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Gibrat's Law and the British Industrial Revolution[1]

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Abstract

This paper examines Gibrat's law in England and Wales between 1801 and 1911using a unique data set covering the entire settlement size distribution.We find that Gibrat's law broadly holds even in the face of population doubling every fifty years,an industrial and transportrevolution, and the absence of zoning laws to constrain growth. The result is strongest for the later period, and in counties most affected by the industrial revolution. The exception were villages in areas bypassed by the industrial revolution.We argue that agglomeration externalities balanced urban disamenities such as commuting costs and poor living conditions to ensure steady growth of many places, rather than exceptional growth of few.

Keywords: Gibrat's law, city-size distribution, industrial revolution

JEL: N93, R12

[1] We are grateful to Tony Wrigley and Leigh Shaw-Taylor for generously sharing their data with us, and seminar participants at Cambridge and LSE for helpful comments.

Introduction

Gibrat's law- an empirical regularity that postulates that the growth rate of places is identical for places of all initial sizes-has drawn a lot of scholarly attention in recent decades. It has been tested on numerous occasions since Gibrat's original article in 1931, with a large number of studies in the last decade.[2]Some studies find that Gibrat's lawholdswhile othersfind that it does not.[3]This paper is a contribution to this thriving research agenda.Ittests Gibrat's law for the nineteenth and the first decade of the twentieth centuryin England and Wales. This is particularly interesting for the following reasons: (i) this period covers the world's first industrial revolution,(ii) population doubles every fifty years[4], (iii) urbanisation is unprecedented in its speed and extent, and (iv) the economy had no planning or zoning rules,so that urban growth was the result of market forces. We examine Gibrat's Laws using a unique, authoritativeand comprehensive dataset of all cities, towns and villages (henceforth places) in England and Wales in the periods 1801-11, 1841-51, and 1901-11.

Testing whether Gibrat's law holds in past centuries and foran economyundergoingsubstantial structural and demographic changes is important for establishing its universality andthe industrial revolution in the nineteenth century Britain is an ideal historical circumstance to do that. The industrial revolutionradically changed the structure of the English economy and turned it into the first industrial nation and the most prosperous economy in the world. It is only natural then to ask:did Gibrat's law hold during the first industrial revolution? By answering that questionthis article contributes not only to

[2]A survey can be found in Gabaix et al. (2004), with a parallel literature in Industrial Organisation reviewed by Sutton (1997).

[3]Eaton and Eckstein (1997), Overman and Ioannides (2003), Eeckhout (2004), Gonzáles-val (2010) find that Gibrat's law holds whiles Black and Henderson (2003), Soo (2005), Garmestani et al. (2007), Bosker et al. (2008), Glaeser et al. (2011) and Michaels et al. (2012) find the cases when its universality is violated.

[4]Wrigley and Schofield (1981), p. 588.

the general literature on Gibrat's law, but also to the emerging literature specifically testing its universality when a country is subjected to economic shocks. It finds thatGibrat's law holds, except in small places in counties bypassed by the industrial revolution.

The structure of the paper is as follows: the second section discusses relevant literature relating both to Gibrat's law and to England and Wales in the period in question, the third section describes the data, sections four looks at whether Gibrat's Law holds, while section five places this finding in the context of the economy. Section six explains the findings, and the last section concludes.

Literature survey

Gibrat first postulated his law in his 1931 book, *Les Inégalités économiques*. The literature on Gibrat's law has grown dramatically over the past decade and includes studies covering different countries, using different methodologies, and with different size of settlements. Some of those studies confirm Gibrat's law, and somedo not.Most of the studies have looked at the United States. Overman and Ioannides (2003), Eeckhout (2004), and Gonzáles-val (2010) find that Gibrat's law broadly holds, whileBlack and Henderson (2003),Garmestani et al. (2007), Glaeser et al. (2011), and Michaels et al. (2012) find departures from it. It is likely that the differences in the results of those studies are due at least in part to different size of settlements and different methodologies including parametric and non-parametric regressions.[5]Despite these differences, some common results stand out. Gibrat's law appears to hold in the long run, but not in the short-run, andsmall and intermediate sizeplacestend to violate it. Indeed, both Gonzáles-val (2010) and Glaeser et al. (2011) point out that even

[5]Black and Henderson (2003), Overman and Ioannides (2003) and Garmestani et al. (2007) use sample consisting of large cities only while Eeckhout (2004), Gonzáles-val (2010), Glaeser et al. (2011), and Michaels et al. (2012) use sample consisting almost all cities.

though Gibrat's law seems to hold in the long-run – such as the period 1900-2000 in the former and 1790-1990 in the latter– there are decades when that is not so. Michaels et al. (2011) find that Gibrat's law is violated for intermediate-size places, while Eeckhout (2004) and Garmestani et al. (2007) suggest that Gibrat's law is less likely to hold for small places.

Studies examining other countries also use different size of settlements and different methodologies (Guerin-Pace (1995) for France, Eaton and Eckstein (1997) for France and Japan, Soo (2007) for Malaysia, and Bosker et al. (2008) for WestGermany). The results are, again, mixed, but there is good evidence that smaller placestend to violate Gibrat's law.[6] Since a similar conclusion was reached by the U.S. studies, it seems that the violation of Gibrat's law occurs mostly at the bottom of the city-size distribution.

The literature also finds that economic shocks can lead to the violation of Gibrat's law. Bosker et al. (2008), for example, examine the effect of the Second World War on the growth of German cities. They find that Gibrat's law holds before but not after the war, suggesting that the disruption caused by the war and its aftermath had a substantial impact on West Germany's urban system.The literature also covers long run shocks such as the movement from an agrarian to an industrial economy (Glaeser et al., 2011, Michael's et al 2012), or the later movement from an industrial to a service based economy (Black and Henderson, 2003). This literature again suggests that Gibrat's law can be violated in these circumstances. This paper is related most closely to this body of literature.

The nineteenth century British industrial revolution saw four major interrelated changes. First, the population grew at an unprecedented rate. Having grown by 1 million in the seventeenth century, it grew by almost 4 million in the eighteenth, and then by almost 24

[6]Soo (2007) also finds that state capitals and cities in the states of Sabah and Selangor do not follow Gibrat's law.

million in the nineteenth century (Mitchell 1988, pp. 7-9).Second, both total income and incomes per head rose. Third, England ceased to be a largely agrarian nation, in which people's locations were tied to the land. Finally, the nineteenth century witnessed a transport revolution covering almost every form of transport. Coal replaced human, animal and wind power. The steam train meant that people no longer walked, and goods no longer travelled by cart. Likewise the steam ship replaced sailing ships for both coastal and international journeys.

These changes both allowed and required changes in the location of population. Economic growth meant that the additional people were able to remain in England, rather than starving, or being forced to emigrate, as was the case in neighbouring Ireland. As a result some places were bound to grow dramatically. The growth of coal (as opposed to human, animal, or water) power as the dominant source of energy for industry led to a concentration of industry in and around the major coalfield areas which was to have important implications for the location of population. The application of coal to transport also allowed industry to be geographically concentrated, with products shipped by rail across Britain, and by steamship across the world. Trains also allowed food to be brought into cities from much further away, much more cheaply, eliminating an effective cap on city size. Finally, the arrival of the railway meant that people were able to migrate from one part of the country much more easily than they had done before, and for the first time in human history opened up the prospect of regular contact with family left behind.

England and Wales in this period was an almost pure market economy, virtually devoid of planning, zoning, and building laws. As a result we can see whether three simultaneous shocks - population increase, industrial transformation, and transport revolution – were sufficient to lead Gibrat's law to be overturned.

Data Description

Great Britain undertook the first census in 1801, and has had decennial censuses ever since. From 1811 onwards the censors usually reported the population in a place both at the census date, and as per the previous census. This allows us to have considerable confidence that a place with a given name is defined on a consistent basis over the decade. We use population data of all cities, towns, and villages in England and Wales between 1801 and 1911and look at changes in the size of places within 1801-1811, 1841-51, and 1901-1911, to represent the beginning, middle and end of the era.

