Malthus to Romer: On the Colonial Origins of the Industrial Revolution

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Abstract

We propose a unified theory to explain the diverse paths of economic and institutional development of colonized and colonizers following the great discoveries at the end of the XV century. In our theory, the institutional and economic divergence between Spain and England observed during the age of colonization obeys to the same forces put forward by Engerman and Sokoloff (1997) to explain the divergence between Latin America and North America: factor endowments at the moment of the conquest.

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> "The discovery of America and that of a passage to the East Indies by the Cape of Good Hope, are the two greatest and most important events recorded in the history of mankind. Their consequences have already been very great; but, in the short period of between two and three centuries which has elapsed since these discoveries were made, it is impossible that the whole extent of their consequences can have been seen. What benefits or what misfortunes to mankind may hereafter results from those great events, no human wisdom can foresee." (Adam Smith, 1789, Book IV, Chp. VII, Part. III, page 590)

1. Introduction

The roots of the industrial revolution and the rise of the western world during the XIX century are frequently traced to events that occurred during the mercantilist period of the XVI and XVII centuries. For example, North (1981) emphasizes the rise of the Parliament in England in the second half of the XVII century and its role in securing efficient property rights; North and Thomas (1973) stress the significant population growth during this period as the engine of institutional changes; Mokyr (2002) highlights the *scientific revolution* of the XVII century lead by Fracis Bacon writings; Weber (1905) emphasizes religion differences that became apparent with the Protestant Reformation movements of the XVI and XVII centuries. All these suspects share two things in common. They provide only a proximate, as opposed to ultimate, explanations of the industrial revolution since these transformations themselves call for an explanation. Second, they occurred shortly after what Adam Smith called "the two greatest and most important events recorded in the history of mankind": the discovery of the New World and the passage to East Asia by the Cape of Good Hope.

The great discoveries at the end of the XV century, or The Great Discoveries for short, provide a sort of genuine and massive exogenous shock that could potentially explain many of the crucial economic, political, social, and cultural events that lead to the industrial revolution. This view has been attributed to Adam Smith, but it is perhaps better described by Raynal, a philosopher contemporaneous of Smith:

> "There has never been any event which has had more impact on the human race in general and for Europeans in particular as that of the discovery of the new world, and the passage to the Indies around the Cape of Good Hope. It was then when the commercial revolution began, a revolution in the balance of power, and in the customs, the industries and the government of every nation . ..[some nations that were of no consequence are become powerful: others, that were the terror of Europe, have lost their authority]... Everything changed and will go on changing. But will the changes of the past and those that are to come, be useful to humanity? Will his condition be better, or will be simply one of constant change?" (Raynal 1780. Cited by Outram, pg 57).

This paper develops a theory of comparative development driven by large persistent shocks. The purpose is to provide a unified theoretical framework useful to rationalize the diverse paths of institutional and economic development observed after the Great Discoveries for both the colonies and the colonizers. The model formalizes the idea of North and Thomas (1973) that population growth is the key parameter shift explaining institutional changes, and the ideas of Engerman & Sokoloff (ES, 1997) and Acemoglu, Johnson & Robinson (AJR 2001, 2002) regarding the role of initial endowments at the moment of the conquest and optimal colonization strategies in explaining the diverse paths of developments among colonies in the Americas, Africa and Asia.

I utilize the model to argue that the same ideas proposed by ES and AJR to explain the reversal of fortunes among colonies such as Latin America and the United States, can also explain the reversal of fortunes among European colonizers, in particular Spain and Britain. Specifically, while Britain entered into a process of sustained economic growth and institutional reforms, Spain stagnated after an initial period of prosperity. I concentrate on Britain and Spain as they provide two polar cases of interest.

The focus of the paper is not on comparing competing theories that could explain these observations, but in developing a unified theory of development for colonizers as well as colonized based on the Great Discoveries. While diverse theories of comparative development rely on proximate explanations such as differences in human capital, TFP, physical capital, institutions, religion, or culture, the theory put forward by ES and AJR relies on truly exogenous forces where geography provided a set of initial conditions in the form of factor endowments, but discovery and colonization shape the subsequent pattern of development, what ES called "path influenced" development. ES and AJR focus on colonies, but a similar theory has also been used in the past to explain the colonizers.

