

Population growth and manufacturing real wages in 18th century England: a spatial perspective*

Kristian Behrens[†]

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Abstract

We develop a two-region population growth model of economic geography and show that a process of urbanization has a substantial impact on the evolution of manufacturing real wages. Whereas real wages decline as the population increases when the spatial structure of the economy is fixed, they actually rise in the long-run when factors are mobile. Agglomeration may hence be seen as a rational response to declining real wages and provides a new explanation of why manufacturing real wages did not decline prior to the Industrial Revolution in England, despite a historically unprecedented population growth.

Keywords: population growth; real wages; economic geography; agglomeration; Industrial Revolution

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[†]CORE, Université Catholique de Louvain (Belgium), and LEG, Université de Bourgogne (France). E-mail: behrens@core.ucl.ac.be

1 Introduction

Ever since Malthus' "An Essay on the Principle of Population" (1798), economists and demographers have largely considered that, in the absence of technological progress, long-run population growth in a primarily agricultural society necessarily leads to decreasing per capita real wages in the short- and medium-run.

"The constant effort towards population, which is found even to act in the most vicious societies, increases the number of people before the means of subsistence are increased [...] The labourer therefore must work harder to earn the same as he did before" (Malthus, 1798, first edition, I.II.16).

Although there is much empirical evidence supporting this 'population pressure' scenario throughout most of history (see, e.g., Galor and Weil, 2000, for further references), Malthus himself would have been surprised to witness that the case of 18th century England constituted, in retrospect, a notable exception. Indeed, economic historians have repeatedly wondered why, despite a rapidly increasing population, real wages remained surprisingly constant throughout the 18th century and even slightly increased.¹ Technological progress in both agriculture and industry, rapidly expanding export markets and better property rights and incentives due to improvements in the institutional framework are the explanations most often put forward (see, e.g., North, 1981; Baldwin *et al.*, 2001). Although there has been some controversy on the relative importance played by each of these factors, existing theories have almost completely disregarded all *spatial aspects* in their analyses. Yet, we believe this is increasingly becoming a handicap as new empirical evidence is gathered, and new theoretical results are derived, showing that space and economic growth are closely intertwined.² Indeed, agglomeration is considered by many as being the spatial counterpart of economic growth, with the cities being its engines (Fujita and Thisse, 2002). According to Bairoch (1985) the urbanization rate increased from 13-16% to 22-24% in England during 1700 and 1800. Given the magnitude of this phenomenon it is, we believe, legitimate to ask how the rapid urbanization

¹According to Lee (1980), real wages in England were roughly the same in 1800 than they were in 1300.

²See, e.g., Sala-I-Martin (1996) and Quah (1996a, 1996b) for empirical and theoretical developments. Martin and Ottaviano (1999) as well as Fujita and Thisse (2002, Ch. 11) offer more theoretical economic geography oriented approaches to growth.

of England possibly influenced growth and hence the evolution of real wages during the 18th century.

There are presently only few contributions investigating the interactions of space, population growth and economic growth (see Baldwin and Martin, 2004, for a recent survey). Closest in spirit to our own work are the papers by Baldwin *et al.* (2001) and by Galor and Weil (1999, 2000). The first paper focuses on growth take-offs due to decreasing transport costs and capital accumulation, whereas population size is kept constant. The second group of papers focuses on population growth, yet neglects all spatial aspects. Other contributions dealing with space and growth, yet without a historical dimension, include Waltz (1996), Baldwin (1999), Martin and Ottaviano (1999, 2001) and Fujita and Thisse (2002, Ch. 11). All of these papers usually disregard the role of structural changes in the composition of the population as one switches from a predominantly agricultural to an industrial society.

In the present paper, we try to bridge the intellectual gap still separating *space and growth in economic history* by showing that spatial aspects play a decisive, yet neglected, role in determining whether or not a growing population leads to a Malthusian outcome in industrializing societies. In order to isolate the spatial components *per se*, we will abstract from more traditional factors like technological progress, expanding export markets and better institutions. This does of course not imply that these factors are unimportant or negligible. The main message we want to convey is simply that *spatial phenomena have a direct impact on real wages and growth on their own*, hence providing an additional (independent) explanation of why real wages did not decline during the 18th century in England.

Although there exist by now many different models of economic geography (see Fujita *et al.*, 1999a, as well as Fujita and Thisse, 2002, for recent surveys), most of these models are difficult to adapt to a historical context. Indeed, they usually put too much emphasis on the role of declining transport and trade costs (i.e. on the ‘prerailroad aspect’) and not enough on population growth and changes in the population structure (i.e. on the ‘preindustrial aspect’). Yet, this turns out to be problematic when dealing with the rise of agglomeration during the 18th century, because transport costs remained high and did only decrease little during this period (see, e.g., Armstrong, 1989). It seems that profound changes in the structure of the population were more at the origin of urbanization and agglomeration than decreases in the costs of transporting goods and people (Bairoch, 1985; Fisher, 1992). Stated differently, whereas urbanization steadily rose from the early 18th century on, the impacts of the ‘Great Transformation’

in transportation technologies were only felt from the late 1840s on, when railroads began to play a major economic role. Given the chronological order of the events, it is our contempt that the rapid urbanization of 18th century England cannot be explained in a satisfying way by a strong decrease in transport and trade costs.

We therefore develop an alternative model of economic geography which builds on several *key assumptions* that make it more suited to deal with the questions of agglomeration and growth from a historical perspective. This is because, even more than in Krugman (1991b), we rely on a modelling framework whose main assumptions “would have been satisfied in a prerail-road, preindustrial society”. First, there is an immobile agricultural sector, acting as a dispersion force. Although by now standard in models of New Economic Geography (henceforth NEG), it is becoming increasingly evident that such an assumption is more suited to the analysis of location patterns in industrializing countries than in industrialized ones. Indeed, the share of the agricultural population in today’s developed countries is quite low, so that urban congestion and land rents seem more plausible factors in explaining the limits to agglomeration (Tabuchi and Thisse, 2003). Second, we focus on a setting in which there is no interregional trade. Albeit particular, this simplifying assumption captures the historical fact that trading goods on the land route remained quite costly during the 18th century. Most goods were hence either produced for, and sold on, local markets only or were shipped to overseas markets via the cheaper sea routes. Only with the development of railroads during the 19th century and with the establishment and enforcement of efficient property rights, did transport and trade costs start to decrease significantly so that large-scale trade on the land route became economically feasible.³

In Section 3 we present some evidence that suggests that our modelling framework is well suited to the analysis of growth and agglomeration in a historical context like that of 18th century England. We briefly discuss the topics of changes in the population structure due to the emergence of the industrial sector and provide some figures that reveal the magnitude of internal migratory movements. Some evidence on transport and trade costs completes this historical overview.

³Although transport costs (especially those of ocean shipping) declined during most of history, this secular movement was very slow. Transport and transaction costs hence remained sufficiently large to foreclose most complex economic exchange (North, 1981). Only from the 1840s on is there a ‘revolution’ in transportation technologies, leading to a very sharp and rapid decrease in the costs of transporting goods and people and (somewhat later) in the costs of transmitting information.

In Section 4 we develop a “dynamic model” that allows for an *exogenous growth* in the agricultural and the manufacturing populations. We show that the non-agricultural population must grow at a faster pace than the agricultural one in order for agglomeration to be sustainable in the long-run. Yet, we also show that the ‘spatially constrained equilibrium growth path’ is associated with decreasing real wages should this condition hold. Hence, our model exhibits a Malthusian behavior: as population gradually increases real wages decrease. Such a result only holds when the spatial structure of the economy is kept invariant. When the economy is free to evolve along its ‘spatial-temporal equilibrium growth path’, an increasing population leads to both increasing agglomeration and increasing real wages, thus showing that the Malthusian tendencies possibly get reversed when production factors are mobile between regions.

Because there are obvious limits to agglomeration, there are corresponding limits to economic growth. Ultimately, as argued in Section 5, only technological change can spur some additional growth once the population gets sufficiently large. This is reminiscent of Kelly (1997, p. 940), who argues in the context of Smithian growth that if “the sources of further growth – capital accumulation, innovation, and learning by doing – are blocked, the acceleration that occurs when the Smithian threshold is reached will be followed by stagnation”. In other words, the *agglomeration-driven growth uncovered here tapers progressively off and need to be followed by Schumpeterian growth*.

Section 2 outlines the static model, whereas Section 6 concludes.

2 The static model

In this section, we present the static model based on the quadratic-linear framework by Ottaviano *et al.* (2002) and its extension by Behrens (2004). Consider an economy with two regions, labeled H and F . Variables associated with each region will be subscripted accordingly. There are two production factors in the economy: manufacturing workers, who produce a continuum of a differentiated good under monopolistic competition and increasing returns to scale; and agricultural workers, who produce a homogeneous good under constant returns to scale and perfect competition. Whereas manufacturing workers are geographically mobile between regions, agricultural workers are immobile. We denote by L the mass of mobile and by A the mass of immobile factor in the economy. In order not to endow one region a priori with a larger market size than the other, the immobile factor

is assumed to be evenly split between the two regions. The distribution $\lambda \in [0, 1]$ of the mobile factor located in region H is, on the contrary, determined endogenously. Finally, N stands for the mass of varieties produced by the differentiated industry. We assume that there are no economies of scope in the production of manufacturing varieties, so that increasing returns to scale imply that each firm produces a single variety. Hence, N also stands for the total mass of firms in the economy.