Table 1 presents basic descriptive statistics. A few facts stand out. First, the average size of places grew from 656 people in 1801 to 2,314 in 1901, an impressive 250% growth rate. At the same time, the number of places recorded increased from 12,633 in 1801 to 14,059 in 1901, a growth rate of 11%. This meansthatthe growth in population wasled primarily by the growth in the size of existing places, rather than the emergence of new places. This is consistent with the characteristics of the country at that time: all of England and Wales was populated in 1801, so there was no frontier to open up. Some new settlements developed – along railway lines, for example – but population growth took place overwhelmingly in places that already existed.

Although the size of every class of place grew over the century – even the smallest 100 places grew from an average of 4 residents to 6 and then 7 over the century – larger places experienced the fastest growth. The largest 100 places grew from 22,941 in 1801 to 168,699 in 1901 – a growth rate of 630% – while all other places taken together grew by 135%. Of these, London was always dominant, growing from around 1 million in 1801, to 2 million in 1841 to 6 million in 1901, not far from its current size. When we look at our three individual decades, we find that average growth rates were 8%, 3% and 4% respectively, thus forming a

U shape over time. In contrast, the growth rates of the largest 100 places were 16%, 19% and 10% respectively, forming a ∩ shape over time.

Table 2provides further insights by presentingdata on the ten largest cities in England and Wales over thecentury. Threeitems are worth noting. First, not only was London always the largest city, but it was broadly an order of magnitude larger than the second city, Liverpool, in all periods. Second, Liverpool, Manchester and Birmingham make up the next three positions, in that order, in all three periods. This stable hierarchy was new: Bristol and Norwich had been the second and the third largest cities in England and Wales in the eighteenth centuries (de Vries 1984).The early stages of the industrial revolution disrupted the previous city hierarchy.Third, the absolute size needed to be in the top ten grew dramatically – from 31,000 to 240,000 over the century. That said, by 1900 the growth of the largest places was slowing, with 9 out of 10 recording rates of growth lower than the national average, in contrast to both earlier periods, in which top ten cities typically grew faster than average.

Figures 1a – 1c show scatter plots of the initial size of a place against its growth rate in each of our three decades. No obvious patterns are visible, suggesting that growth is independent of initial size in line with Gibrat's Law. What follows is a detail examination of the relation between growth and size.

City Growth

We now go on to investigate whether Gibrat's Law holds by using non-parametric regression analysis to test what, if any, relationships exist between growth rates and initial population rates. We use the non-parametric methodologypioneered by Ioannides and Overman (2003), and used since by Eeckhout (2004) and Gonzáles-Val (2010). The regression equation has the following specification:

$$g_i = m(S_i) + \varepsilon_i \qquad (1),$$

where g_i is the standardized growth rate of a place i (defined as the difference between the growth rate of the place i and the sample mean divided by the sample standard deviation), $S_i$is the log of the population size of the place $i$at the start of the period and m is a functional relationship.[7] We do not assume any specific relationship between g_i and S_i. Instead, we use the local average around S smoothed with a kernel – symmetrical, continuous and weighted function around S.We use the Nadaraya-Watson method in which

$$\hat{m}(s) = \frac{n^{-1}\sum_{i=1}^{n} K_h(s - S_i)\, g_i}{n^{-1}\sum_{i=1}^{n} K_h(s - S_i)}$$

where K_h is the Epachenikov kernel. The bandwidth h was calculated using Silverman (1986) rule. The 99-percent confidence intervals were bootstrapped from 1499 random samples with replacement.[8]The implication of Gibrat's law is that growth is independent of initial size. Since the growth rates are normalized, Gibrat's law will be strictly fulfilled when the estimated kernel takes the value of zero for all initial sizes. Deviations from that value imply violations of Gibrat's law. We can see this graphically by plotting 99-percent confidence intervals.If the zero-value line (in this case the x-axis) is outside the confidence intervals, then the relationship betweengrowth and size is not constant and Gibrat's law is violated.

[7]Ioannides and Overman (2003) and Gonzáles-Val (2010) use relative size. As a robustness check, we have also used the relative size and the results show no notable difference.

[8] We replicated the results with the bootstrapped standard errors using 500 random samples and no difference in statistical significance of the findings was revealed.

Figures 2a-2c present the non-parametric estimates, including 99-percent confidence intervals.[9]The confidence intervals for the smallest places are exceptionally wide – up to a factor of 30 – and therefore do not plot well. In these cases, the confidence intervals always include the line y=0, and thus there is no violation of Gibrat's Law.[10]

In all three cases we see an interesting and reasonably consistent pattern. The estimates of growth ratesare above zero for smallplaces (up to around 40, 20, and 40 inhabitants in 1801-11, 1841-51, and 1901-11 respectively). After this, the estimatesare generally negative, until a population size of about 1,000, 4,000 and 1,500 for the three dates. The right hand of the distribution is less consistent. In 1801-11, we have a twin-peak shape, in which the estimate is positive and rises to 12,000 inhabitants, falls off and even becomes just negative at around 40,000, before rising again to a second peak at around 80,000. 1841-51 shows a similar pattern but without the final dip. There is a rise to 40,000, an immediate dip to almost zero, and then a somewhat erratic rise thereafter. In contrast, 1901-11 sees a rise, something of a plateau at around 10,000, and then a decline, becoming negative for places of 60,000 people and above, being consistently negative when population exceeds 280,000.The variation of the growth rates also shows an interesting pattern: in all three cases, smallest places exhibit much larger variation in growth rates than large places.

When we look at the confidence intervals, we see a clearer picture. In all three decades, Gibrat's law holds for most size classes. The exceptions are reasonably small places. Specifically,in 1801-11, Gibrat's law is violated for places with populations 204-670. There

[9]The non-parametric estimator proposed by Nadaraya-Watson has potentially large bias near the boundary of the support. This means that London may bias the estimates as support at this boundary contains only one observation. For that reason the non-parametric estimates in Figures 2a-2c omit London. We have also used local polynomial regressions as a robustness check: the overall results do not change.

[10]The graphs scaled such that the confidence intervals for the smallest places are fully visible are available from the authors upon request.

are 5,476such places containing1.8mpeople, a little over a fifth of the total population of 8.3m.In 1841-51, Gibrat's Law is violated for places withpopulations between 144 and 167, and between 224 and 1,499. There areof such8,090 places, containing4.5m people, 30% of of the total population of 14.8m. In the decade 1901-11, Gibrat's law is violated for the places with populations between 100 and 135, and between 332 and 522. There are3,026such places and they containjust under 1m people, around 3% of the total population of 32m people.

Gibrat's law is also characterized by size-independent variance. We use Nadaraya-Watson estimation method to non-parametrically estimate variance $\sigma^2(s)$ as follows

$$\hat{\sigma}^2(s) = \frac{n^{-1}\sum_{i=1}^{n} K_h(s - S_i)\,(g_i - \hat{m}(s))}{n^{-1}\sum_{i=1}^{n} K_h(s - S_i)}$$

The bandwidth h was again calculated using Silverman (1986) rule.The estimates are presented in Figure 2d-2f. We can see that variance does depends on size for very small and very large places.There is no relationship between size and variance when we exclude the largest and smallest 2.5% of places. This is consistent with Eeckhout (2004) and Ioannides et al. (2003).

City Growth and the Industrial Revolution

We find that Gibrat's law holds for most of the populationduring the industrial revolution. This is an important finding, given the scale and revolutionary nature of the industrial revolution, as well as the extent of the accompanying urbanisation. It is hard to overstate the pace of change. For example, the number of miners rose by three quarters in the 1840s, during which the numbers working in transport – on roads, railways and in the docks – more than doubled (Mitchell 1988, pp. 103-4). The numbers working in the most "revolutionary" sector – textiles – rose by almost a half, to surpass a million for the first time.