The main argument of the paper can be outlined in a rather simplistic way. After the Great Discoveries the Spanish Crown evolved into a more centralized, bureaucratic, and absolutist power for the same reasons that Latin American institutions did: the abundance of labor and natural resources in the territories conquered by the Spaniards. This abundance favored the establishment of extractive institutions in the colonies, but also strengthen the Spanish Crown that could afford to concentrate power and resources in few hands. On the economic side, the abundance of natural resources also produced a chronic case of Dutch disease in Spain, which delayed industrialization and growth.

In contrast, the English monarchy did not enjoy the bullion of the Spanish Crown, at least not directly, due to its late arrival into the colonization era. Instead, it was left with an expanded set of trading and exploitation opportunities in Africa, Europe, Asia, and the New World that could only materialize if the monarchy and/or the English society provided the proper incentives and rights to its citizens. The nature of the new economic opportunities opened to Britain by the Great Discoveries empowered common citizens, created an entrepreneurial base, and was conductive to a weaker monarchy that eventually lost power to other forces represented in the Parliament.

This basic argument requires more elaboration to answer a multiplicity of questions that arise. The plan of the paper is to address some key questions with the help of a tractable model suitable for the period of analysis. The model economy is composed of two sectors, a rural sector operating a Malthus technology, and an urban sector operating a Romer type of technology. The urban technology exhibits increasing returns to scale due to specialization, as in Romer (1987). Moreover, population evolves endogenously in a Malthusian fashion, as in Kremer (1993) and Hansen and Prescott (2002). We measure the degree of property right protection, or "institutions", as the number of varieties produced in the urban sector. The reason is that those varieties would not be produced by competitive firms and therefore the society must grant some degree of protection (monopolistic power) for them to be produced. Finally, we focus the analysis on the efficient allocation of resources, and therefore, on efficient institutions. In our set up, institutions are endogenous.

The only state variable in the model is population size. The efficient solution is characterized by a threshold level of population. If population is below the threshold, Malthusian stagnation is efficient and locally stable. If population is above the threshold, sustained economic growth is efficient. Our model thus provides a formalization of North & Thomas' thesis that "the predominant parameter shift which induced the institutional innovations that account for the rise of the Western World was population growth" (1973, p. 8. See also North 1981, and Boserup 1981).

Population, however, is not a parameter but a state variable in the model. Therefore, the ultimate determinant of growth and industrialization in the model is not population itself but shifts in productivity and/or demographic parameters. More precisely, the model economy can scape Malthusian stagnation if there is a significant and persistent change in the productivity of the urban and/or rural technologies, and/or in demographic parameters. We argue that the Great Discoveries shitfted the key parameters.

The rest of the paper is organized as follows. Section 2 discusses the related literature, Section 3 presents some relevant evidence, Section 4 sets up the model, Section 5 characterizes the efficient allocations, Section 6 uses the model to rationalize the experiences of Spain and England after the Great Discoveries, Section 7 summarizes the main findings, and Section 8 concludes.

2. Related Literature

The thesis that the industrial revolution had colonial origins is associated to Marx, and more recently to Williams (1944), Wallerstein (1974), Gunder Frank (1978), and Samir Amir (1974)[1]. They argue that profits from slavery, colonization, and overseas trade provided the capital required for the industrial revolution. These ideas were successfully challenged in seminal works by Engerman (1972), De Vries (1976), and O'Brien (1982), who show that profits from these activities were minor relative to the overall capital accumulation at the time[2]. Our model abstracts from capital accumulation and therefore, by construction, avoids this critique since none of the effects act through profits or capital accumulation. Instead, the key variable is population size.

The thesis have been recently revived by Acemoglu, Johnson, and Robinson (AJR, 2005). They provide evidence that the rise of Western Europe between 1500 and 1850 corresponds mostly to Atlantic Europe, and that countries that benefited the most were those engaged in colonialism and transoceanic trade. To overcome the critics regarding the minor role of profits for European accumulation, AJR complement their argument with an amplification mechanism: colonialism and trade facilitated institutional reforms favorable for economic growth but only in countries with a tradition of placing checks on the monarchy. They thus provide an alternative explanation for the divergence among european powers since, they argue, England had more checks on the monarchy than Spain at the time of the Great Discoveries.

