death rate (per 1,000 people) for 194 city-decade observations in the UK. Subfigure A.4b shows the crude death rate (per 1,000 people) for 204 city-decade observations in the U.S. The figures also show for each decade the average unweighted rates (see the black connected lines) and the average rates when weighting each city-decade observation by its population in that decade (see the grey connected lines). The dashed vertical line shows the decade the (First) Industrial Revolution started in each country (1760 and 1790, respectively).

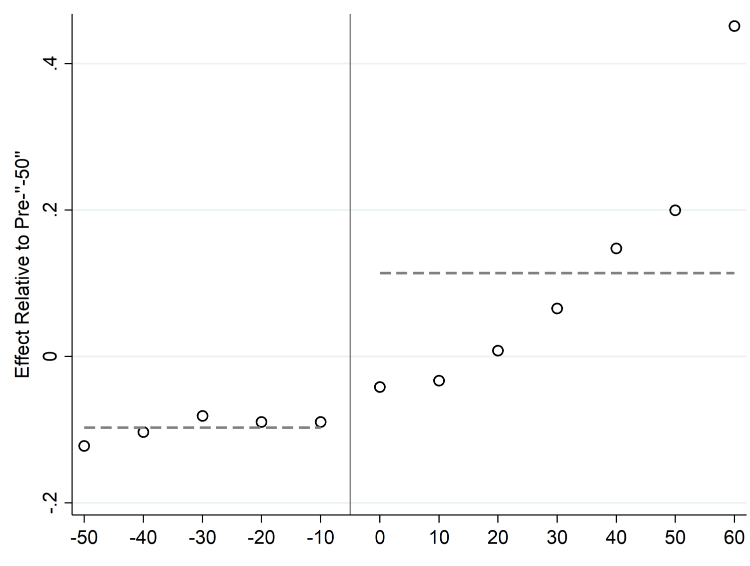
Figure A.5: Evolution of Income and Urbanization for Five Selected Countries, 1700-1910

(a) Per Capita GDP (b) Urbanization Rate



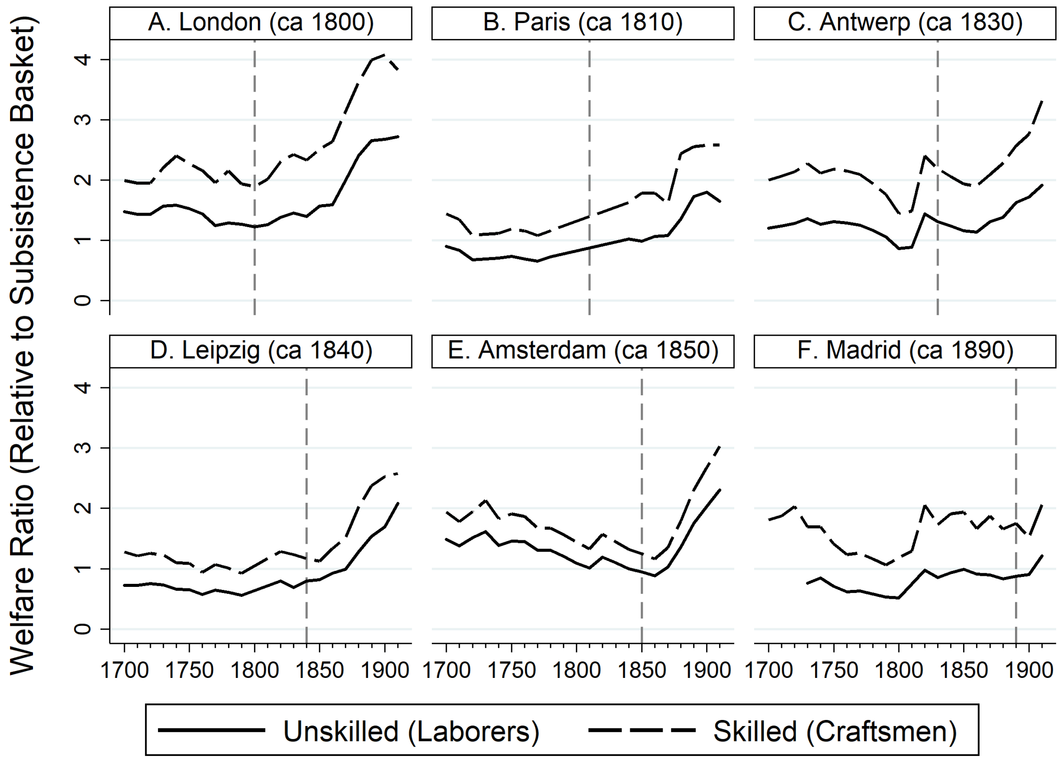
Notes: Subfigure A.5a shows the evolution of per capita GDP (cst 2011 intl dollars) for five selected countries (UK = United Kingdom; US = United States; FR = France; DE = Germany; BE = Belgium) in 1700-1950. Subfigure A.5b shows the evolution of the urbanization rate (based on cities above 5,000 inh.) for the same five selected countries in 1700-1950 (data only available in 1700, 1750, 1800, 1850, 1870 and 1910). See text for details on the sources used.