The agricultural good can be transported at no cost both within and between regions.⁴ Hence, its price is the same across all regions, which makes it a suitable choice for the numéraire. The differentiated good can be transported at no cost within each region, whereas shipping one unit between regions H and F involves a unit transportation cost of $\tau > 0$ units of the numéraire. Each worker is endowed with one unit of labor, which she supplies inelastically, and $\bar{q}_0 > 0$ units of the numéraire at each period of time. The endowment $\bar{q}_0$ is supposed to be fixed but large enough for her consumption of the numéraire to be strictly positive at the market outcome at all periods of time. A typical agent established in region $r = H, F$ thus solves the following consumption problem:

$$(\mathcal{P}_Q) \begin{cases} \max_{q_r(v), \forall v \in [0, N]; q_0} & \alpha \int_0^N q_r(v) dv - \frac{\beta - \gamma}{2} \int_0^N q_r(v)^2 dv - \frac{\gamma}{2} \left[\int_0^N q_r(v) dv \right]^2 + q_0 \\ \text{s.t.} & \int_0^N p_r(v) q_r(v) dv + q_0 = y_r + \bar{q}_0 \end{cases}$$

where $\alpha > 0$, $\beta > \gamma > 0$ are parameters, $p_r(v)$ is the consumer price of variety v in region $r = H, F$ and y_r is the agent's income (which depends on whether she works in the agricultural or in the manufacturing sector).

As can be easily verified, the problem $(\mathcal{P}_Q)$ yields *linear* demand functions. Hence, demand $q_r^*(v)$ for variety v drops below zero once the price $p_r(v)$ exceeds some endogenously determined reservation price. In order to obtain a meaningful specification, only the positive part of the demand is taken into consideration (see Behrens, 2004, for an economical and mathematical justification). The demand functions can hence be expressed as

$$q_r^*(v) = [a - (b + cN)p_r(v) + cP_r]^+, \quad (1)$$

⁴As shown by Picard and Zeng (2003), positive agricultural transport costs alter the equilibrium path of the model when transport costs for manufactured goods decrease. Because we assume that manufacturing transport costs remain constant, normalizing agricultural transport costs to zero entails no loss of generality. When trading the agricultural good is costly, agglomeration is less likely to occur, yet the qualitative results of the model remain the same.

where $[\cdot]^+$ denotes the positive part, where a , b and c are positive coefficients given by

$$a \equiv \frac{\alpha}{\beta + (N-1)\gamma}, \quad b \equiv \frac{1}{\beta + (N-1)\gamma}, \quad c \equiv \frac{\gamma}{(\beta - \gamma)[\beta + (N-1)\gamma]} \quad (2)$$

and

$$P_r \equiv \int_0^N p_r(v) dv \quad (3)$$

is the aggregate price index of the manufacturing industry in region r . Clearly, $\bar{P}_r = P_r/N$ can be interpreted as the average price of the manufacturing products in region $r = H, F$.

In what follows, we assume that markets are *segmented* so that firms are free to set a price particular to each market they sell their output in. Indeed, there is ample evidence suggesting that even in today's integrated world of 'free trade', international (and even interregional) markets remain significantly segmented and hence prone to discriminatory pricing policies (see, e.g., Greenhut, 1981; Haskel and Wolf, 2001). We can hence safely assume that in the past, when transport costs were high and information was very incomplete, market segmentation was the rule and not the exception. Denote by $p_{rs}(v)$ the price charged for a variety produced in region $r = H, F$ when sold in region $s = H, F$. Assuming that all firms are symmetric, except for their location and the variety they sell, we drop the firm index v in what follows. Using expression (1), the demand a firm located in region r faces in region s is given by

$$q_{rs}^*(p_{rs}) = [a - (b + cN)p_{rs} + cP_s]^+. \quad (4)$$

Each firm in the manufacturing sector incurs a fixed cost of $\phi > 0$ units of mobile labor and mq units of immobile labor to produce the quantity q . Without loss of generality, we may set $m = 0$ because this amounts to rescaling firms' demand intercepts (see Ottaviano *et al.*, 2002). Labor market clearing in the manufacturing sector then requires that the equilibrium masses of firms in the two regions are given by

$$n_H = \lambda L / \phi \quad \text{and} \quad n_F = (1 - \lambda) L / \phi. \quad (5)$$

Under these assumptions, the profit of a representative firm established in region $r = H, F$ is given by

$$\pi_r = p_{rr} q_{rr}^*(p_{rr}) \left(\frac{A}{2} + \phi n_r \right) + [p_{rs} - \tau] q_{rs}^*(p_{rs}) \left(\frac{A}{2} + \phi n_s \right) - \phi w_r, \quad (6)$$

where q_{rr}^* and q_{rs}^* are given by (4) and w_r is the manufacturing wage in region r . As argued previously, demand drops to zero once the price charged by the firm exceeds some consumer reservation price. Using expression (6), one can show that firms will necessarily set such a price once the costs τ of trading goods across regions exceed some threshold value. Stated differently, when trading varieties across regions is too expensive, the profit maximizing firm will set a price such that consumers in the other region do not buy at that price. The threshold value of trade costs for this to happen for all firm distributions $\lambda \in [0, 1]$ is given by

$$\tau_a \equiv \frac{a}{b} = \alpha. \quad (7)$$

In what follows, we assume that $\tau \geq \tau_a$ so that there is no interregional trade in manufactured goods. This implies that *competition is very localized* and does not directly take place across the whole industry, which makes the assumption of monopolistic competition more acceptable. As shown by Behrens (2004), when condition (7) holds, the equilibrium prices are given by

$$p_{rr}^* = \frac{a}{2b + cn_r}, \quad r = H, F \quad \text{and} \quad p_{sr}^* = 2p_{rr}^*, \quad s \neq r, \quad (8)$$

whereas individual equilibrium demands can be expressed as

$$q_{rr}^* = (b + cN)p_{rr}^*, \quad r = H, F \quad \text{and} \quad q_{sr}^* = 0, \quad s \neq r. \quad (9)$$

Entry as well as exit of firms in the manufacturing sector are free, which implies that wages in this sector are determined by the zero-profit condition. Although this assumption is not likely to hold, the 18th century saw the rise and fall of many small and medium-sized proto-industrial and industrial firms. Stated differently, there was a fast turnover of firms, many of which sprang up rapidly in response to new economic opportunities, only to disappear as quickly when business conditions became less favorable.

Substituting (8) and (9) into (6) and equating the resulting expression to zero, we obtain

$$w_r^* = \left(\frac{A}{2} + \phi n_r \right) \frac{(b + cN)(p_{rr}^*)^2}{\phi}, \quad r = H, F. \quad (10)$$

Using the symmetry between firms and substituting expressions (8) – (10) into $(\mathcal{P}_Q)$, the equilibrium indirect utility in region $r = H, F$ can be expressed as

$$V_r^* = \frac{b(b + cN)}{2} \left[\frac{a}{2b + cn_r} \right]^2 \left[3bn_r + cn_r^2 + b \frac{A}{\phi} \right] + \bar{q}_0. \quad (11)$$

Define the *indirect utility differential* between the two regions H and F as

$$\Delta V^*(\lambda) \equiv V_H^*(\lambda) - V_F^*(\lambda). \quad (12)$$

A *spatial equilibrium* is such that no mobile worker has an incentive to change location, conditional upon the fact that the product markets clear at the equilibrium prices (8) and the labor markets at the equilibrium wages (10). Formally, a spatial equilibrium arises at $\lambda \in (0, 1)$ when $\Delta V^*(\lambda) = 0$, or at $\lambda = 0$ if $\Delta V^*(0) \leq 0$, or at $\lambda = 1$ if $\Delta V^*(1) \geq 0$. Such an equilibrium always exists because ΔV^* is a continuous function of λ (Ginsburgh *et al.*, 1985, Proposition 1). An interior equilibrium is stable if and only if the slope of the indirect utility differential (12) is negative in a neighborhood of the equilibrium, whereas the two agglomerated equilibria are always stable whenever they exist.