AJR evidence is compelling but their particular hypothesis to explain the evidence is controversial. Cameron for example argues that "Henry VIII (1509-47) was as much an absolute monarch in England as any of his follow sovereigns were in their countries. But whereas royal absolutism increased in most continental countries in the sixteenth and seven-

[1] A recent restatement is Blaut (1993).
[2] See also Bairoch (1993, Part II).

teenth centuries, a contrary development occurred in England, resulting in the establishment of a constitutional monarchy under parliamentary control after 1688" (1997, p. 157); North and Thomas state that "with the Tudors, the English monarchy was at the zenith of its powers" (1973, p. 146); Also, Graves asserts that ".. at least until the seventeenth century, some continental assemblies, such as the Cortes of Aragon, Catalonia and Valencia, the Sicilian *Parlamento*, and the Polish *Sejm*, wielded more authority, possessed stronger safeguards and enjoyed greater privileges and liberties than their English counterpart" (2001, p. 1).

The alternative thesis put forward in this paper is consistent with the views of Raynal, Cameron, and Graves among others. The thesis is that England's institutional development was itself a result of the Great Discoveries. Due to exact sequence of events that gave Spain a first mover advantage, and the geographical position of Britain as a natural fortress right in front of the Atlantic, the Great Discoveries did not affect Spain and England symmetrically. Instead, it opened very different opportunities for each country which explain their subsequence institutional and economic divergence. Thus, the amplification mechanism via institutions is key in our model as in AJR, but its origin is different. Another important difference is that our theory assigns a central role to population growth, which plays no role in AJR theory.

The works of Pomeraz (2000) and Landes (1998) give also support to the thesis in a different form. Pomeraz stresses the idea that the New World provided Europe with new grounds for ecological relief that Asia did not have. Landes recognizes the importance of the discoveries but only as a catalyzer. The idea that Spain suffered from a case of Dutch disease is an old one and has recently supported by Landes (1998) and formally tested by Drelichman (2005).

Regarding to the modelling approach, our work is related to a growing literature interested in applying stylized general equilibrium models to the study of the industrial revolution (Goodfriend & McDermott 1995, Galor & Weil 2000, Stockey 2001, Hansen & Prescott 2001, Jones 2001). These models predict that the industrial revolution was inevitable due to either exogenous technological progress or endogenous improvements driven ultimately by population growth[3]. In our model the industrial revolution is not inevitable, but the result of a large and persistent shock. Our model is more suitable to study North & Thomas or Smith ideas. Moreover, models in which the industrial revolution is inevitable are silent about questions like why the industrial revolution occurred in England, or why it happened in the eighteen century. Our theory instead suggests an explanation for these questions.

Our model is also related to the "Big Push" theory of Murphy, Shleifer & Vishny (1989) but conceptually different. In their model, industrialization is always efficient and the government may induce industrialization by coordinating a "big" move toward the modern sector. In our model, industrialization is not efficient if the economy lacks sufficient population size. Moreover, population is exogenous in their model but endogenous in our theory. Our model is also related to Kremer (1995) in the key role of population size but in Kremer's theory stagnation is not possible. Our model is also related to Krugman (1991) in the production structure, but different in other respects and questions addressed. Finally, our theory also formalize arguments by Wrigley (1967), and Jacobs (1984) regarding the importance of cities for growth.

3. Evidence

Figure 1 and Table 1 present some of the evidence that motivates this study. For the period 1400 to 1800, Figure 1 shows the share of urban population and the logs of population, wages, rents, and prices in England. The graph suggests that a structural change took place around 1500-1520. Specifically, during the XV century population, urban population, and prices remained roughly constant, but after 1500-1520, the English economy is under

[3] An exception is Lucas (2001) who requires an exogenous shock affecting the returns to human capital accumulation.

substantial transformation: population, real rents, and prices rise more or less systematically, and real wages fall and then increase. The behavior of the economy up to 1640 is consistent with the predictions of a Malthusian model.

Figure 1 suggests that another break took place around 1640. Although population kept rising systematically, real wages also start rising systematically. This observation was stressed by Clark (2005), who argues that England escaped Malthusian stagnation for the first time in 1640. Another remarkable and robust observation illustrated in Figure 1 is the systematic rise of urban population in England starting at around 1500. this is particularly significant because AJR have used urban population as their preferred indicator of economic growth. Figure 2 provides further evidence on this issue. It shows the rapid rise of London. By 1500, London was the 17th largest city of Europe with around fifty thousand inhabitants. By 1800, just at the outset of the industrial revolution, London was already the largest city in Europe, the second largest in the world, and had a population of over 1.2 million inhabitants, all in spite of a great fire in 1666 that destroyed most of the city.