“Unrevolutionary” sectors saw remarkably similar rises: both clothing and brickmaking rose by more than a half (Mitchell 1988, pp. 103-4). Surely, we might expect changes of these orders of magnitude to lead to widespread violations in the laws on the growth of city size. Yet we find that they did not, giving a sense of the strength of Gibrat’s Law.

To understand that findings better, a regional nature of the industrial revolution needs to be recognized. Indeed, the industrial revolution was not a country wide phenomenon. Instead, itoccurred in clusters – textiles in Lancashire, wool in Yorkshire, ship building in the North East ports. The core of industrial Britain moved north, away from the prosperous market towns of Southern England, surrounded by high quality agricultural land, and towards the coal fields of the North. Therefore, to illuminate our findings in Figures 2a-2c and to understand the effect of the industrial revolution on city growth, we divide the country into those areas that were affected by the industrial revolution and those that were not, and estimate equation (1) for both areas separately. This then helps us to understand why most of cities, towns and villages obey Gibrat’s law during the industrial revolution.

We divide places at the county level, according to the share of employment in modern industrial sectors, using Crafts (1985) as our source.[11] Those counties with 29.6% or greater of the male workforce in modern industries are counted as industrial revolution counties, while those with 14% or fewer in these industries are counted as non-industrial revolution counties.[12]We exclude the nine counties that lie between these figures, as they do not fit well

[11] Crafts (1985), Table 1.1, pp. 4-5.

[12] The cutting point of 29.6% is an obvious one because if we rank all counties by their share of employment in modern industrial sector, the county following the one with 29.6% is the one with 21.3% and the one before is 31.3%. The cutting point of 14% is less obvious and we used extensive historiography of the English counties to determine which counties did not belong to the core industrial revolution region. In addition, we conducted robustness checks and used the cutting points ranging from 13.1% to 14.7% and no significant change was revealed.

into either group.[13] We also exclude London, as not being readily comparable with any other place.In total, 21% of the population in 1801, 25% in 1841, and 28% in1901 are included in the industrial revolution category, while 52% in 1801, 45% in 1841, and 37% in 1901 are classified as non-industrial revolution places.Table 4 presents some descriptive statistics of places in the industrial revolution and non-industrial revolution counties respectively. We see that the industrial revolution cities are larger and grow faster than the non-industrial revolution ones andthe difference is most pronounced in 1841-51. We then repeat the earlier non-parametric analysis on each group of counties separately andthe results are given graphically in Figures 3a-3f. The left hand column gives the results for the industrial revolution counties, while the right hand column gives the equivalent figures for the non-industrial revolution counties. Similarly to the graphs in Figure 2a-2c, we face an issue of the scaling of the graphs so that the non-parametric estimates are presented clearly. We have again scaled the y-axes such that the estimates are clearly visible even though 99-percent confidence bounds for the smallest places are not fully visible.[14]

All of the figures except 3e are similar to the aggregate figures for the nation as a whole. This is true in the sense that the very smallest places are generally characterised as having positive growth rates with wide error bounds. The next set of places by size generally have negative growth rates, although this is not always statistically significant. Larger places generally have positive growth rates, although this is not statistically significant. The negative growth rates for small to medium sized places are statistically significantly different to zero for non-industrial revolution counties, but this is not true for industrial revolution counties. In 1801-

[13] We have also examined Gibrat's law for those nine counties and the analysis shows that it holds. The results are available from the authors upon request.

[14]The graphs which are scaled such that the confidence intervals for the smallest places are visible in their entirety are again available from the authors upon request.

11, 1.9million people lived in places with statistically significantly negative standardised growth rates, 42% of the total population of the non-industrial revolution counties. The equivalent figures for 1841-51 and 1901-11 are 4 million and 56%, and 2.8 million and 21% respectively.

Figure 3e shows the position for industrial revolution counties for 1901-11. This figure is *qualitatively* different to the other figures. A comparison of figures 3a and 3e shows that the central estimate is not statistically different to zero in both cases. That said, there is visually clearer pattern in 3a than in 3e. The pattern discernible in 3a is in fact seen in all other panels of figure 3 except 3e. In contrast the central estimate in 3e looks like a textbook representation of noise, centred around a mean of zero.Thus we can say, on the basis of Figure 3e, that there is evidence that the most advanced counties, in the latest period in our analysis, show a deeper level of compliance with Gibrat's Law than is the case in any combination of period and place.

Taken together, these figures show us that although Gibrat's Law was not broken by the Industrial Revolution, Gibrat's Lawdid not apply as strongly as we find in studies of more modern eras. There is a discernible pattern, and a minority of people live in places of sizes that violated Gibrat's law. By 1901-11, in contrast, when the industrial revolution counties were mature industrial economic regions, their city size relationships had settled down, and the strength and power of Gibrat's Law increased.

Understanding these Findings

Some of the recent economic models attempting to explain the reasons for Gibrat's law provide useful tools to understand the reasons why Gibrat's law would hold during the British industrial revolution, although others are less applicable.

Eaton and Eckstein (1997) offer a model based on the human capital accumulation and spillovers, which, however, delivers Gibrat's law only under a strict condition of zero discounting. This is not a plausible assumption. Similarly, Gabaix (1999) requires cities to be are characterized by amenity shocksthat are independent and identically distributed for Gibrat's law to hold. Again, this is not an accurate characterisation of this period. Rossi-Hansberg and Wright (2007) develop a stochastic urban model based on Henderson's (1974) system of cities model and Black and Henderson's (1999) model of urban growth. As well as other assumptions they require either no physical capital or no human capital in order for Gibrat's law to hold. This is not a plausible description of this period.

The models developed by Eeckhout (2004) and Córdoba (2008), unlike the above reviewed models, provide less restrictive and more applicable conditions under which Gibrat's law holds. Both share a common trait: they model Gibrat's law as an equilibrium condition between positive and negative externalities. Specifically, in Eeckhout's (2004) model, a city is characterized by a productivity parameter reflecting the city's technological advancement. Firms are identical and consist of one worker whose marginal productivity depends on the city's productivity parameter and a positive local externality from being in the city. On the other hand, not all labor is productive because of a negative externality due to commuting. Perfect mobility imposed by the model implies that in the equilibrium, city population will be such that the level of utility is the same across cities. This yields a function that depends on both positive and negative externalities. Gibrat's law then holds so long as the positive productivity externalities are not too large relative to the negative commuting externality. The Córdoba (2008) model looks for the restrictions on a general urban growth model that yield Gibrat's law.[15] The model is more complex than Eeckhout (2004) but its

[15]Córdoba (2008) paper looks at a wider range of issues than just Gibrat's law. The paper also studies the necessary conditions that explain a Pareto distribution of city sizes.

implication is similar: Gibrat's law is satisfied only if positive and negative externalities are identical across cities.[16] The externalities enter Córdoba's model in the production function. The positive externalities influence the firm's production function and may include informational spillovers, pecuniary externalities, and/or search and matching in local labor markets. Negative externalities, on the other hand, reduce the productivity of industries, and include congestion costs.

The models of Eeckhout (2004) and Córdoba (2008) provide a useful framework of thinking about Gibrat's law during the industrial revolution in Britain.On the one hand cities will grow because they create positive externalities that raise productivity, attracting more firms and leading to further city growth. On the other hand, the growth of the city creates commuting and congestion costs with raise workers reservation wages, thus giving firms an incentive to locate elsewhere. The combination of these two factors keep the city growth at balance, and ensure that Gibrat's law holds. The literature on the industrial revolution in Britain suggests that this combination of factos may well hold.. There is an extensive literature on the role of agglomeration economies in textiles, the core industrial revolution industry. This literature goes back to Alfred Marshall (1919, 1920), who identified "external economies of scale" as a source of firms' high productivity. Both industries were based on many almost atomistic firms, supported by a wide range of support services. Leunig (2003) shows that small textile firms took advantage of highly localised, within-city, agglomeration economies to ensure competitiveness despite much higher labor costs than prevalent in rival nations. The benefits of agglomeration were, however, exhausted at relatively low city sizes:

[16]The proposition 1 in the paper provides the conditions which restrict technologies, and preferences. Gibrat's law holds if, no matter what type of preferences, increasing returns are identical across industries. Gibrat's law holds if preferences are Cobb-Douglas so that the elasticity of substitution between goods equals 1.

even as late as 1906, Oldham was the centre of the global cotton spinning industry with just under 70,000 workers (Leunig 2003).