As shown by Behrens (2004), in the absence of interregional trade the spatial equilibria are as follows:

Proposition 1 *Assume that $\tau \geq \tau_a$. Then, depending on the mass of immobile factor A and mobile factor L in the economy, the stable spatial equilibria are as follows:*

[1] *a completely agglomerated equilibrium with $\lambda = 0$ or $\lambda = 1$ if A lies below the sustain point A_s , given by*

$$A_s \equiv \frac{4b\phi}{c} \frac{3b\phi + cL}{4b\phi + cL}.$$

[2] *a dispersed equilibrium with $\lambda = 1/2$ if A lies above the break point A_b , given by*

$$A_b \equiv \frac{3\phi b}{c} + \frac{L}{4}.$$

[3] *a partially agglomerated equilibrium with $0 < \lambda < 1$, $\lambda \neq 1/2$ if A lies between the sustain point A_s and the break point A_b . In that case, the interior equilibria are given by*

$$\lambda^\pm = \frac{1}{2} \pm \sqrt{\frac{1}{4} + 4b\phi \frac{3b\phi + c(L - A)}{L^2 c^2} - \frac{A}{L}}.$$

Without loss of generality, we assume that agglomeration takes place in region H whenever it occurs (i.e. $\lambda \geq 1/2$). Because λ must be real and lies in the interval $[1/2, 1]$ a more concise way to write the spatial equilibrium is given by

$$\lambda^* = \min \left\{ \text{re} \left(\frac{1}{2} + \sqrt{\frac{1}{4} + 4b\phi \frac{3b\phi + c(L - A)}{L^2 c^2} - \frac{A}{L}} \right), 1 \right\}, \quad (13)$$

where $\text{re}(\cdot)$ denotes the real part. One should note right from the beginning that the nature of the spatial equilibrium is mainly determined by the relative values of the mobile and the immobile factors (i.e. by A and L).

3 The historical background

Let us provide some historical facts explaining why we believe our analytical framework is rather well suited to the analysis of 18th and early 19th century England. For the sake of brevity, we focus on three important topics only: *enclosure acts and population structure*; *demography and internal migration*; and *transport costs and trade*. These three topics are each important on their own. When taken together, they show that the main assumptions of our modelling framework roughly match the historical evidence.

3.1 Enclosure acts and population structure

One cannot understand the particular economic dynamics of England during the 18th century without taking a closer look at the great agrarian reorganization of the territory, i.e. the movement of *parliamentary enclosure* which involved about 6.8 million acres of land (Dewey, 1989). The precise reasons underlying this large enclosure movement, which had already begun earlier and on a smaller scale in the 16th and 17th centuries, are not known with certainty. Yet, most economic historians agree with Dewey (1989) on the fact that the rapid spread of enclosure was a rational response to population and market growth. In the presence of sustained population growth and the resulting economic opportunities, subsistence farming was slowly giving way to large-scale and market-oriented agriculture. Hence, economic factors like productivity and scale economies certainly played a major role in explaining both the rapidity and magnitude of this movement.

Despite its absolute importance (it involved about one-fifth of the land area of England!), the enclosure movement was neither uniformly spread over time nor space. Concerning the spatial dimension, the enclosure movement was strongest in predominantly agricultural counties that still had a large proportion of open field, commons and wastes. The North-East (Lincolnshire, Nottinghamshire), the East (Cambridgeshire, Norfolk) and some central regions (Oxfordshire) were the most affected, with 25-50% of their agricultural area being enclosed by Act of Parliament during the 18th and early 19th century (all figures are taken from Cook and Stevenson, 1983; Dewey, 1989). On the contrary, the enclosure movement was very weak in the emerging industrial and commercial core regions (the industrializing

North-West and the London area in the South-East), as well as in the remote periphery of the South-West (e.g. Cornwall, Devon) and the North (e.g. Northumberland, Cumbria). In these regions, enclosures amounted to less than 5% of the agricultural area.

These figures reveal that the geographical distribution of enclosure was highly uneven, with a strong downward gradient from the more centrally located regions towards the North-West and the South-East. Stated differently, the uneven spatial distribution of enclosures released a large number of workers in essentially rural areas, creating strong incentives for their migration to more urbanized regions.

Concerning the distribution of parliamentary enclosure in time, it is of interest to note that it was also very unevenly spread throughout the one and a half centuries between 1700 and 1850. There are especially two peaks, covering the periods 1760-1770 and 1793-1815, during which about 80% of enclosures took place (Cook and Stevenson, 1983; Dewey, 1989). If we reasonably assume that there is a lag between the release of agricultural labor and the acceleration of agglomeration due to population migration, the enclosure peak of 1760-1770 might explain the rapid changes in urbanization that took place from the early 1780s on.

Although the enclosure movement had several different impacts on the organization of the English economy, one point is of particular interest for the issue of agglomeration and growth: *being no longer tied to the land, a larger fraction of the labor force became increasingly mobile*. Stated differently, because the enclosure movement mainly consisted in a reorganization of land towards larger scale farming without open fields and commons, it released an important number of workers formerly active in the agricultural sector from its spatial immobility (Fisher, 1992). As an important consequence, the structure of the English population significantly changed during the whole 18th century. Indeed, although the agricultural population of England grew in absolute numbers until approximately 1850 (Dewey, 1989), the ratio of agricultural to manufacturing workers significantly decreased (see, e.g., Jackson and Timmins, 1989; Fisher, 1992). The speed and the magnitude of this phenomenon reached a scale unprecedented in human history:

One of the most striking movements towards the specialization of a country's industries, which history records, is the rapid increase of the nonagricultural population of England in recent times (Marshall, 1890, first edition, IV.X.16).

A good indicator of the magnitude of this structural modification can be found in the evolution of the main components of GNP. According to Fisher

(1992), whereas English GNP approximately tripled between 1700 and 1800, the share of the agricultural sector dropped from 40% to 26.7%. At the same time, the share of manufacturing and industry in GNP rose from 33% to approximately 45%. Table 1 summarizes these evolutions.

Insert Table 1 about here.

Two remarks are in order. First, the increasing share of manufacturing and industry in GNP suggests that the share of national income of manufacturing workers rose (in absolute but not necessarily in per capita terms). Hence, because manufacturing workers were no longer tied to the land, *purchasing power became more and more mobile in space*. This in turn constitutes a factor that significantly raises the propensity for an economic agglomeration process to trigger through demand-driven backward linkages (see, e.g., Krugman, 1991; Fujita *et al.*, 1999a; Ottaviano *et al.*, 2002). Second, the structural modifications did not affect the nonagricultural, nonindustrial (and commerce) sector, whose part in GNP remained relatively constant throughout the 18th century.⁵ Hence, we can neglect the influence of these components in what follows and solely focus on the evolution of the agricultural and manufacturing population without essentially violating the historical evidence.

3.2 Demography and internal migration

It is a well documented fact that, by historical standards, population grew at a sustained rate throughout most parts of Europe during the 18th century (see, e.g., Bairoch, 1985; Fisher, 1992). England was no exception and it can even be safely stated that population growth was particularly sustained in this region of Europe. Rapid population growth from the mid-18th century on is probably one of the main reasons for the two subsequent peaks in the enclosure movement. Indeed, increasing population put pressure on agricultural prices, which in turn significantly raised the economic value of wastes and commons, creating a strong economic incentive in favor of private property (North, 1981; Dewey, 1989). The detailed implications of the macroeconomic effects of rapid population growth are clearly beyond the scope of this paper. Yet, we will focus more closely on the implications of *migration-driven differential population growth* affecting the main regions of England during the 18th century.

⁵The 1780 decade being an exception directly linked to the War of Independence with the future United States

As argued by Jackson and Timmins (1989), the population of the North-West as well as that of Greater London grew at a faster pace than the national average until the beginning of the twentieth century. Let us try a ‘statistical’ exercise in order to illustrate how ample this differential population growth may have been.

According to Fisher (1992), the English population grew by approximately 73.2% between 1701 and 1801 (see Table 2, Column 4). Therefore, in the absence of internal (and/or external) migratory movements, the population should have roughly been multiplied by a factor of 1.7 at every location of the English territory. That this was not the case is obvious from the historical data. Liverpool and Manchester grew from approximately 6000 and 9000 inhabitants in 1700 to respectively 76000 and 81000 inhabitants in 1800, whereas Leeds and Sheffield grew from 7000 and 8000 to respectively 52000 and 47000 during that same period (Bairoch, 1985, p. 331). The cities of the urban core in the North-West (Manchester, Liverpool, Sheffield and Leeds) hence grew from 30000 inhabitants in 1700 to 256000 inhabitants in 1800, i.e. their size was multiplied by a factor of 8.53. This trend was further amplified during the early 19th century, when clusters of small industrial towns and villages sprang up around them (Brown, 1989).

The growth of London between 1700 and 1800 was, at first sight, less spectacular. Indeed, according to Bairoch (1985), its size increased from 550000 to 860000 inhabitants, i.e. it was multiplied by a factor of 1.53 ‘only’. Yet, this figure is a lower estimate than the actual value, because life expectation was worse and fertility lower in large cities than in the countryside during this period. Most cities had an internal demography that did not even allow for a constant population size. Therefore, immigration was vital in order for cities to maintain their size and, *a fortiori*, to grow.