Overall, the figures shows that the rise of Britain in the centuries following the discoveries was impressive. By 1500, England was a small country of around 2.5 million people, and a lightweight player in European affairs dominated by Mediterranean countries. Three hundred years later, England's population had increased 3.5 times while population in other European powers scarcely doubled, Britain had became the major naval power in the world, and London the largest city in Europe, soon to become the largest in the world.

Finally, Table 1 provides some figures for Britain and Spain compiled from difference sources. Data for Spain is not as abundant as for Britain, and less reliable. The Table shows that Spain experienced a jump in the growth rate of population and in per-capita GDP for around a century after the discoveries, and then population and GDP mostly stagnated for around a century (between 1600 to 1700). Also, its urbanization rate was not much affected by the great discoveries overall, and some reduction may have occurred initially. As for

England, the data suggests a more systematic increase in its population and GDP after the discoveries.

4. The Model

Consider an economy populated by N_t identical individuals and endowed with a fixed amount of land L. Individuals live for one period. There are two final goods of production, rural and urban goods, and I_t intermediate goods. Goods are non-storable. Population growth follows a Malthus type of dynamics. To simplify notation, time subscripts are suppressed whenever possible.

4.1. Production Technologies

Rural goods are produced according to:

$$Y_r = z_r F^r(L_r, N_r) \tag{1}$$

where F^r is a constant returns to scale technology in land, L_r, and labor, N_r, and z_r is rural total factor productivity. Urban goods are produced by combining I varieties of intermediate goods, $\{x_i\}_{i=1}^I$, using the following increasing returns to scale technology:

$$Y_u = \left[\sum_{i=1}^{I} x_i^\gamma\right]^{1/\gamma} - \psi I \tag{2}$$

where ψ is a fixed cost per variety and $1/(1-\gamma)$ is the elasticity of substitution between varieties, and $0 < \gamma \leq 1$. Intermediate goods are produced according to:

$$x_i = z_I F^u(N_i, L_i) \tag{3}$$

where F^u is a constant returns to scale technology in land, L_i, and labor, N_i, and z_I is a productivity parameter common to all intermediate inputs. Denote $f^i(l_i) \equiv F^i(l_i, 1)$, where

$l_i \equiv \frac{L_i}{N_i}$ is land per-worker in sector $i \in \{r, u\}$ and $l \equiv \frac{L}{N}$. As a rule, lowercase variables denote per-worker variables. Furthermore, assume that:

$$F^i = L^{\alpha_i} N^{1-\alpha_i} \text{ for } i = \{r, u\}. \tag{4}$$

and that $\alpha_r > \alpha_u$ so that the rural technology is more land intensive.

The following restriction on parameters would make endogenous growth possible, and guarantee that land windfalls delay industrialization, as shown below.

Assumption 1: $\frac{1}{2-\alpha_u/\alpha_r} < \gamma < \frac{1}{1+\alpha_u}$.

Note that if land is not used in the urban sector, $\alpha_u = 0$, this assumption becomes $\frac{1}{2} < \gamma < 1$.

4.2. Preferences

Individuals derive utility from a composite consumption good made of rural and urban goods according to:

$$C = G(Y_r, Y_u) \equiv \left(Y_r^{\theta} + Y_u^{\theta}\right)^{1/\theta} \tag{5}$$

where $1/(1-\theta)$ is the elasticity of substitution between rural and urban goods and $\theta \leq 1$.

4.3. Population Dynamics

Population growth is Malthusian. Population, N_t, evolves according to:

$$\frac{N_{t+1}}{N_t} = n(c_t), \tag{6}$$

where $c \equiv \frac{C}{N}$ is per-capita consumption, $n(c_t)$ is a differentiable function satisfying $n(0) = 0$, crosses 1 only at a unique consumption level denoted c^*, is convex at c^*, single peaked, and $lim_{c \to \infty} n(c) = n > 1$. The shape of the function $n(\cdot)$ is described in Figure 3.a. A similar function is used by Kremer (1993) and Hansen & Prescott (2002). This specification allows to capture a demographic transition of the sort observed in the data: the relationship between consumption and population growth reverses as consumption increases.