Those external economies of scalewere balanced, however, by significant urban disamenities. These included high commuting costs, congestion and poor living conditions. Mass urban transportation is essentially a twentieth century phenomenon. Although the first trams were installed in the 1870s, a combination of limited route mileage and initially high fares relative to wages meant that tram use was limited until the twentieth century and most people walked (Bagwell 1974, p. 143;Briggs, 1963). Although the monetary cost of walking is obviously minimal, the shadow cost in terms of time (and thus wages foregone) was high (Leunig 2006). This in turn meant that it was optimal for people to live and work in the same area of a town. Without planning laws to separate industrial and residential housing, the market provided what people wanted: tight urban areas with mixed use land patterns. The idea of a central business district, and residential suburbs was not yet a reality in England or any other country. This in turn limited the extent of agglomeration economies, as large cities became at least in part separate adjacent economic units, as opposed to a single economic entity.

Furthermore, larger cities were known to have substantial urban disamenties manifesting themselves as pollution, and unsanitary conditions. For example, in 1841, life expectancy at birth was just 25 in Manchester, 17 years lower than the national average (Voth 2004, 285).No wonder that Friedrich Engels described the conditions as “social murder” (Voth 2004, 284). Williamson (1990) estimated urban disamenity premiums neededfor potential migrants to consider moving to towns at three to seven percent. Since, as we argued above, external economies of scale were exhausted at low city sizes, the economies of scale available from locating in an outstandingly large city were not, for most firms, sufficient to allow them to pay sufficiently high wages to persuade people to endure the additional disamenity of the larger city. Places of the size of Oldham proved to be an optimal size for many firms, particularly in manufacturing as opposed to service sectors. As a result,the negative externalities of cities acted as a check and preventing cities from growing disproportionately fast. Therefore, English cities grew, but they grew proportionately, rather than developing into a handful of metropolises. This means, of course, that Gibrat's Law held.

We have noted in the previous section that figure 3e was qualitatively if not statistically different to the other panels in figure 3. In graphs 3a and 3c, representing industrial revolution counties in 1801-11 and 1841-51, there is a sense that the smaller places are being left behind, while the larger places, taken as a whole, are growing more quickly. This is simply not the case for the decade of 1901-11, where all places grow at similar rate and we get a sense that Gibrat's law seems to be obeyed completely and utterly. The reason is that by 1901 the industrial revolution, in the sense of transformation from agriculture to industrial economy, is over in these places: agriculture is now a tiny fraction of the economy. They remain industrial but the sense of change and newness has ended. There is development, but it is now the development of mature industrial areas. Some industrial towns were even beginning to shrink, in what would prove to be the start of a century long process of shedding manufacturing jobs. Demand for cotton and woollen textiles was still growing, but the rate of growth was slower than before. Low growth of demand, combined with reasonable rates of labor productivity growth meant that labor inputs were at best stable, and even beginning to decline in some areas (Leunig 2003). Indeed, cotton towns such as Rawtenstall and woollen towns such as Halifax began to lose population in this decade while many of the great merchant trading cities – places such as Liverpool and Manchester – saw rates of growth slightly below those of the nation as a whole. Many of the factors we take for granted to facilitate city living were yet to occur – mass urban transit schemes, electricity or gas rather than coal for heating, and universal indoor sanitation. Without a pressing rationale for expansion of these cities, expansion was no faster than elsewhere.

Figures 2a-2b and 3a-3d show that smaller places typically grew more slowly than larger places.This stems from the nature of English agriculture in this era, and its interaction with the emerging industrial communities. By 1800 Britain had a mix of large and small farms, but all were run on a capitalist rather than a subsistence or communal basis (Wordie, 1983). If a family was unnecessarily large for the labor demands of the farm, the excess family members would be expected to leave. Since small places were overwhelmingly agricultural, this generally meant leaving the village as well as the farm. As such small places grew less quickly than larger places.

These figures also show that small villages in industrial revolution counties grew more quickly than small villages in non-industrial revolution counties. This occurred for three reasons. First, small villages in industrial counties were more likely to make the transition from village to town, as industry arrived, than were villages in other counties. Major cotton towns such as Blackburn grew up from almost nothing, exemplifying this change (Beattie, 1992).Second, industrial revolution villages were more likely to be near successful industrial revolution towns, enablingsmall scale cottage industry and commercial services to survive and prosper more readily because of their proximity to larger places (Morris and Rodger 1993, p. 47). Finally, English agriculture responded well to the presence of local population. A large industrial town nearby changes the optimal crop towards relatively labor intensive fresh products, most obviously dairy (Hunt and Pam, 1997). This means thatin urbanising areas even villages that remain villages are likely to see a rise in population, unlike villages in other areas that cannot sustain such a rise. Taken together, these three factors mean that small villages in the industrial revolution counties experienced faster population growth compared with those in non-industrial revolution counties. And as figures 3b, 3d, and 3f show, those three factors were strong enough for villages in the non-industrial revolution counties to violate Gibrat's law: their standardized growth rate – growth rate relative to the average growth rate of the whole country – was negative, and statistically significantly so.

Conclusion

This paper has examined Gibrat's law for England and Wales in the period 1801-1911, the century of industrial revolution. It has found that Gibrat's law broadly holds though small villages in areas bypassed by the industrial revolution tended to violate it. While statistical tests indicate little or no violation of Gibrat's law during the entire nineteenth and the beginning of the twentieth century, the qualitative picture is slightly different. The nineteenth century witnessed more rapid growth of large towns and citieswith slower growth of small villages. In contrast the beginning of the twentieth centurydid not see any differences in the growth rates of places of different sizes in areas that had been affected by the industrial revolution. These counties were now mature. The paper also offers an explanation of the findings, based on the models of Eeckhout (2004) and Córdoba (2008). Specifically, it argues that the fact that Gibrat's law largely holds even during the rapidly changing environment of the British industrial revolution is because of the balance between positive agglomeration externalities and negative externalities of high commuting costs and large disamenities of urban life. The paper contributes to a growing literature on Gibrat's lawand complements earlier articles analysing population growth of cities during significant economic changes and shocks such as structural transformation in the U.S. (Michaels et al. 2012) and the Second World War (Bosker et al. 2008).

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Table 1: Descriptive statistics of all places in England and Wales, 1801-1901.

Range of cities	City size					Growth Rate non-standardized			
	N	Min	Max	Mean	Stdev	Min	Max	Mean	Stdev
1801									
All	12,633	2	958,863	656	8,696.61	-2.303	2.508	0.081	0.183
100 largest	100	5,746	958,863	22,941	95,338.48	-0.071	0.493	0.159	0.102
100 smallest	100	2	9	4	3.61	-0.693	2.508	0.398	0.604
In between	12,394	13	5,745	484	661.89	-2.303	2.199	0.079	0.177
1841									
All	13,544	2	1,945,327	1,096	17,140.06	-2.166	3.114	0.032	0.195
100 largest	100	12,104	1,945,327	49,756	193,841.00	-0.062	0.684	0.193	0.118
100 smallest	100	2	10	6	3.18	-1.253	2.197	0.250	0.607
In between	13,305	13	11,955	741	1,232.41	-2.166	3.114	0.029	0.186
1901									
All	14,059	2	5,847,903	2,314	51,213.35	-1.469	3.113	0.043	0.199
100 largest	100	38,309	5,847,903	168,699	585,675.10	-0.069	0.419	0.101	0.092
100 smallest	100	2	11	7	2.60	-0.847	2.197	0.290	0.601
In between	13,851	12	38,212	1,130	2,998.73	-1.469	3.113	0.041	0.192

Source: see text

Note: growth rates are in the logarithmic form

Table 2: Ten largest cities in the England and Wales, 1801-1901.