When taken together, London and the North-West grew by approximately 547000 inhabitants, which roughly corresponds to 15% of the total increase in the English population during the 18th century. This evolution was reflected in the urbanization rate, which increased from 13-16% in 1700 to some 22-25% in 1800 (see, e.g., Bairoch, 1985; Braudel, 1984a), leading to a spectacular growth in markets for certain types of products like textiles, clothing and manufactures.

3.3 Transport costs and trade

Although it is extremely difficult to make any precise statement about the evolution of transport costs in England during the 18th century, some general conclusions can be drawn from the historical evidence. First, it is sure

that *transport costs were still high* because the ‘Great Transformation’, due to railroads and steamboats, was only about to begin in the 19th century. Indeed, it seems that railroads began to play a major economic role only in the late 1840s (Hohenberg and Lees, 1985; Bairoch, 1985), date from which on transport costs decreased significantly. The principal modes of transportation for both goods and passengers during the 18th century were small ships (coasters) or horse-drawn coaches. The coasters had a much higher carrying capacity than coaches and allowed for the transport of bulky loads, but their reliance on navigable inland waterways, wind power, seasonal conditions and weather made them rather unreliable and therefore unsuited to fast and scheduled shipment. Further, because there was only a restricted number of navigable rivers and canals, freight often had to be transferred back on the road, which was ruinously costly for more bulky industrial goods and machinery. Although numerous canals were constructed during the first half of the 18th century, their impact on the overall value of trade costs remained low. Horse drawn coaches were much faster and reliable than coasters, but their inherent *lack of scale economies due to restricted carrying capacities* made them unsuited for large-scale goods transport. Further, the general state of English roads in the 18th century was rather bad. Even if the Turnpike Trusts contributed a lot to their improvement during the 18th century, road transport remained still slow and expensive, especially for bulky and/or fragile goods (see, e.g., Jackman, 1962; Armstrong, 1989). We can hence safely conclude that *interregional transport costs on the land route remained relatively high and did not decrease much* until the introduction of railroads in the early 19th century.

There is some debate on the role and importance of trade during the 18th century (see Baldwin *et al.*, 2001, for further references). Indeed, it seems that *international trade* increased at a much faster pace and played a more important role than *interregional trade* in the economic development of England. According to Braudel (1984b), English firms producing primarily for the domestic market increased their output by only 50% during the 18th century, despite a 70% population growth, whereas firms producing primarily for export markets increased their output by about 500% during the same period. This large difference could be driven by the fact that the costs of exporting goods were much lower than the costs of shipping goods across the English countryside.⁶ Indeed, ocean freight allowed for some scale

⁶Note also that England had a complicated system of transit-duties during the 18th century, which impeded even more the transport by land routes (e.g. the Turnpike Trusts had local authority to collect tolls, the structure of which remained obscure and was subject to ‘arbitrary’ changes). The so-called regime of ‘free trade’ did not emerge in

economies and its costs had declined significantly from the late 16th century on (essentially due to the eradication of piracy and some technological improvements in shipbuilding), whereas terrestrial transport costs and inland shipping remained comparatively costly. Locations with good access to the sea gained from the ‘commercial revolution’ that transformed the ports of London and of Liverpool into central nodes of the emerging world trade network (Hohenberg and Lees, 1985). Of course, there was interregional trade between the different parts of England. Nevertheless, much of the small-scale manufacturing production was still primarily produced for and sold on local markets, whereas a large share of the industrial production (e.g. textiles) was exported.⁷ Although there is no historical data on the importance of manufacturing trade flows between the English regions during the 18th century, it seems that the rapid growth in the volumes of international trade was the driving force behind the increase in market size.

4 Population growth, geography, and real wages

Although economic geography models describe an inherently dynamic process, namely the *evolution of the distribution of economic activities in space*, they are most often of a static nature (see, e.g., Krugman, 1991; Fujita *et al.*, 1999a). Our model developed in Section 2 is no exception to this rule. In the present section, we extend the model to cope with spatial equilibrium under a growing population and a changing population structure. Although our model is not really a dynamic one, because it lacks intertemporal optimization, we believe it is more than a comparative statics exercise since we focus on variables that grow at different rates.

In what follows, we assume that the mass of manufacturing workers grows at a *constant exogenous rate* l , whereas the mass of agricultural workers grows at a constant exogenous rate k . Such a hypothesis of unexplained population growth is standard in neoclassical growth theory and some models of economic geography (see, e.g., Puga and Venables, 1998; Fujita *et al.*, 1999b). Time is continuous and at each period t the economy is described by an instantaneous equilibrium in which agents maximize their objectives and factor and product prices adjust to clear all markets. We further assume, in order to keep the model as simple as possible, that all agents are myopic and

England until the 1840s.

⁷Some important English industries already exported an unusually high proportion of their output. The cotton industry, for example, depended for more than 50% of its sales on foreign markets (Baldwin *et al.*, 2001).

have a very high future discount rate. Hence, all agents take their decisions at time t based on current considerations only. The populations A and L at time t can be described by the functions

$$A(t) = A_0 e^{kt} \quad \text{and} \quad L(t) = L_0 e^{lt}, \quad t \geq 0, \quad (14)$$

where A_0 and L_0 are the historically given populations at time $t = 0$.

Let us assume for now that the *population composition*, namely the ratio of agricultural to manufacturing workers A/L remains unchanged. Of course, this is only possible if $k = l$, i.e. both A and L must grow at the same constant rate g . Historically, this seems to have been the case for a rather long period before the 18th century (see Bairoch, 1985). Under these assumptions, we can show the following (all proofs are relegated to the appendix):

Proposition 2 *Assume that $\tau \geq \tau_a$. Assume further that both A and L grow at the same constant rate g . Then, there exists a period $\bar{t}$ from which on dispersion is the only stable spatial equilibrium.*

Proposition 2 shows that if the population grows at a constant rate and if *its composition remains unchanged*, we necessarily end up sooner or later with a completely dispersed spatial equilibrium. As argued in Section 3.2, the English population increased sharply between 1700 and 1800, whereas the urbanization rate rose from 13-16% to 22-24% (Bairoch, 1985). Yet, as argued in Section 3.1, there was a major *structural change* in the population composition as more and more labor was drawn from the agricultural to the industrial sector. Stated differently, the ratio A/L strongly decreased.

Let us hence drop the ‘unrealistic’ assumption that A and L grow at the same rate and assume henceforth that $l > k$. This can be interpreted in terms of a shift in labor from the agricultural to the manufacturing sector. Given this assumption, we clearly have

$$\lim_{t \rightarrow +\infty} A(t) = +\infty, \quad \lim_{t \rightarrow +\infty} L(t) = +\infty \quad \text{and} \quad \lim_{t \rightarrow +\infty} \frac{A(t)}{L(t)} = 0. \quad (15)$$

Roughly speaking, the population grows whereas the fraction of the labor force employed in the agricultural sector steadily decreases.⁸ This scenario

⁸The assumption of a constant growth rate in the agricultural population is made for analytical convenience. It is easy to check that the same results would hold in case A grows but $\lim_{t \rightarrow +\infty} A(t) = \bar{A} < +\infty$. One can also show that when conditions (15) hold, the qualitative behavior of the dynamic model does not depend on the fact that the agricultural output can be costlessly traded.

is consistent with the historical evidence presented in Section 3.2 and summarized in Table 1. Consider the aggregate industry price index, given by (3). The average price of manufacturing goods in region $r = H, F$ can be expressed in dynamic form as $\bar{P}_r^*(t) = P_r^*(t)/N(t)$. Some simple substitutions, using expressions (2), show that

$$\bar{P}_H^*(t) = \frac{\epsilon\alpha(2-\lambda)\phi}{2\epsilon\phi + \gamma\lambda L(t)} \quad \text{and} \quad \bar{P}_F^*(t) = \frac{\epsilon\alpha(1+\lambda)\phi}{2\epsilon\phi + \gamma(1-\lambda)L(t)}. \quad (16)$$

Next, using (10), we can rewrite the nominal wage in region H in its dynamic form as

$$w_H^*(t) = \left(\frac{A(t)}{2} + \lambda L(t) \right) \frac{\alpha^2 \epsilon \phi}{[2\epsilon\phi + \gamma\lambda L(t)]^2}. \quad (17)$$

The real wage in region $r = H, F$ is then given by $\omega_r^*(t) = w_r^*(t)/\bar{P}_r^*(t)$ which, using (16) and (17), yields

$$\omega_H^*(t) = \left(\frac{A(t)}{2} + \lambda L(t) \right) \frac{\alpha}{(2-\lambda)[2\epsilon\phi + \gamma\lambda L(t)]} \quad (18)$$

for region H . The real wage in region F is defined analogously and can be expressed as

$$\omega_F^*(t) = \left(\frac{A(t)}{2} + (1-\lambda)L(t) \right) \frac{\alpha}{(1+\lambda)[2\epsilon\phi + \gamma(1-\lambda)L(t)]}. \quad (19)$$

The first term in $\omega_r^*(t)$ captures the *market size effect*; ceteris paribus, a larger local market allows to increase profits via increasing returns to scale in production, which increases real wages through the zero-profit condition. The second term captures the *market crowding effect*; ceteris paribus, a larger local manufacturing industry leads to decreasing profits via fiercer price competition in the product and labor markets. Note that, as always in models with multiple regions, different market sizes and varying degrees of price competition imply that there can be a real wage differential between regions. Because the historical data only accounts for average real wages at the national level, we define the *average manufacturing real wage* in the two-region setting as follows:

$$\bar{\omega}^*(t) = \lambda\omega_H^*(t) + (1-\lambda)\omega_F^*(t). \quad (20)$$

We henceforth distinguish between two cases: (i) we assume that $\lambda^* = \bar{\lambda}$ is constant and given, a setting we will refer to as the *aspatial growth path* of the economy; (ii) we consider that $\lambda^* = \lambda^*(t)$ as given by the dynamic version

of (13), a setting we will refer to as the *spatial growth path* of the economy. Roughly speaking, the economy cannot change its spatial structure in the first case, whereas it can in the second one. To the best of our knowledge, only the first case has been investigated until now in the literature. In what follows, we investigate more closely the evolution of $\bar{\omega}^*$ and ω_r^* , $r = H, F$ along both the spatial and aspatial growth paths of the economy.