5. Efficient Allocations and Efficient Institutions

An efficient allocation maximizes aggregate consumption, as defined by (5), subject to (2)-(4) given N and L. The choice variables are the allocation of land and labor across sectors - rural and intermediates - and the number of varieties. The following Proposition states that the efficient allocation can be simplified to the choice of a single variable, $n_u \equiv \frac{N_u}{N}$, the share of labor in urban activities. Proofs are in the Appendix.

Proposition 1 An efficient allocation solves the problem:

$$c(N) = \max_{0 \leq n_u \leq 1} G\left[z_r f^r(\phi l_u(n_u))(1-n_u), z_u (f^u(l_u(n_u))n_u)^{\mu} N^{\mu-1}\right] \tag{7}$$

where $c(N)$ is the efficient amount of consumption per-capita, $\mu \equiv \frac{\gamma}{2\gamma-1}$, $\phi \equiv \frac{\alpha_r}{1-\alpha_r}\frac{1-\alpha_u}{\alpha_u}$, $z_u \equiv \left(\frac{2\gamma-1}{\gamma}\right)\left(\frac{1-\gamma}{\gamma}\frac{1}{\psi}\right)^{\frac{1-\gamma}{2\gamma-1}} z_I^{\frac{\gamma}{2\gamma-1}}$, and $l_u(n_u) \equiv \frac{l}{\phi(1-n_u)+n_u}$.

Two key parameters defined in Proposition 1 are μ and z_u. μ is the degree of increasing returns in the urban sector which only depends on the degree of substitutability between intermediate inputs, γ. The more substitutable inputs are the lower the degree of increasing returns ($\mu'(\gamma) < 0$). By Assumption 1, $\mu(1-\alpha_u) > 1$. This restriction guarantees that the degree of increasing returns in the reproducible input, labor, is sufficiently strong to overcome the fixity of land. z_u is the urban total factor productivity parameter (TFP), a function of different parameters in the model. In particular, z_u increases with z_I and decreases with ψ.

The efficient allocation can be easily solved in a computer by directly maximizing (7) over a grid of points in the unit interval. An analytical solution is complicated by the fact that the problem is not convex and first order conditions may be misleading. To see this, define $M(n_u; N)$ as the function to be maximized in the right hand side of (7):

$$M(n_u; N) \equiv G\left[z_r f^r(\phi l_u(n_u))\,(1-n_u)\,, z_u f^u(l_u(n_u))^{\mu} n_u^{\mu} N^{\mu-1}\right]$$

Figure 4 shows this function for values of n_u in the horizontal axis, three possible values of N (low, medium and large), and tree possible values of θ. Points A, B, and C in the three panels correspond to the optimal choices of n_u. These examples shows that the function M is not necessarily concave, in fact it is convex for large values of θ and N, that it has interior minimums and maximums, and that the maximizer may not be unique (compare points B and D in second panel). Due to these issues, our strategy is to derive some intuition and analytical results for the special case of $\theta = 1$, and then provide quantitative analysis for the more general case. As illustrated in Figure 4, if θ is large then an efficient solution involves either $n_u = 0$ or $n_u = 1$.

Nonetheless, the examples in Figure 4 illustrate two general properties of the solution. First, the efficient share of urban population (weakly) increases with total population. Second, there is a discontinuity in the optimal share of urban population: as N increases, the optimal share of urban population jumps from zero to a positive number. The larger θ the larger the jump. This last property of the problem imposes some discipline for the choice of θ in order to obtain sensible predictions on the share of urban population.

As argued in the introduction, the number of varieties I can be regarded as the "degree of property rights protection" or "quality of institutions". The reason is that these varieties would not be produced by pure competitive firms in a decentralized equilibrium due to the fix cost of producing a variety. A decentralization would therefore require some degree of monopolistic power granted by the society, just as in Romer (1987). The following Proposition describes the efficient degree of protection.

Proposition 2 The efficient degree of property right protection, I^e, is given by:

$$I^e = I(\underbrace{n_u^e}_{+}, \underbrace{N}_{+}; \underbrace{z_I}_{+}) = \left(\frac{1-\gamma}{\gamma}\frac{z_I f^u(l_u(n_u^e))n_u N}{\psi}\right)^{\mu}.$$

where n_u^e is the efficient rate of urbanization.

According to the Proposition, the efficient degree of protection increases with the efficient rate of urbanization, population size and the productivity of the urban sector.