Rank at the beginning of decade	City	Population at the beginning of decade	Ratio to London	Pop_{end} /$Pop_{beginning}$	Stand. Growth Rate
		1801-11			
1	London	958,863	1.000	1.15	0.066
2	Liverpool	77,653	0.081	1.22	0.322
3	Manchester	70,409	0.073	1.13	-0.003
4	Birmingham	60,822	0.063	1.15	0.093
5	Bristol	40,814	0.043	1.14	0.045
6	Leeds	36,468	0.038	1.16	0.119
7	Norwich	36,238	0.038	1.01	-0.432
8	Portsmouth	33,226	0.035	1.25	0.457
9	Newcastle-on-Tyne	31,620	0.033	0.97	-0.603
10	Sheffield	31,314	0.033	1.14	0.056
		1841-51			
1	London	1,945,327	1.000	1.21	0.329
2	Liverpool	223,003	0.115	1.16	0.143
3	Manchester	163,856	0.084	1.14	0.087
4	Birmingham	138,215	0.071	1.26	0.476
5	Leeds	104,593	0.054	1.16	0.133
6	Sheffield	68,186	0.035	1.22	0.361
7	Bristol	64,266	0.033	1.02	-0.307
8	Norwich	61,846	0.032	1.10	-0.041
9	Newcastle-on-Tyne	55,884	0.029	1.17	0.174
10	Salford	53,200	0.027	1.19	0.256
		1901-11			
1	London	5,847,903	1.000	1.08	-0.086
2	Liverpool	704,134	0.120	1.06	-0.120
3	Manchester	644,873	0.110	1.11	-0.018
4	Birmingham	523,179	0.089	1.01	-0.237
5	Leeds	428,968	0.073	1.04	-0.165
6	Sheffield	409,070	0.070	1.11	-0.010
7	Bristol	339,042	0.058	1.05	-0.134
8	Bradford	279,767	0.048	1.03	-0.181
9	Newcastle upon Tyne	247,023	0.042	1.08	-0.079
10	Kingston upon Hull	240,259	0.041	1.16	0.087

Source: see text

Table 4: Population growth of counties by their Industrial Revolution status, 1801-1911.

	City size					Population Growth							
	N	Min	Max	Mean	Stdev	Min	Max	Mean	Stdev	Min	Max	Mean	Stdev
	1801					Pop_{1811}/Pop_{1801}				Stand. Growth Rate 1801-11			
Industrial revolution counties	2,086	2	77,653	831.9	2909.6	0.00	12.29	1.14	0.38	-4.23	41.76	0.04	1.44
Non industrial revolution counties	8,298	4	40,814	517.1	1169.0	0.00	9.02	1.09	0.22	-4.23	29.53	-0.14	0.81
	1841					Pop_{1851}/Pop_{1841}				Stand. Growth Rate 1841-51			
Industrial revolution counties	2,275	0	223,003	1641.6	7357.0	0.00	22.52	1.06	0.53	-3.70	71.01	-0.18	1.75
Non industrial revolution counties	8,784	0	64,266	772.1	2051.0	0.00	9.00	1.04	0.24	-3.70	26.16	-0.23	0.80
	1901					Pop_{1911}/Pop_{1901}				Stand. Growth Rate 1901-11			
Industrial revolution counties	2,075	2	704,134	4340.0	28575.8	0.31	18.98	1.13	0.72	-1.71	38.18	0.05	1.54
Non industrial revolution counties	9,838	3	339,042	1230.6	6890.1	0.23	22.48	1.06	0.40	-1.88	45.66	-0.11	0.86