4.1 Evolution of real wages along the aspatial growth path

Assume that $\lambda = \bar{\lambda}$ is given and fixed. Straightforward differentiation of ω_H^* with respect to t yields after some rearrangements

$$\left. \frac{\partial \omega_H^*}{\partial t} \right|_{\lambda=\bar{\lambda}} = \frac{\alpha [0.5\gamma\bar{\lambda}(\dot{A}L - A\dot{L}) + \epsilon\phi(\dot{A} + 2\bar{\lambda}\dot{L})]}{(2 - \bar{\lambda})^2(2\epsilon\phi + \gamma\bar{\lambda}L)^2}, \quad (21)$$

where a dot superscript denotes the partial derivative with respect to time. As one can see from expression (21), the sign of the derivative depends on two distinct effects. First, in case $\dot{A}L - A\dot{L} \geq 0$, i.e. $k \geq l$, the manufacturing real wage in region H is increasing for all spatial distributions λ . The reasons underlying this result are easy to understand. If, on the one hand, the agricultural population increases at a faster rate than the non-agricultural one, new firms benefit from larger average market size without generating too much additional pressure on price competition and the labor market. Hence, due to scale economies at the firm level, each firm produces at a lower average production cost, which allows to increase profits and hence wages.⁹ Should on the other hand, the non-agricultural population increase at a faster rate than the agricultural one, fiercer price competition is no longer offset by a sufficient increase in overall market size. In that case, real wages can either increase or decrease, depending crucially on the relative strength of the market size and the market crowding effect as well as on the spatial distribution $\bar{\lambda}$. Using expression (21), it is straightforward to show that

$$\left. \frac{\partial \omega_H^*}{\partial t} \right|_{\lambda=\bar{\lambda}} \begin{matrix} \geq \\ \leq \end{matrix} 0 \quad \Leftrightarrow \quad k \left[\bar{\lambda}\gamma + \frac{2\epsilon\phi}{L(t)} \right] \begin{matrix} \geq \\ \leq \end{matrix} \bar{\lambda}l \left[\gamma - \frac{4\epsilon\phi}{A(t)} \right]. \quad (22)$$

Therefore, manufacturing real wages can increase or decrease, depending on the *relative rate of growth of the two labor forces*, on population sizes A and L and on the spatial distribution $\bar{\lambda}$. First, one should note that if region

⁹It is of interest to note that expanding export markets can play an analogous role to that of a growing agricultural population, at least as long as exports are not matched by additional imports which would increase price competition within the country.

H has only a small share of the manufacturing industry (i.e. if $\bar{\lambda}$ is small), manufacturing real wages are increasing in region H . Stated differently, the market size effect dominates the market crowding effect when $\bar{\lambda}$ is sufficiently small, hence making the smaller region more attractive for manufacturing production. This leads to the following result.

Proposition 3 *Assume that $\bar{\lambda} \in (0, 1)$ is given and fixed. Then there exists $\bar{t}_r \geq 0$ such that the manufacturing real wage in region $r = H, F$ decreases for all $t > \bar{t}_r$.*

This proposition states that for any distribution $\lambda \in (0, 1)$, population growth leads to a decline in real wages once the population becomes large enough. Of course, the same result holds for region F . Because the average manufacturing real wage in the economy is a weighted average of the two regional manufacturing real wages, we have the following result.

Proposition 4 *Assume that $\bar{\lambda} \in [0, 1]$ is given and fixed. Then there exists $\bar{t} \geq 0$ such that the (average) manufacturing real wage in the economy decreases for all $t > \bar{t}$.*

Proposition 4 states that, for any given spatial distribution $\bar{\lambda}$, real wages in our model decrease once the non-agricultural population has grown sufficiently large. The reasons for the decrease in manufacturing real wages are of course very different from the traditional decreasing returns in agriculture (recall that agriculture is competitive and produces under constant returns to scale). In our model, the effects on prices and wages go through the labor market and competition between firms. Due to full employment, an increasing labor force leads to an increase in the number of firms which, by price competition, leads to cuts in equilibrium profits and hence wages. Therefore, the pressure of labor supply on both product and labor markets leads to decreasing real wages, a result for which there exists strong empirical support throughout most of history (North, 1981). Yet, as can be seen from Table 2, this relation does not seem to fit the data for 18th century England. Real wages in 1791 are still approximately equal to those in the base year 1701, despite a population increase of about 50%. This agrees with the results by Fisher (1992, p. 31), who concludes his empirical analysis as follows: “We have found an interesting and significant Granger-causal relation between population and prices, but nothing between prices and real wages [...] the second fastest population growth is associated with a rising real wage”. Hence, the Malthusian relation between population growth and decreasing

real wages does not seem to hold for 18th century England. One explanation usually put forward in the literature is that of technological progress.¹⁰ Yet, another explanation may be found in the spatial organization of the economy, a point that has been mostly overlooked until now.

4.2 Evolution of real wages along the spatial growth path

Until now, we have considered as given and fixed the spatial distribution of firms as the population of the economy grows and structurally changes. *This strong assumption neither holds theoretically nor historically.* From a theoretical point of view, we know that the spatial distribution of firms is likely to change as the economy evolves along its equilibrium path. From a historical perspective, we have argued in sections 3.2 and 3.3 that the spatial organization of productive activities fundamentally changed in England during the 18th and early 19th century. Therefore, we have to examine how real wages behave when the spatial structure of the economy is no longer taken as given.

Assume now that the spatial distribution λ is endogenously determined. More precisely, we assume that at any moment t the distribution of the mobile manufacturing industry is described by the instantaneous spatial equilibrium

$$\lambda^*(t) = \min \left\{ \text{re} \left(\frac{1}{2} + \sqrt{\frac{1}{4} + 4\sigma\phi \frac{3\sigma\phi + \gamma(L(t) - A(t))}{L(t)^2\gamma^2} - \frac{A(t)}{L(t)}} \right), 1 \right\}, \quad (23)$$

where we have used (2) with (13) and where we have set $\sigma \equiv \beta - \gamma$ for notational convenience. Unlike in the previous section, mobile labor and industrial firms move now across regions in response to economic opportunities induced by population growth and changes in market conditions.

Insert Figure 1 about here.

Unfortunately, expression (23) is a complex and non-differentiable function of t . This can be seen from Figure 1, where we have plotted an example of

¹⁰Galor and Weil (2000) argue that the 1700-1820 period is characterized by technological progress, which drives the increase in both population and real wages. Although the 18th century saw many significant technological advances, their economic impact depended mainly on their large scale industrial exploitation and was mostly felt in the 19th century.

the two symmetric stable equilibrium paths.¹¹ Let us start with a numerical example in order to highlight some properties of the model and to boost intuition. As one can see from Figure 1, the economy first disperses. This is due to the fact that the initial regional imbalance (corresponding to $\lambda = 0.8$) is not sustainable as the size of the market increases, which draws firms into a more symmetric configuration.

Insert Figure 2 about here.

Figure 2 plots the evolution of the real-wage ratio ω_H^*/ω_F^* along the spatial growth path. As one can see, in the initial configuration at $t = 0$, real wages in the larger region H are approximately 1.5 times higher than in the smaller region F . Therefore, any increase in the local market size of region F allows some firms to escape the high wage levels in region H by relocating to region F . This leads to a first phase of gradual convergence of both industrial location and regional real wages, because the wage effects dominate the demand linkages.¹² In a second phase, as total population continues to increase, demand linkages come to dominate wage effects and the industry starts to agglomerate again. This leads to (definitive) regional divergence in terms of industrial structure and real wages.