5.1. Perfect Substitutes: $\theta = 1$

If rural and urban goods are perfect substitutes then it is efficient to allocate all factors into a single technology, the one that produces more output. Given that the urban sector exhibit increasing returns to scale, then either all or none of the factors must be allocated in that sector. Denote $\widehat{N}$ the population size that makes this choice indifferent: $z_r L^{\alpha_r}\widehat{N}^{1-\alpha_r} = z_u L^{\mu\alpha_u}\widehat{N}^{\mu(1-\alpha_u)}$. Solving for $\widehat{N}$ produces:

$$\widehat{N} = \left[\frac{z_r}{z_u}L^{\alpha_r-\mu\alpha_u}\right]^{\frac{1}{\mu(1-\alpha_u)-1+\alpha_r}}. \tag{8}$$

Thus, the efficient amount of percapita consumption satisfies:

$$c(N) = \left\{\begin{array}{c} z_r(L/N)^{\alpha_r} \text{ if } N \leq \widehat{N} \\ z_u L^{\mu\alpha_u}N^{\mu(1-\alpha_u)-1} \text{ if } N > \widehat{N}. \end{array}\right\}. \tag{9}$$

Figure 3.b shows $c(N)$ as a function of population size, N. The "V" shape of $c(N)$ results from two opposite forces. First, the rural technology exhibit decreasing returns to population size due to the fixity of land; second, the urban technology exhibit increasing returns to scale. For a small scale ($N < \widehat{N}$), the efficient economy is rural and decreasing returns prevail. But for a large scale ($N > \widehat{N}$), the efficient economy is urban and increasing returns kick in. Assumption 1 guarantees that $\mu(1-\alpha_u) - 1 + \alpha_r > 0$ and $\alpha_r - \mu\alpha_u > 0$. Thus, an increase in $\frac{z_r}{z_u}$ or L increases $\widehat{N}$. Denote $\widehat{c} = c(\widehat{N})$ the minimum efficient level of consumption.

Using Proposition 2, the degree of protection is given by:

$$I^e = \left\{ \begin{array}{c} 0 \text{ if } N \leq \widehat{N} \\ \left(\frac{1-\gamma}{\gamma} \frac{z_I F^u(L,N)}{\psi}\right)^{\mu} \text{ if } N > \widehat{N}. \end{array} \right\}.$$

Thus, no protection is efficient as long as the economy is small and rural, but the switch to the urban technology also requires to a jump in protection.

Equations (6) and (9) fully determines the efficient allocation path for a given initial population level, N_0. Alternatively, the efficient path is described by the difference equation:

$$N_{t+1} = n(c(N_t))N_t. \tag{10}$$

We now characterize the efficient allocation. Consider first the steady states of this equation. Notice that $N = 0$ is a steady state. Additional steady states exist if there are levels of population such that $n(c(N)) = 1$. Since $n(c)$ is required to satisfy $n(c) = 1$ at the single value $c = c^*$, then additional steady states exist if $c^* = c(N)$ for some $N > 0$. Given that $c(N)$ is "V" shaped, this last equation have two solutions if $c^* > \widehat{c}$, no solution if $c^* < \widehat{c}$, or one solution if $c^* = \widehat{c}$. Since the last case only occurs for a very particular set of parameters, we only consider the first two cases.

5.1.1. *Malthusian Stagnation ($c^* > \widehat{c}$)*

The case $c^* > \widehat{c}$ is illustrated in Figure 3.b. by the curve $c(N)$. This curve crosses the value c^* at two levels of population: N^* and $\overline{N}$, where $N^* < \overline{N}$. In this case, there are two additional steady states: (c^*,N^*) and (c^*,$\overline{N}$). Direct inspection of the graphs reveal that the only locally stable steady state is (c^*,N^*)[4]. In particular, for any $N_0 \in (0, \overline{N})$, $N_t \to N^*$ and $c_t \to c^*$. If $N_0 > \overline{N}$, then $N_t \to \infty$ and $c_t \to \infty$. In this last case, N_t eventually grows

[4] Since time is discrete, an additional regulary condition is required for (c^*,N^*) to be locally stable. By linearizing (10) one obtains the condition $|1 - n'(c_M)\alpha_r c_M| < 1$ for stability. This condition imposes a bound on the size of $n'(c_M)$ and is authomatically satisfied given our assumption that $n(c)$ is convex around c_M.

at the constant rate n and percapita consumption eventually grows at the constant rate $(1+n)^{\mu(1-\alpha_u)-1} - 1 > 0$.