Source: see text

Figure 1a

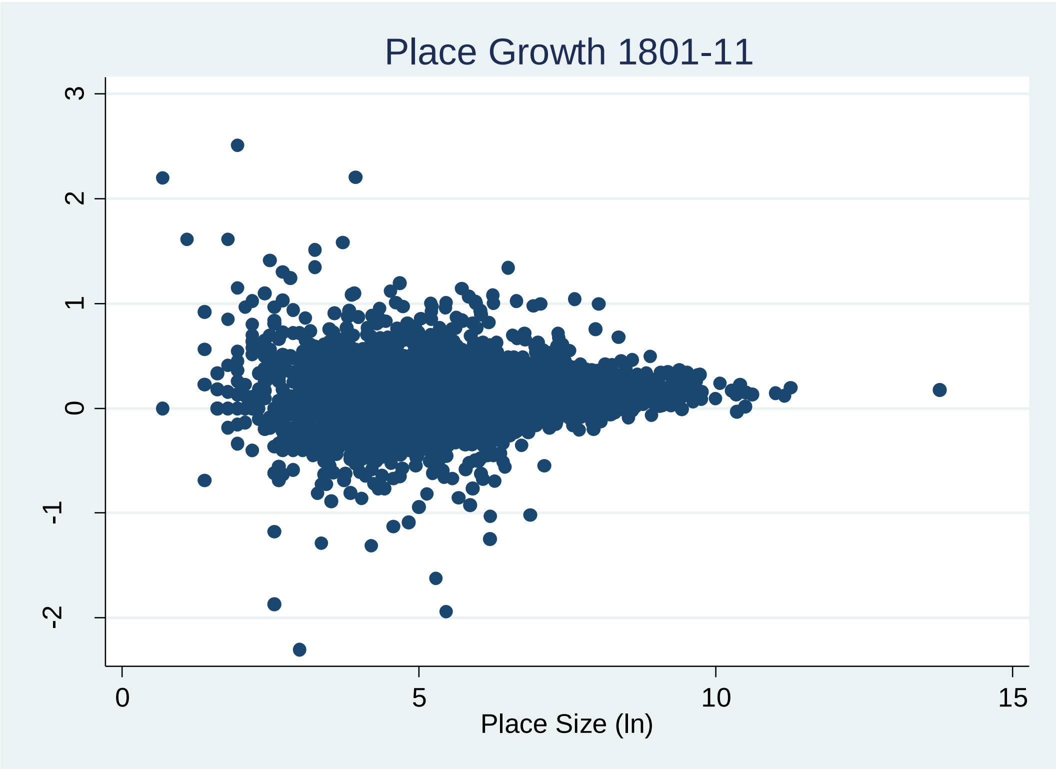


Figure 1b

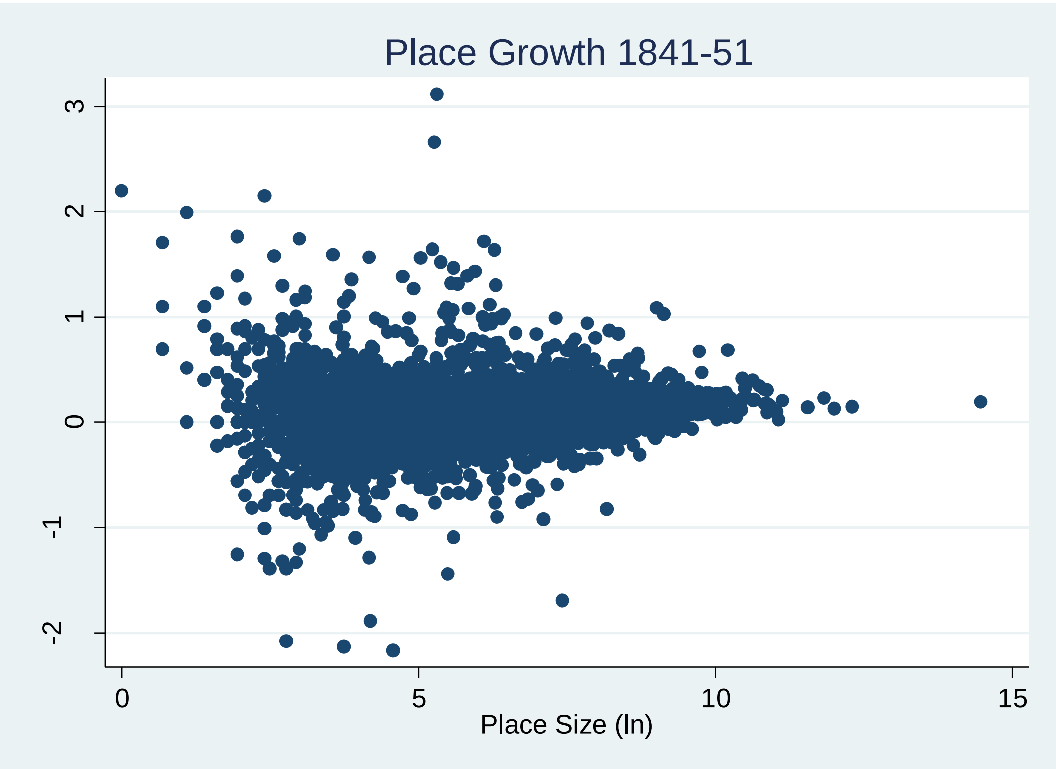


Figure 1c

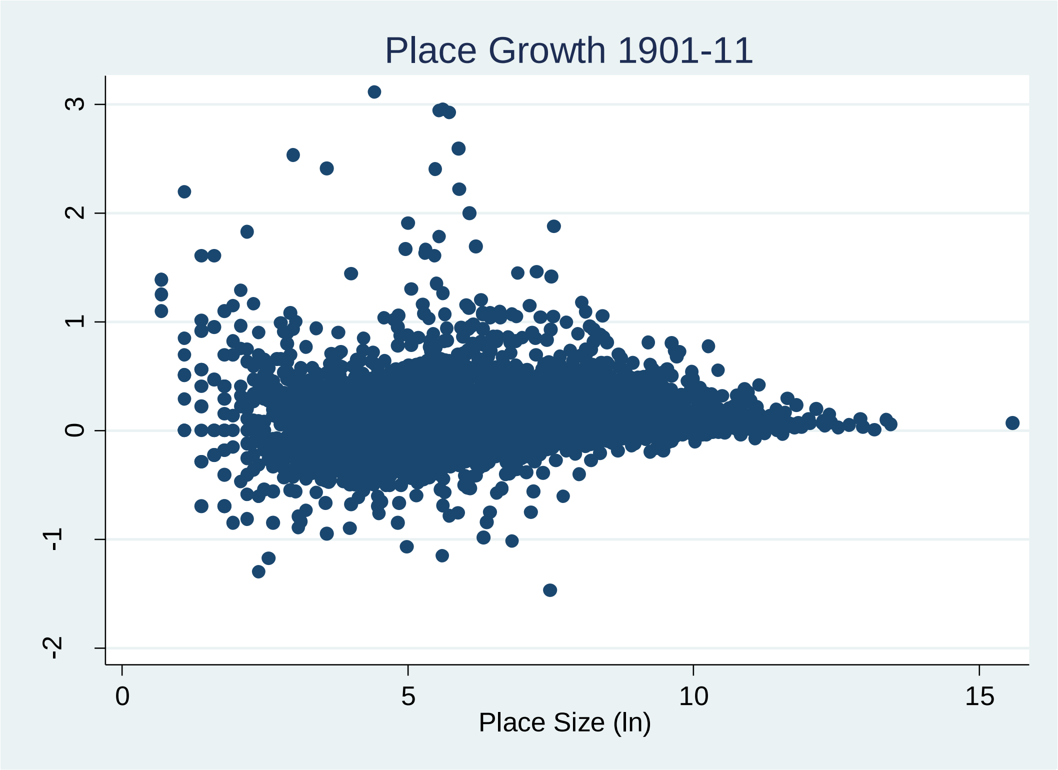


Figure 2a: Non-parametric estimates of population growth, England and Wales 1801-11

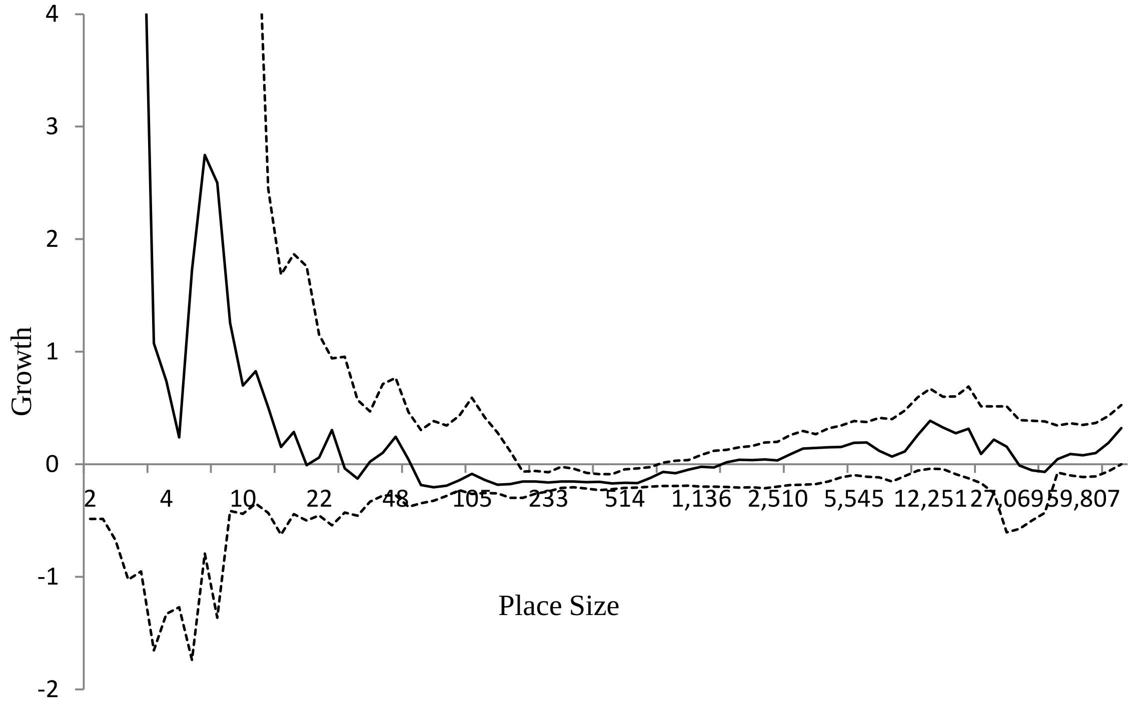


Figure 2b: Non-parametric estimates of population growth, England and Wales 1841-51