Plugging (23) into (18) and using the same set of parameter values as before, we can simulate the evolution of real wages in region H along the spatial growth path of the economy. Figure 3 depicts this case. In order to highlight the fundamental difference with the case discussed in Section 4.2, the dashed line depicts the real wage in region H along the aspatial growth path with $\bar{\lambda} = 0.5$. As one can see from Figure 3, the evolution of real wages is fundamentally different along both paths. Especially, the real wage along the spatial growth path does not display a long-run Malthusian behavior as the mobile factor grows at a faster rate than the immobile one. This is due to the fact that *the spatial redistribution of economic activities can counterbalance, at least temporarily, the decline in real wages in the presence of an increasing industrial population*. Stated differently, whereas our model displays a Malthusian growth regime when the spatial configuration is fixed,

¹¹The parameter values are set as follows: $L_0 = 5$, $A_0 = 4$, $\alpha = \beta = 1$, $\gamma = 0.5$, $l = 0.1$ and $k = 0.05$. Note that these values are abstract ones, because $L_0 > A_0$ is not likely to hold for England at the beginning of the 18th century.

¹²Dispersion of economic activities due to high real wage differentials has been emphasized in modern international trade theory and can be found in a spatial context in Puga and Venables (1998) and Fujita *et al.* (1999a). Contrary to our results, convergence in these models is catastrophic as less industrialized regions quickly catch up with the more developed ones.

it switches to a Post-Malthusian regime once production factors are allowed to move.

Insert Figure 3 about here.

As illustrated by our introductory example, the exogenous growth of both mobile and immobile factors significantly modifies the spatial equilibrium. Similar results are obtained by Puga and Venables (1998) with the help of numerical simulations. They show, in an international context, that industrialization spreads from country to country in a series of waves, leading gradually to convergence as poor nations quickly join the rich club. Proposition 2 suggests that such a convergence result seems the most likely in the case in which the mass of mobile factors grows at a rate not higher than that of immobile factors (which is precisely the case considered by Puga and Venables, 1998, because they assume that both factors grow at the same rate).

Despite some technical difficulties due to the expression of λ^* , several clear analytical results can be derived. It is easy to check that, when the mobile population grows at a faster rate than the immobile population, $\lim_{t \rightarrow +\infty} \lambda^*(t) = 1$. Hence, the economy goes through a process of agglomeration and regional divergence. The reasons underlying this result are the following. As the population increases, so do both the market size and the degree of price competition in manufacturing product and labor markets. Yet, the competition effect is always dominated by the market size effect beyond some population size. Stated differently, in that case price competition is no longer strong enough to prevent firms from exploiting the demand-driven backward linkages which leads to the agglomeration of all firms into one of the two regions. We may therefore conclude that *a structural change in the population composition can trigger a process of agglomeration when the mobile factor grows at a faster rate than the immobile factor*.¹³

Assume for now that λ^* is a differentiable function of t (conditions under which this assumption holds are provided later). Using expression (17), it is easy to check that

$$\frac{\partial \omega_H}{\partial t}(t) \geq 0 \quad (24)$$

¹³Most models focusing on growth and space disregard population growth (Baldwin *et al.*, 2001; Martin and Ottaviano, 2001). Yet, as argued by Fujita and Thisse (2002, p. 392), “changes in the population of skilled and unskilled workers could be important”.

if and only if

$$\begin{aligned} & [2\sigma\phi(A + 4L) + 2\gamma\lambda^2L^2 + 2A\gamma L(\lambda - 1)]\dot{\lambda} \\ & + (2 - \lambda)[A\gamma\lambda L(k - l) + 2\sigma\phi(Ak + 2\lambda lL)] \geq 0. \end{aligned} \quad (25)$$

This allows us to establish the following result.

Proposition 5 *Assume that $l > k$ and that conditions (15) hold. Then there exists $\bar{t}$ such that manufacturing real wages increase for all $t > \bar{t}$.*

We can further show the following:

Proposition 6 *Assume that $l > k$. Then, manufacturing real wages on the spatial growth path are not lower in the long-run than manufacturing real wages on all aspatial growth paths of the economy.*

4.3 Limits to growth and utility

As shown in the previous section, the evolution of real wages is reversed beyond some population size when the spatial structure of the economy is endogenously accounted for. Because consumer surplus is increasing along the spatial growth path (as the mass of available varieties increases), the indirect utility increases if real wages increase. One may hence be tempted to conclude, in the light of the previous results, that indirect utility is an increasing function along the spatial growth path. This is so indeed. Nevertheless, because there are limits to agglomeration (given by $\lambda = 1$ in our setting), the indirect utility should be constrained by those limits. That this is indeed so is established in the following proposition.

Proposition 7 *Consider an economy in which total population grows and suppose that the mobile population grows at a faster rate than the immobile one. Assume further that conditions (15) hold. Then the indirect utility along the spatial growth path grows and converges to*

$$\lim_{t \rightarrow +\infty} V_H^*(t) = \frac{1}{2} \frac{\alpha^2}{\gamma}.$$

Hence, when the manufacturing population grows at a faster rate than the agricultural one, the utility level that can be reached in the long-run is bounded above. Stated differently, as can be seen from (29), in the absence of technological change the maximal value of utility is constrained by both preferences and technology. The more differentiated the goods are (i.e. the smaller γ) and the stronger consumers' preferences (i.e. the larger α), the higher the maximal level of utility that can be reached.

5 Tying together theory and history

How do the results derived in Section 4 relate to the English economy of the 18th and early 19th century? As can be seen from Table 2, population increased steadily with an acceleration in the second half of the 18th century. Yet, as can also be seen from Table 1, the ratio A/L strongly decreased. Increasing total population put some pressure on prices and led to inflation. The increase in the cost of living, when combined with fiercer competition in the labor market, should logically lead to decreasing real wages in the economy. Or, as can be seen from Table 2, real wages remained approximately constant until the 1790s; only from then on do we observe a sharp decline until 1820-1830, when real wages start to rise again. Hence, two questions need answering. Why did real wages not decline much during the 18th century, despite a growing population and increasing pressure on both product and labor markets? Why did real wages decline sharply after 1790 and why did they rise again from 1820-1830 on?

First, as can be seen from Table 2, compared with later standards the rate of population growth was moderate between 1700 and 1780. Therefore, the pressure on prices and wages was moderate too, so that *the spatial redistribution of population* and the expansion of local and foreign markets could possibly counterbalance the negative effects of a growing population. Second, the population increased at a much faster pace from 1780 on, a period during which the effects of the enclosure peak of 1760-1770 became very obvious. Therefore, an *increasing spatial redistribution of population and production and/or larger markets were needed in order to keep real wages at a constant level*. In case this redistribution was not possible (urbanization eventually lagged behind what would actually have been needed, especially since the supply of housing is inelastic in the short-run) the result on real wages was a depressive one. This case can precisely be seen from Figure 3 when $t \geq 20$. If λ is constrained to the symmetric configuration (or to some other off-equilibrium value), real wages decline while they actually rise if λ can increase. Hence, *obstacles to the spatial redistribution of economic activities can lead to decreasing real wages in the presence of a growing population*. After 1820-1830, it is most probably the decrease in transportation costs and the very sustained growth in export markets that provides an overall increasing market size; hence, average production costs decreased and wages and profits increased.

Let us summarize our main findings that could explain the evolution of manufacturing real wages in England during the 18th and 19th century as

follows. During the first half of the 18th century, population grows at a ‘modest’ rate and the small number of enclosure acts does not significantly modify the ratio of mobile to immobile production factors (see Table 1, columns 3 and 4 as well as Table 2, column 4). Therefore, ‘modest’ spatial redistributions of firms and workers make sure that real wages remain actually very constant (see Table 2, column 2). From 1750–1760 on, population starts to increase at a more rapid pace. This raises the economic value of wastes and commons and leads to an intensification of the enclosure movement; the result is a significant increase in the ratio of mobile to immobile factor, combined with a growing overall population (see Table 1, columns 3 and 4 as well as Table 2, column 4). The pressure on both labor and product markets increases, which leads to increasing prices and decreasing real wages towards the end of the 18th century (see Table 2, columns 2 and 3). This decrease in real wages could eventually have been balanced by an increasing redistribution of economic activities in space, i.e. by increasing agglomeration. Yet, this was physically impossible, since the stock of housing was not elastic enough to allow for an increasing agglomeration that keeps pace with the sustained rate of migration to urban areas. Therefore, urbanization lags behind what was needed and the pressure on the housing market drives up housing prices, which puts additional pressure on real wages (and, of course, on workers living conditions, as so vividly depicted by Bairoch, 1985). After a depressive period, revolutions in transport technologies during the 1820–1830 decade allow firms to increase their overall market sizes, both at home and abroad. This raises operational profitability and lowers production costs (and hence consumer prices). At the same time, these new transport technologies allow for an increasing redistribution of activities in space, which finally counterbalances the Malthusian decline in real wages.

6 Concluding remarks

As shown in this paper, the temporal evolution of the space-economy under regional autarky is determined by the evolution of the ratio of mobile to immobile production factors. Therefore, agglomeration can be the outcome of a structural modification in population composition and can arise even if transport costs remain constant and high. As we have also shown, a growing population is not necessarily synonymous with decreasing real wages, since the *spatial redistribution of economic activities can counterbalance the Malthusian tendencies*. Our main results conform closely to the historical evidence on the economic evolution of 18th and early 19th century England.