Figure A.6: Onset of the Industrial Revolution and Per Capita Income



Notes: This figure show the timing of the effects of the Industrial Revolution on log per capita GDP (in 1990 Geary-Khamis dollars, which is equivalent to PPP and constant international 1990 $), when using a panel-event study framework at the country level (N = 651; see text for details on the specification).

Figure A.7: Industrialization and Evolution of Standards of Living in Selected Cities



Notes: This figure shows the evolution of welfare ratios for six in-sample cities with data for both unskilled and skilled workers throughout the period 1700-1910. Welfare ratios measure the ratio of mean income to the income needed to afford a “subsistence basket” of goods and services allowing one individual to survive. The dashed vertical line shows the decade industrialization more or less started in each city. See text for details on the sources.

Table A1: NUMBER OF OBSERVATIONS AVAILABLE PER COUNTRY-PERIOD

		<1800		1800-1840		1850-1890		1900-1950	
	Country	CDR	CBR	CDR	CBR	CDR	CBR	CDR	CBR
1	Argentina	8	10	5	5	5	5	6	6
2	Australia					5	5	6	4
3	Austria			2		3	2	6	6
4	Belgium	2	2	5	5	13	13	14	14
5	Brazil					4	2	12	11
6	Canada					10	8	8	6
7	Chile					3	3	4	4
8	China							3	4
9	Cuba			5		5	2	6	3
10	Czech Republic	1		1		2	1	6	6
11	Denmark	3	3			2	2	6	6
12	Egypt					4	4	12	12
13	France	9	10	3	4	15	20	14	13
14	Germany	8		8	1	34	17	68	65
15	Hungary					3	2	6	6
16	India					9	6	20	14
17	Ireland					4	4	6	6
18	Italy	1	1		10	9	3	40	39
19	Japan					1	2	7	16
20	Latvia					3	3	6	6
21	Mexico					1		4	2
22	Myanmar					2	2	2	2
23	Netherlands	10	10	6	5	9	9	16	16
24	Norway					2	2	6	6
25	Poland							14	12
26	Portugal					2	1	3	2
27	Romania					1	1	1	1
28	Russia					8	5	7	7
29	Spain					3	2	16	16
30	Sweden	8	8	5	5	5	5	6	6
31	Turkey							2	2
32	Ukraine							2	
33	United Kingdom	20	17	16	5	57	51	101	102
34	United States	19	16	18	8	53	35	114	84
35	Uruguay	4	4	5	5	2	3	6	6
	Sum	93	81	79	53	279	220	556	511

Notes: This table shows the number of observations available for each country-period. CDR = crude death rate. CBR = crude rate of birth.

Table A2: SUMMARY STATISTICS FOR THE MAIN TABLES (TABLES 1-3)