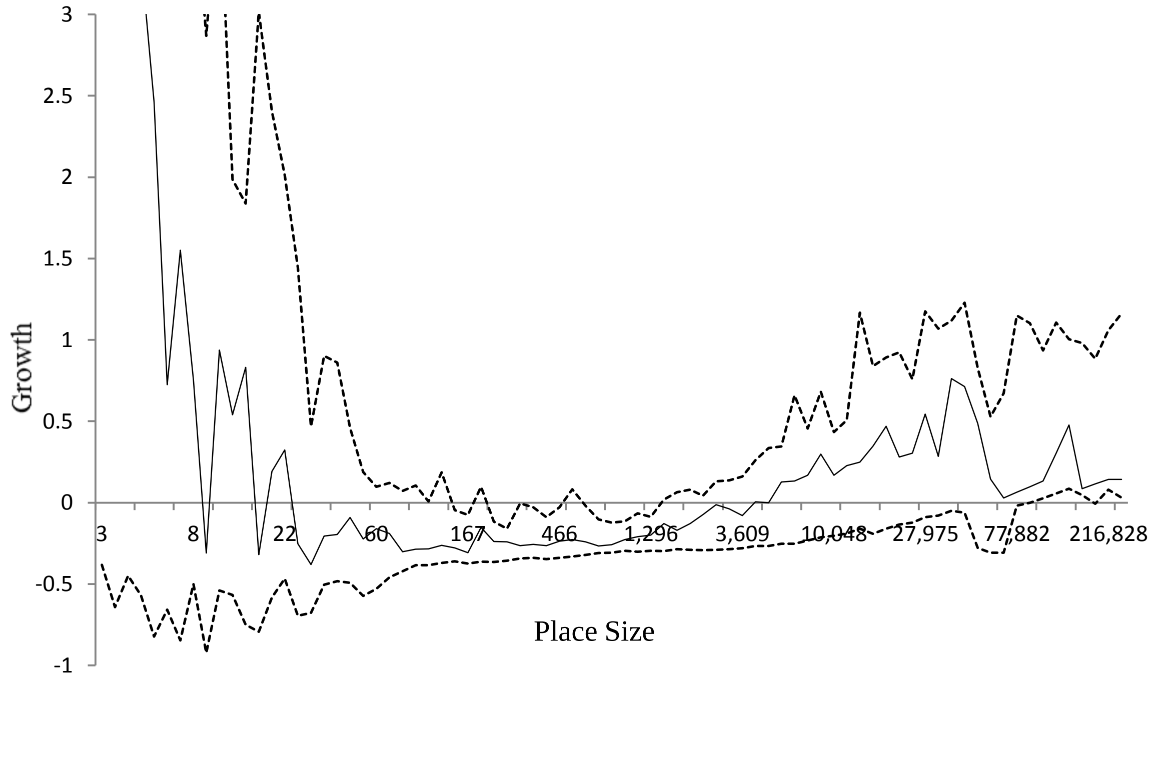


Figure 2c: Non-parametric estimates of population growth, England and Wales 1901-11

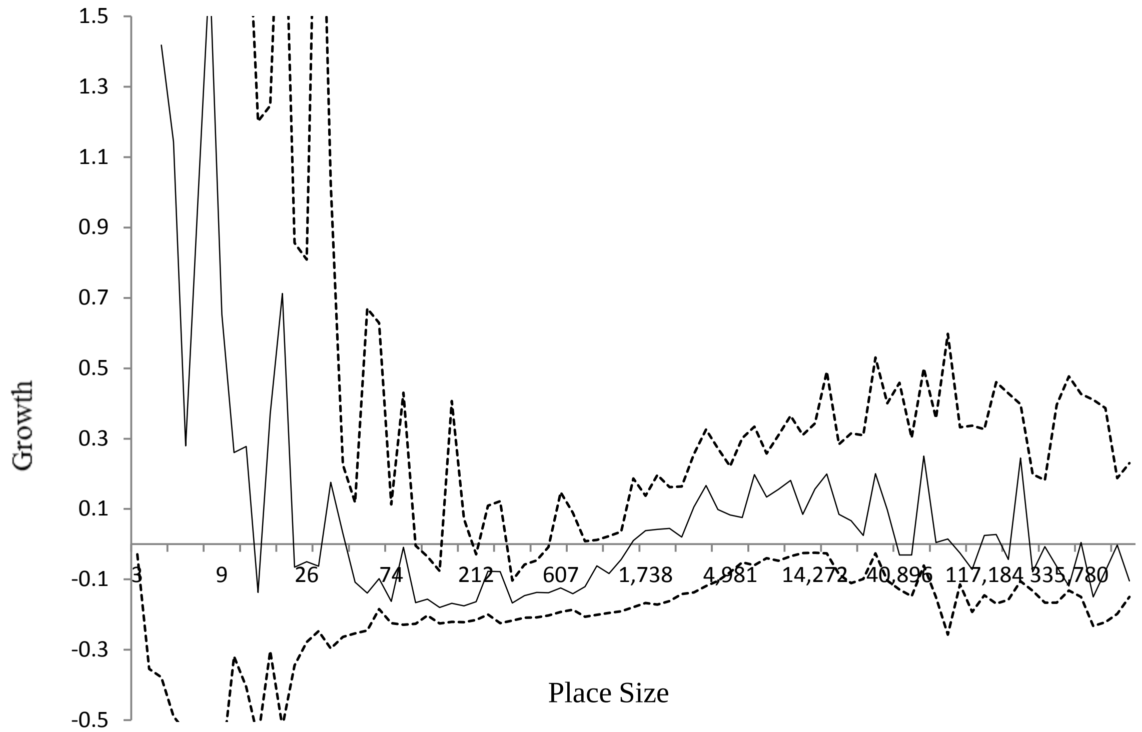


Figure 2d: Non-parametric estimates of the variance population growth, England and Wales 1801-11

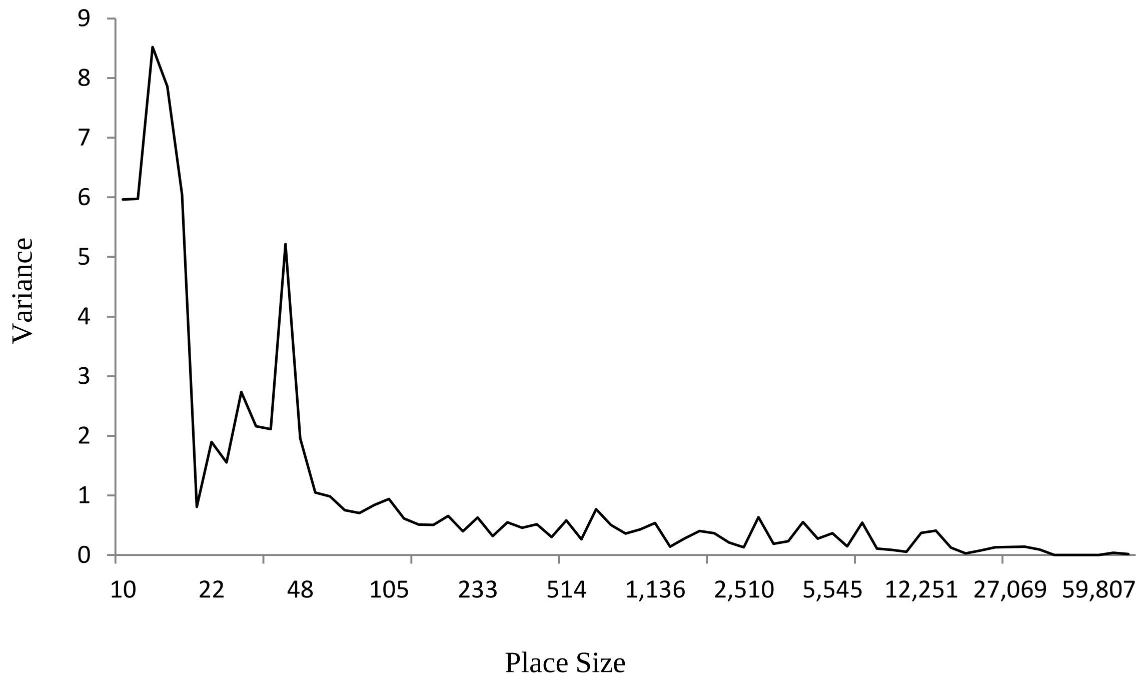


Figure 2e: Non-parametric estimates of the variance population growth, England and Wales 1841-51