It is tempting to extrapolate parts of our results to the case of today's developing countries. Indeed, many features like high interregional transport costs, a structural modification of the population composition and sustained migratory movements seem to be very similar. Our analysis suggests that the rise of mega-cities in the Third World need not necessarily be associated with decreases in real wages. Stated differently, developing countries could be even worse off nowadays without the rise of huge urban agglomerations. Clearly, more work is called for here.

References

- [1] Armstrong J. (1989). 'Transport and trade', in R. Pope (Eds.) *Atlas of British Social and Economic History*, London: Routledge.
- [2] Bairoch P. (1985). *De Mexico à Jericho: Villes et économie dans l'Histoire*. Paris: Editions Gallimard. English translation, 1988, *Cities and Economic Development: From the Dawn of History to the Present*, Chicago: University of Chicago Press.
- [3] Baldwin R.E. (1999). 'Agglomeration and endogenous capital', *European Economic Review*, vol. 43, pp. 253-280.
- [4] Baldwin R.E., Martin P. and G.I.P. Ottaviano (2001). 'Global income divergence, trade and industrialization: The geography of growth take-offs', *Journal of Economic Growth*, vol. 6, pp. 5-37.
- [5] Baldwin R.E. and P. Martin (2004). 'Agglomeration and regional growth'. In V. Henderson and J.-F. Thisse (Eds.) *Handbook of Regional and Urban Economics*, vol 4, Amsterdam: North-Holland, forthcoming.
- [6] Behrens K. (2004). 'Agglomeration without trade: how *non-traded* goods shape the space-economy', *Journal of Urban Economics* 55, 68-92.
- [7] Braudel F. (1984a). *The Structures of Everyday Life: Civilization & Capitalism 15th-18th Century*, vol. 1, New York: Harper and Row.
- [8] Braudel F. (1984b). *The Perspective of the World: Civilization & Capitalism 15th-18th Century*, vol. 3, New York: Harper and Row.
- [9] Brown C. (1989). 'Urbanization and living conditions', in R. Pope (Eds.) *Atlas of British Social and Economic History*, London: Routledge.

- [10] Cook C. and J. Stevenson (1983). *The Longman Handbook of Modern British History (1714-1987)*, London: Longman Publisher.
- [11] Dewey P. (1989). 'Agriculture', in R. Pope (Eds.) *Atlas of British Social and Economic History*, London: Routledge.
- [12] Fisher D. (1992). *The Industrial Revolution: A Macroeconomic Interpretation*, New York: St. Martin's Press.
- [13] Fujita M., P. Krugman and A.J. Venables (1999a). *The Spatial Economy. Cities, Regions and International Trade*, Cambridge, MA: MIT Press.
- [14] Fujita M., P. Krugman and T. Mori (1999b). 'The evolution of hierarchical urban systems', *European Economic Review*, vol. 43, pp. 209-251.
- [15] Fujita M. and J.-F. Thisse (2002). *Economics of Agglomeration: Cities, Industrial Location and Regional Growth*, Cambridge, MA: Cambridge University Press.
- [16] Galor O. and D.N. Weil (1999). 'From Malthusian stagnation to modern growth', *American Economic Review*, vol. 89, pp. 150-155.
- [17] Galor O. and D.N. Weil (2000). 'Population, technology and growth: From the Malthusian regime to the demographic transition', *American Economic Review*, vol. 90, pp. 806-828.
- [18] Haskel, J. and H. Wolf (2001). 'The law of one price - A case study', *Scandinavian Journal of Economics*, vol. 103, pp. 545-558.
- [19] Hohenberg P. and L.H. Lees (1985). *The Making of Urban Europe (1000-1950)*, Cambridge, MA: Harvard University Press.
- [20] Jackman W.T. (1962). *The Development of Transportation in Modern England*, London: Frank Cass and Co.
- [21] Jackson S. and G. Timmins (1989). 'Demographic changes 1701-1981', in R. Pope (Eds.) *Atlas of British Social and Economic History*, London: Routledge.
- [22] Kelly M. (1997). 'The dynamics of Smithian growth', *Quarterly Journal of Economics* 112, pp. 939-964.
- [23] Krugman P. (1991). 'Increasing returns and economic geography', *Journal of Political Economy* vol. 99, pp. 483-499.

- [24] Krugman P. (1991b). *Geography and Trade*, Cambridge, MA: MIT Press.
- [25] Lee R.D. (1980). 'A Historical Perspective on Economic Aspects of the Population Explosion: The Case of Preindustrial England', in R.A. Easterlin (Eds.) *Population and Economic Change in Developing Countries*, Chicago: University of Chicago Press.
- [26] Malthus T.R. (1798). *An Essay on the Principle of Population*. Online at: <http://www.econlib.org/library/Malthus/malPlong.html>.
- [27] Marshall A. (1890). *Principles of Economics*, London: MacMillan, 8th edition published in 1920.
- [28] Martin P. and G. Ottaviano (1999). 'Growing locations: industry location in a model of endogenous growth', *European Economic Review* vol. 43, pp. 281-302.
- [29] Martin P. and G. Ottaviano (2001). 'Growth and agglomeration', *International Economic Review* 42, pp. 947-968.
- [30] North D. (1981). *Structure and Change in Economic History*, New York: W.W.Norton&Co.
- [31] Ottaviano G.I.P., T. Tabuchi and J.-F. Thisse (2002). 'Agglomeration and trade revisited', *International Economic Review*, vol. 43, pp. 409-436.
- [32] Quah D.T. (1996a). 'Regional convergence clusters across Europe', *European Economic Review*, vol. 40, pp. 951-958.
- [33] Quah D.T. (1996b). 'Empirics for economic growth and convergence', *European Economic Review*, vol. 40, pp. 1353-1375.
- [34] Sala-I-Martin X. (1996). 'Regional cohesion: Evidence and theories of regional growth and convergence', *European Economic Review*, vol. 40, pp. 1325-1352.
- [35] Tabuchi T. and J.-F. Thisse (2003). 'Regional Specialization, Urban Hierarchy, and Commuting Costs'. CORE Discussion Paper n°2003/60.
- [36] Picard P. and D.-Z. Zeng (2003). 'Agricultural sector and agglomeration'. CORE Discussion Paper n°2003-22.

- [37] Puga D. and A.J. Venables (1998). ‘Agglomeration and economic development: Import substitution vs. trade liberalisation’. CEP Discussion Paper N°377.
- [38] Waltz U. (1996). ‘Transport costs, intermediate goods and localized growth’, *Regional Science and Urban Economics*, vol. 26, pp. 671-695.

Appendix

Proof of Proposition 2

Using the definitions of a , b and c , given by (2), we can rewrite the break point of Proposition 1 as

$$A_b(t) \equiv \frac{3(\beta - \gamma)\phi}{\gamma} + \frac{L(t)}{4},$$

which is a function of t .¹⁴ Because L grows at a constant rate g , it is easy to check that

$$\frac{(\partial A_b / \partial t)}{A_b} = g \frac{\gamma L(t)}{12(\beta - \gamma)\phi + \gamma L(t)} \leq g.$$

Therefore, A_b grows at a rate that is not higher than that of A , which implies that there exists $\bar{t} \geq 0$ such that A exceeds A_b . As shown by Proposition 1, dispersion is then the only stable spatial equilibrium. One should note that A_b grows at the same rate than A if and only if either $\phi = 0$ or $\beta \rightarrow \gamma$ (i.e. $c \rightarrow +\infty$). This particular case can be disregarded, since only dispersion would be sustainable as a spatial equilibrium anyway (see [1] of Proposition 1).

Proof of Proposition 3

We show the result for region H only, because the proof for region F is similar. Take the limit of

$$k \left[\bar{\lambda} \gamma + \frac{2\epsilon\phi}{L(t)} \right] < \bar{\lambda} l \left[\gamma - \frac{4\epsilon\phi}{A(t)} \right]$$

to obtain $k\bar{\lambda}\gamma \leq l\bar{\lambda}\gamma$, which always holds because $\bar{\lambda} \in (0, 1)$ and $l > k$.

¹⁴This way of rewriting the expression is necessary because the coefficients a , b and c , as given by (2), depend on N (and hence on L).