We call the stable steady state Malthusian because it has all the properties of a typical Malthusian model: per-capita consumption is determined only by demographic factors (by the condition $n(c^*) = 1$), and changes in technologies or land availability only affects population but not per-capita consumption.

5.1.2. Perpetual Growth ($c^* < \widehat{c}$)

Curve $c'(N)$ in Figure 3.b illustrates the case in which no solution exist for the equation $n(c'(N)) = 1$. The curve $c'(N)$ lies above c^* for all N. In this case, population always grows and, regardless of its initial level, population eventually surpasses the level $\overline{N}$, the economy eventually fully urbanizes, and the growth rate of per-capita consumption asymptotically approaches the rate $(1+n)^{\mu(1-\alpha_u)-1} - 1 > 0$. There is no possibility of stagnation in this case.

5.1.3. Break from Malthusian Stagnation

Suppose parameters are such that $c^* > \widehat{c}$, so that stagnation is possible, and suppose $N_0 = N^*$ so that the economy is in the Malthusian steady state. Stagnation is efficient because the economy lacks sufficient population size to exploit the increasing returns to scale technology. A break from stagnation may occur if circumstances change, say due to discoveries of new territories, so that condition $c^* > \widehat{c}$ ceases to be satisfied permanently or for a sufficiently long period of time. In that case, population increases systematically until eventually surpasses the threshold level $\overline{N}$. Once population has reached this critical level, the economy can sustain economic growth even if parameters return to their original values, say even if colonies attain independence.

More formally, according to the model the condition $c^* > \widehat{c}$ may cease to hold in the following cases.

1. **A positive demographic change** that shifts the $n(c)$ function upwards, say because of a fall in the mortality rate, and causes c^* to fall. This case is depicted in Figure 5.a where the level of consumption that guarantees zero population growth falls from c^* to c^{**}. After the demographic change, the curve $c(N)$ lies above c^{**}, and Malthusian stagnation is not a steady anymore. Instead, population systematically grows and sustained economic growth eventually appears, after a transitory period of falling consumption.

2. **An upward shift in the urban technology**. Figure 5.b shows the effects of an increase in the productivity of the urban sector, from z_u to z_u'. This shift produces a new function $c'(N)$ that lies lies above c^*. In particular, $\widehat{c}$ moves upward to $\widehat{c}' > c^*$, again eliminating the Malthusian steady state. This change triggers immediate industrialization and urbanization, and a process of sustained economic growth without any temporary fall in consumption.

3. **An upward shift in the rural technology**. Figure 6.a shows the effects of a positive change in rural productivity, from z_r to z_r'. This curve also induces the new $c'(N)$ curve to lie above the level subsistence c^* eliminating the Malthusian stagnation, and triggering systematic population growth. The effect is an initial boom in percapita consumption followed by a period of falling consumption. The critical level of population that triggers urbanization shifts to the right, from $\overline{N}$ to $\overline{N}'$, which delays urbanization and sustained economic growth. However, urbanization and economic growth eventually occur.

4. **A discovery of land**. This discovery simultaneously shifts the urban and rural technologies, but under Assumption 1 the rural technology benefits the most. The net

result is similar to the previous case with an initial consumption boom followed by a recession. Industrialization, urbanization, and growth eventually occurs.

5.2. Imperfect Substitutes: $\theta < 1$

If urban and rural goods are easily substitutable (θ is large) then the efficient development path involves a sudden switch from rural to urban goods as the scale of the economy increases. However, if goods are not easily substitutable, then the efficient path involves only gradual substitution, or not substitution at all if the elasticity of substitution is 1 ($\theta = 0$).

Figure 7 illustrates the $c(N)$ function for an intermediate value of $\theta \in (0, 1)$. For the case of gradual substitution, the $c(N)$ curve has a "U" rather than a "V" shape. The figure also illustrates two experiments: an upward shift in the rural technology and an upward shift in the urban technology. In both cases, the whole curve $c(N)$ shifts upward since all efficient allocations involves some production of both rural and urban goods. However, the qualitative results are similar to the ones found in the previous section.

6. The First Great Divergence: An explanation

We now use the model to provide an explanation for the rise of Atlantic Europe after the discoveries, and in particular to account for the different experiences of Spain and England after the XV century. AJR argue that pre-existing institutional differences among European Atlantic economies are key to understand their different development paths after the discoveries. However, as argued in Section 2, the idea that major institutional differences existed before the great discoveries is controversial. Instead, authors such as Cameron and Graves, suggest that the institutional, political, and social divergence among European powers also arose after the XV century, and Raynals, a contemporaneous of Adam Smith, argued that all these transformations originated in the Great Discoveries.