Variable	Obs	Mean	Std. Dev.	Min	Max
TABLE 1:					
CDR	1,007	22.23	10.17	5.70	70.00
Dummy 1810-1910	1,007	0.54	0.50	0.00	1.00
Dummy 1920-1950	1,007	0.35	0.48	0.00	1.00
Log City Pop. Size	1,007	12.77	1.25	6.91	15.97
Log City Size * 1810-1910	1,007	6.88	6.34	0.00	15.80
Log City Size * 1920-1950	1,007	4.74	6.47	0.00	15.97
CBR	865	28.00	10.20	4.50	65.60
Dummy 1810-1910	865	0.49	0.50	0.00	1.00
Dummy 1920-1950	865	0.41	0.49	0.00	1.00
Log City Pop. Size	865	12.84	1.30	7.38	15.97
Log City Size * 1810-1910	865	6.21	6.39	0.00	15.80
Log City Size * 1920-1950	865	5.50	6.67	0.00	15.97
CRNI	825	6.39	7.79	-26.50	41.20
Dummy 1810-1910	825	0.48	0.50	0.00	1.00
Dummy 1920-1950	825	0.41	0.49	0.00	1.00
Log City Pop. Size	825	12.85	1.28	7.38	15.97
Log City Size * 1810-1910	825	6.13	6.39	0.00	15.80
Log City Size * 1920-1950	825	5.58	6.68	0.00	15.97
TABLE 2:					
CDR	1,007	22.23	10.17	5.70	70.00
Log City Size	1,007	12.77	1.25	6.91	15.97
Indu. Revo.	1,007	0.83	0.38	0.00	1.00
Log City Size	1,007	10.81	4.99	0.00	15.97
$\geq$ UK Inc. 1870	1,007	0.71	0.45	0.00	1.00
Log City Size	1,007	9.22	5.98	0.00	15.97
CBR	865	28.00	10.20	4.50	65.60
Log City Size	865	12.84	1.30	7.38	15.97
Indu. Revo.	865	0.83	0.38	0.00	1.00
Log City Size	865	10.91	5.02	0.00	15.97
$\geq$ UK Inc. 1870	865	0.72	0.45	0.00	1.00
Log City Size	865	9.44	5.95	0.00	15.97
CRNI	825	6.39	7.79	-26.50	41.20
Log City Size	825	12.85	1.28	7.38	15.97
Indu. Revo.	825	0.84	0.37	0.00	1.00
Log City Size	825	11.03	4.92	0.00	15.97
$\geq$ UK Inc. 1870	825	0.73	0.44	0.00	1.00
Log City Size	825	9.61	5.87	0.00	15.97
TABLE 3:					
CDR	1,007	22.23	10.17	5.70	70.00
Log City Size	1,007	12.77	1.25	6.91	15.97
Indu. Revo.	1,007	0.83	0.38	0.00	1.00
Log City Size	1,007	10.81	4.99	0.00	15.97
Indu. Revo. * Indu. City	1,007	0.67	0.47	0.00	1.00
Log City Size	1,007	8.76	6.23	0.00	15.97
Indu. Revo. * Maj Indu.	1,007	0.46	0.50	0.00	1.00
Log City Size	1,007	6.01	6.51	0.00	15.97
CBR	865	28.00	10.20	4.50	65.60
Log City Size	865	12.84	1.30	7.38	15.97
Indu. Revo.	865	0.83	0.38	0.00	1.00
Log City Size	865	10.91	5.02	0.00	15.97
Indu. Revo. * Indu. City	865	0.67	0.47	0.00	1.00
Log City Size	865	8.86	6.28	0.00	15.97
Indu. Revo. * Maj Indu.	865	0.46	0.50	0.00	1.00
Log City Size	865	6.06	6.58	0.00	15.97
CRNI	825	6.39	7.79	-26.50	41.20
Log City Size	825	12.85	1.28	7.38	15.97
Indu. Revo.	825	0.84	0.37	0.00	1.00
Log City Size	825	11.03	4.92	0.00	15.97
Indu. Revo. * Indu. City	825	0.68	0.47	0.00	1.00
Log City Size	825	8.93	6.25	0.00	15.97
Indu. Revo. * Maj Indu.	825	0.46	0.50	0.00	1.00
Log City Size	825	6.08	6.58	0.00	15.97