Proof of Proposition 4

The derivative of the average manufacturing real wage (20) can be expressed as

$$\frac{\partial \bar{\omega}^*}{\partial t} \Big|_{\lambda=\bar{\lambda}} = \bar{\lambda} \frac{\partial \omega_H^*}{\partial t} \Big|_{\lambda=\bar{\lambda}} + (1 - \bar{\lambda}) \frac{\partial \omega_F^*}{\partial t} \Big|_{\lambda=\bar{\lambda}}. \quad (26)$$

Clearly, because of Proposition 3, for every $\bar{\lambda} \in (0, 1)$, $\bar{\omega}^*$ is decreasing beyond $\bar{t} = \max\{\bar{t}_H, \bar{t}_F\}$. Further, for $\bar{\lambda} = 0$ (resp. $\bar{\lambda} = 1$) we have

$$\frac{\partial \bar{\omega}^*}{\partial t} \Big|_{\lambda=0} = \frac{\partial \omega_F^*}{\partial t} \Big|_{\lambda=0} \quad \left(\text{resp. } \frac{\partial \bar{\omega}^*}{\partial t} \Big|_{\lambda=1} = \frac{\partial \omega_H^*}{\partial t} \Big|_{\lambda=1} \right),$$

so that $\bar{\omega}^*$ decreases beyond $\bar{t}_F$ (resp. $\bar{t}_H$).

Proof of Proposition 5

Factorize condition (25) by $AL > 0$ so that

$$\begin{aligned} & \left[2\sigma\phi\left(\frac{1}{L} + \frac{4}{A}\right) + 2\gamma\lambda^2\frac{L}{A} + 2\gamma(\lambda - 1) \right] \dot{\lambda} \\ & + (2 - \lambda) \left[\gamma\lambda(k - l) + 2\sigma\phi\left(\frac{k}{L} + 2\lambda\frac{l}{A}\right) \right] \geq 0. \end{aligned}$$

If conditions (15) hold, λ increases beyond some $\tilde{t}$ and converges to 1 (it is easy to check that λ is differentiable for $t > \tilde{t}$ in this case). Because the first term goes to $+\infty$, whereas the second term goes to $\gamma(k - l)$, we conclude that there exists $\bar{t} \geq \tilde{t}$ such that the derivative of ω_H becomes positive on the spatial growth path.

Proof of Proposition 6

Using expression (17) and $\lim_{t \rightarrow +\infty} \lambda^* = 1$, it is easy to check that

$$\lim_{t \rightarrow +\infty} \omega_H(t) = \frac{\alpha}{\gamma} \quad (27)$$

on the spatial growth path, whereas

$$\lim_{t \rightarrow +\infty} \omega_H(t) \Big|_{\lambda=\bar{\lambda}} = \frac{\bar{\lambda}}{2 - \bar{\lambda}} \frac{\alpha}{\gamma} \quad (28)$$

on the aspatial growth path. Because $\bar{\lambda} \in [0, 1]$, the result follows immediately.

Proof of Proposition 7

Use (2) together with (11) to obtain

$$V_H^*(t) = \frac{1}{2} \left[\frac{\alpha}{2(\beta - \gamma) + \gamma \lambda^*(t) L(t) \phi^{-1}} \right]^2 \left[3 \frac{\lambda^*(t) L(t)}{\phi} (\beta - \gamma) + [\lambda^*(t)]^2 \gamma \frac{L(t)^2}{\phi^2} + A(t) \frac{\beta - \gamma}{\phi} \right],$$

where we have dropped the constant $\bar{q}_0$. Rewrite V_H^* as

$$V_H^*(t) = \frac{1}{2} \left[\frac{\alpha}{2(\beta - \gamma) L(t)^{-1} + \gamma \lambda^*(t) \phi^{-1}} \right]^2 \left[3 \frac{\lambda^*(t)}{\phi L(t)} (\beta - \gamma) + [\lambda^*(t)]^2 \gamma \frac{1}{\phi^2} + \frac{A(t)}{L(t)^2} \frac{\beta - \gamma}{\phi} \right]$$

and use $\lim_{t \rightarrow +\infty} \lambda^*(t) = 1$ to get

$$\lim_{t \rightarrow +\infty} V_H^*(t) = \frac{1}{2} \frac{\alpha^2}{\gamma}, \quad (29)$$

which yields the result.

Year	GNP (in million pounds)	Agriculture	Industry and Commerce	Others
1700	50.00	40.00%	33.00%	27.00%
1710	53.90	38.22%	31.91%	29.87%
1720	57.50	41.91%	34.09%	24.00%
1730	58.70	40.20%	35.95%	23.85%
1740	64.10	40.72%	33.70%	25.58%
1750	70.40	39.91%	34.94%	25.15%
1760	81.90	35.29%	36.14%	28.57%
1770	80.30	36.11%	41.10%	22.79%
1780	92.00	34.24%	35.00%	30.76%
1790	104.10	32.08%	44.38%	23.54%
1800	135.80	26.66%	44.92%	28.42%

Table 1: Composition of GNP in England and Wales 1700-1800
(Source of data: Fisher, 1992, p. 17)

Year (Base 1701)	Real wage	Price level	Population level	Urb. rate
1701	100.0	100.0	100.0	13%
1711	71.9	151.7	104.2	—
1721	107.0	103.1	107.0	—
1731	107.0	102.2	105.7	—
1741	98.2	121.5	112.3	—
1751	122.8	98.0	117.2	16%
1761	114.0	104.8	125.1	—
1771	91.2	132.2	131.8	—
1781	112.3	129.7	143.1	—
1791	96.5	148.5	155.2	—
1801	59.6	298.8	173.2	25%

Table 2: Real wages, prices, population and urbanization in England (1701-1801)
(Source of data: Fisher, 1992, p. 26; Braudel, 1984a, p. 483)

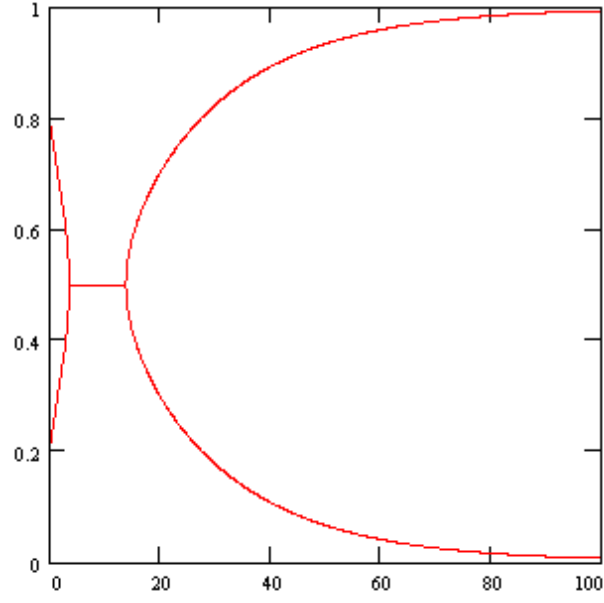


Figure 1: Stable spatial-temporal equilibrium paths in (λ, t) -space

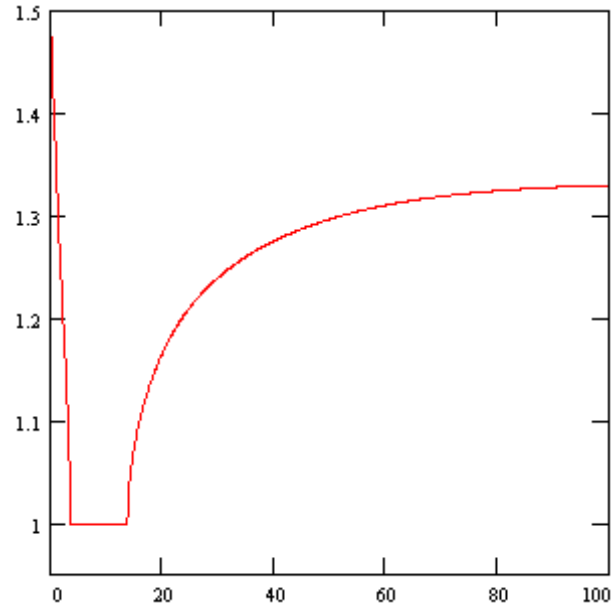


Figure 2: Temporal evolution of real wage ratio ω_H^*/ω_F^*

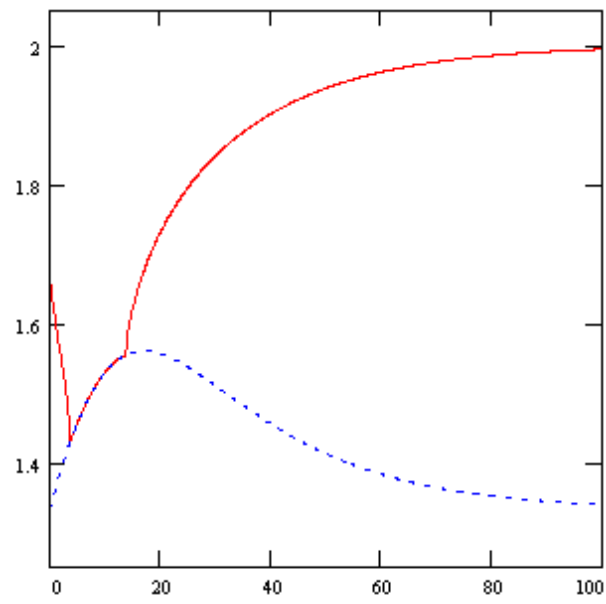


Figure 3: Temporal evolution of real wage ω_H