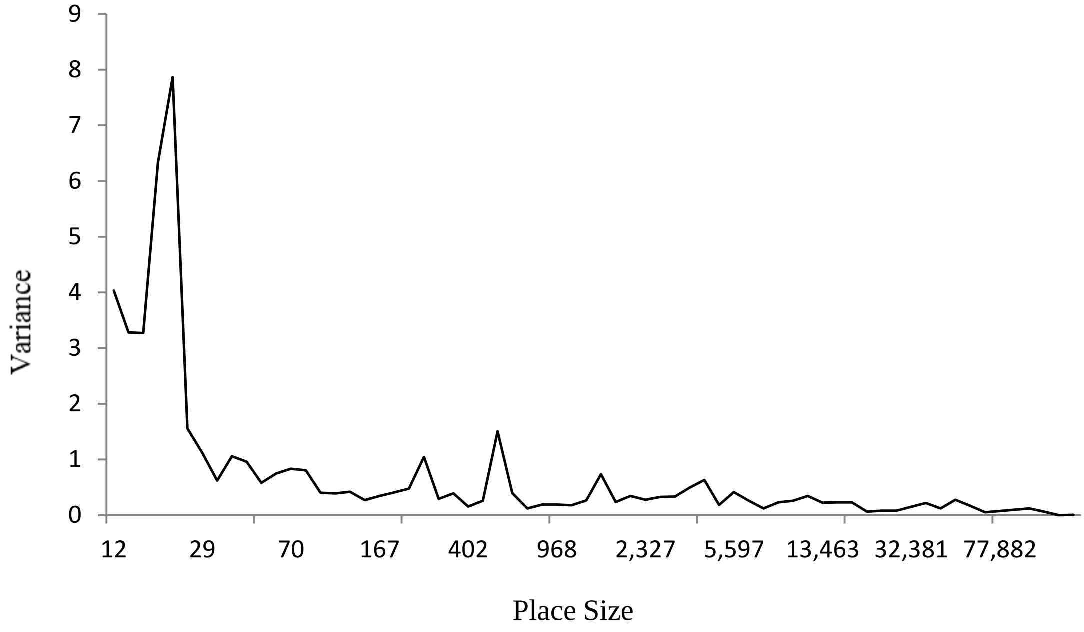
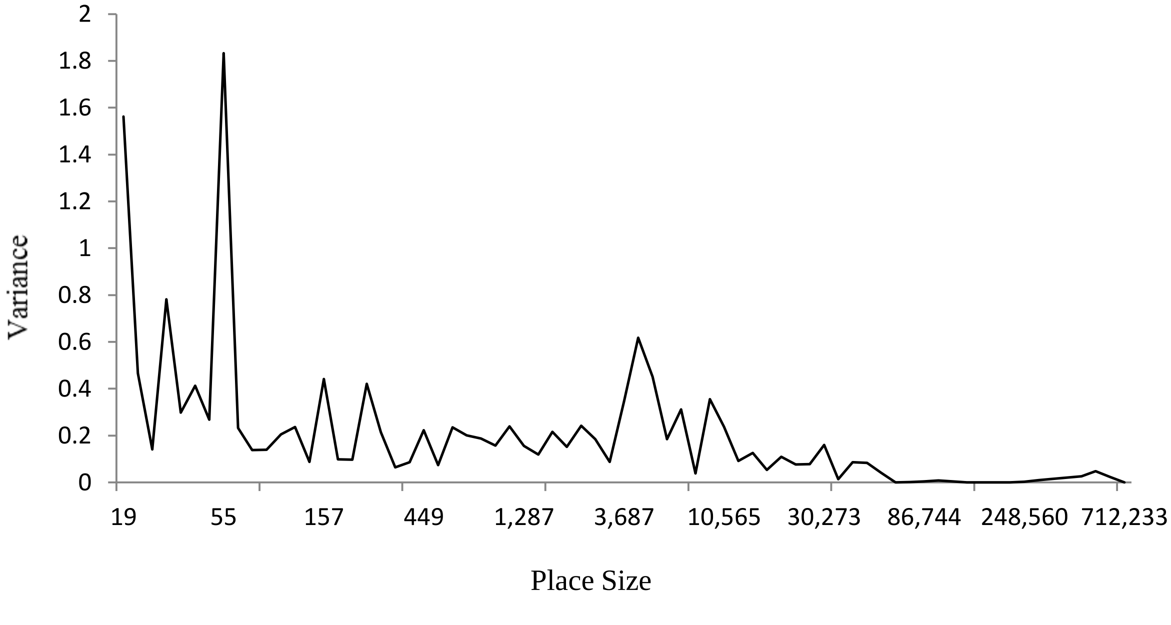


Figure 2f: Non-parametric estimates of the variance population growth, England and Wales 1901-11



Figures 3a-3f

Industrial Revolution Counties

Non-Industrial Revolution Counties

Figure 3a: 1801-11

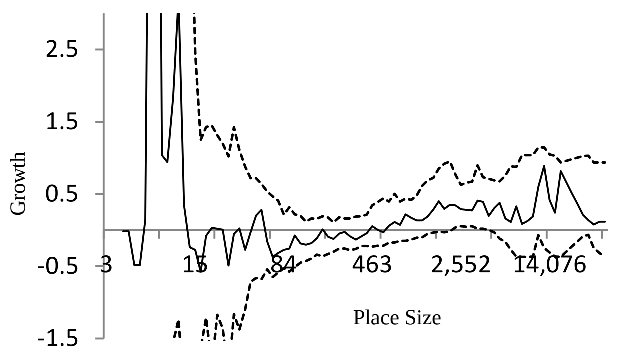


Figure 3b: 1801-11

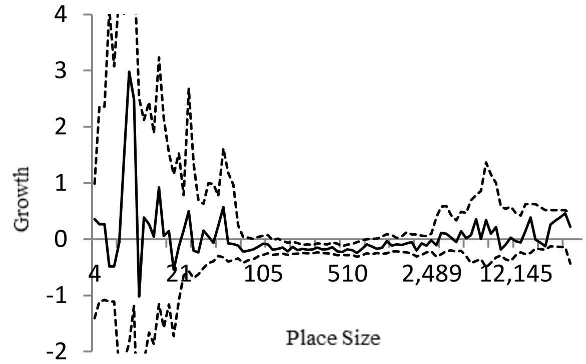


Figure 3c: 1841-51

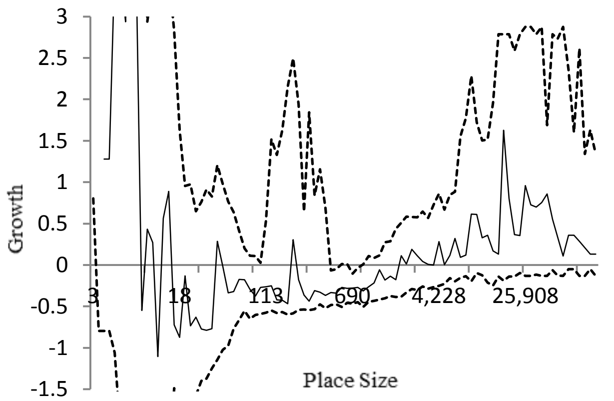


Figure 3d: 1841-51

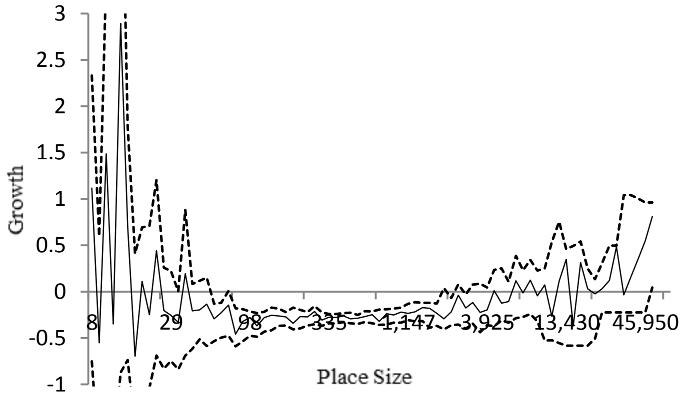


Figure 3e: 1901-11

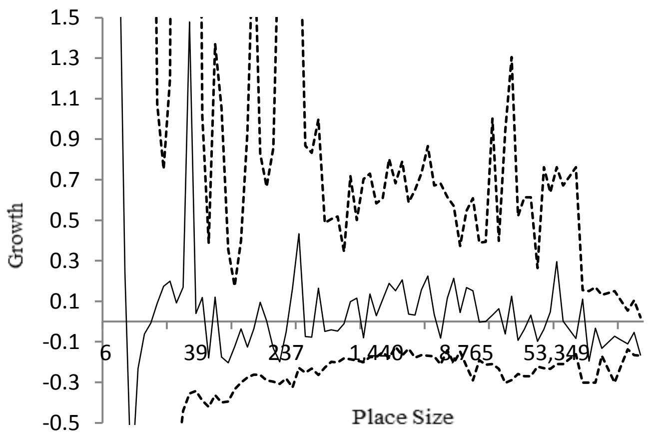


Figure 3f: 1901-11