Table A3: COEF. OF INDUSTRIAL REVOLUTION COUNTRY DUMMY, ROBUSTNESS

Coefficient of $\mathbb{1}$ (Industrial Revolution $_{c,t}$ = 1) for the Dependent Variable Shown at Left:									
	Baseline	Var. of Interest in t-10	All Controls (t-s, t)	All Controls (t-s)	Drop >3 Years Census	Drop Outlying Rate	City's Number Obs. ≥ 5	Pop. Weights Year t	CRNI Sample (N = 825)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. Dep. Var.: CDR$_{c,t}$	-4.28***	-4.47***	-3.22**	-2.88*	-2.16	-1.65	-4.27***	-1.38	-3.46**
	[1.41]	[1.54]	[1.42]	[1.49]	[2.09]	[1.53]	[1.40]	[1.93]	[1.45]
Obs.	1,007	884	673	719	786	908	974	1,007	825
2. Dep. Var.: CBR$_{c,t}$	1.44	1.24	1.41	1.83	2.40	-0.18	1.50	2.06	2.46
	[1.90]	[2.13]	[1.61]	[1.83]	[3.40]	[1.33]	[1.87]	[2.84]	[1.92]
Observations	865	764	673	673	656	774	835	865	825
3. Dep. Var.: CRNI$_{c,t}$	5.82**	5.92**	4.63**	4.71**	4.64*	4.58*	5.82**	4.20*	5.82**
	[2.24]	[2.39]	[2.09]	[2.34]	[2.35]	[2.74]	[2.23]	[2.35]	[2.24]
Observations	825	729	673	673	634	697	802	825	825
City FE, Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table shows that the results for Indu. Revo. c, t (IR) in column (2) of row 1 of Table 2 hold when implementing various robustness checks (see text for details). Robust SEs clustered at the city level. * significant at 10%; ** 5%; *** 1%.

Table A4: COEF. OF CITY SIZE $\times$ INDUSTRIAL REVOLUTION COUNTRY, ROBUSTNESS

	Baseline	Var. of Interest in t-10	All Controls (t-s, t)	All Controls (t-s)	Drop > 3 Years Census	Drop Outlying Rate	City's Number Obs. ≥ 5	Pop. Weights Year t	CRNI Sample (N = 825)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A:	**Dependent Variable: Crude Death Rate$_{c,t}$; Country Trends Specification**								
Log City Pop. x IR	-0.10	-0.01	-0.53	-0.47	3.08	0.03	-0.44	4.77***	-0.52
	[0.80]	[0.02]	[0.91]	[1.01]	[2.02]	[0.93]	[0.36]	[1.72]	[1.02]
Obs.	1,007	884	673	719	786	908	974	1,007	825
Panel B:	**Dependent Variable: Crude Death Rate$_{c,t}$; Country-Year FE Specification**								
Log City Pop. x IR	-1.03**	-0.03	-0.40	-0.17	5.69	-0.85	-0.81***	7.58	-0.37
	[0.49]	[0.03]	[0.43]	[0.99]	[5.00]	[1.31]	[0.29]	[7.79]	[0.57]
Obs.	1,007	884	673	719	786	908	974	1,007	825
Panel C:	**Dependent Variable: Crude Birth Rate$_{c,t}$; Country Trends Specification**								
Log City Pop. x IR	0.94	0.06	-0.18	1.07	5.56*	-0.76	-0.02	3.77	0.24
	[1.07]	[0.04]	[0.68]	[1.16]	[3.33]	[0.58]	[0.99]	[3.19]	[0.96]
Observations	865	764	673	673	656	774	835	865	825
Panel D:	**Dependent Variable: Crude Birth Rate$_{c,t}$; Country-Year FE Specification**								
Log City Pop. x IR	-0.16	0.01	-0.30	0.06	10.90**	-0.30	-0.77**	8.93	-0.43
	[0.93]	[0.04]	[0.51]	[0.70]	[5.10]	[0.54]	[0.30]	[7.30]	[0.75]
Observations	865	764	673	673	656	774	835	865	825
Panel E:	**Dependent Variable: Crude Rate of Natural Increase$_{c,t}$; Country Trends Specification**								
Log City Pop. x IR	0.76	0.05	0.36	1.66*	3.25	0.35	-0.23	-0.37	0.76
	[0.76]	[0.04]	[0.79]	[0.88]	[2.08]	[0.51]	[0.62]	[1.88]	[0.76]
Observations	825	729	673	673	634	697	802	825	825
Panel F:	**Dependent Variable: Crude Rate of Natural Increase$_{c,t}$; Country-Year FE Specification**								
Log City Pop. x IR	-0.06	-0.01	0.10	0.29	4.28	-0.24	-0.50	1.66	-0.06
	[0.43]	[0.04]	[0.37]	[0.37]	[3.70]	[0.38]	[0.35]	[2.08]	[0.43]
Observations	825	729	673	673	634	697	802	825	825
City FE, Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table shows that the results for Log City Pop. x IR in column (2) of row 2 of Table 2 hold when implementing various robustness checks (see text for details). Robust SEs clustered at the city level. * significant at 10%; ** 5%; *** 1%.