The model of the previous sections suggests an alternative explanation for the rise of Atlantic Europe as well as the variety of development paths observed after the discoveries, and in particular the reversal of fortunes among European powers. The thesis is that the discoveries did not affected european powers symmetrically but in ways that prompted different development paths as argued, for example, by Landes:

> "The industrial revolution made some countries richer and other (relative) poorer... This process of selection actually began much earlier, during the age of discovery. For some nations, Spain for example, the Opening of the World was an invitation to wealth, pomp, and pretension.. For others, Holland and England, it was a chance to do new things in new ways, to catch the wave of technological progress." (1998, p. 168-69)

6.1. Spain and the Dutch Disease

> "Spain, in other words, became (or stayed) poor because it had too much money." (Landes1998, p. 173).

The great discoveries affected European countries differently. Portugal and Spain, as the initial discoverers, enjoyed a first movers advantage that was formalized by the Treaty of Tordesillas of 1494. This treaty, sponsored by the Spanish born Pope Alexander VI, divided the non-european world between Spain and Portugal. With a vast territory at its disposal, Spain focused its conquest on the most prosperous and populated regions of the New World: the areas of the Aztec, Inca, and Maya's empires. The abundance of labor made possible for the Spanish Crown to put in place a highly hierarchical system of institutions designed to concentrate power in few hands, slave the indigenous population, and to extract and export the maximum amount of resources to Europe. These included precious metals, sugar, spices, luxuries, agricultural plants among others. The flow of resources made Spain Europe's leader during the XVI and early XVII centuries, a prominence that became even greater after the

Portuguese King Sebastian I died and the Spanish King Phillip II claimed the Portuguese trone in 1580.

Spain gradually lost its position during the early XVII century in the middle of multiple wars and conflicts -the Italian wars, the Dutch revolt, the Anglo-Spanish war, war with France, conflicts with the Ottoman Empire - and continuous piracy in the sea sponsored particularly by England and the Dutchs. Overall, the great discoveries brought a period of prosperity but they did not put Spain into a path of permanent growth.

Figure 8.a. provides a rationalization for these events. For Spain, the discoveries were analogous to windfall of natural resources, say similar to the discovery of gas or oil reserves, which prompted a case of Dutch disease. In terms of the model, the discoveries acted as a positive and persistent productivity shock to the primary or rural sector. The higher productivity shifted the $c(N)$ curve upward to $c'(N)$ but not enough as to eliminate stagnation from being a steady state. In the short term, the economy experiences a boom, but over time it returns to stagnation but with a higher population level.

Our theory is consistent with major developments of Spain during the three centuries following the great discoveries. An economic boom followed by recession, a population boom, and a degree of reversal in the urbanization rate. In the model, the degree of urbanization may go either way because the higher productivity of the primary sector tend to reduce urbanization, but larger population tend to increase it.

This simple story could be enriched by using a specific path for the productivity shock that takes into account the gradual conquest of the new territories, the exploitation of its resources, a peak in the exploitation, and then a gradual fall due to reduction in the bullion, and successive military set backs against England, France and the Dutch that eventually gained access to the new territories. A detailed quantitative analysis of the specific path is left for future research.

6.2. Britain

> "The English came in the Indian Ocean, like the Hollanders, at the end of the sixteenth century. They came as interlopers and plunderers, better at fighting than trading. Only later, and then cautiously, did they shift to trade." (Landes, 1998, p. 152.)

Although Spain (and Portugal) gained an early advantage, other European countries also benefited from the start directly or indirectly. For example, London's growth during most of the XVI century was in large part due to its role as satellite of Antwerp, the Belgium city that became center of international commerce during the XVI century fueled in large part by the bullion from the New World. A key turning point for England, and London in particular, was the destruction of Antwerp in 1576 by a Spanish army. This made evident the advantage of London as a center of commerce because its relative safety from continental wars.

After years of conflicts with other European powers, England eventually emerged as the major naval power in the Atlantic. A second turning point was the destruction of the Spanish Armada in 1588 while attempting to invade England. England's natural fortress proved to be a major advantage in the race for military power. In fact, no foreign army had managed to successfully invade England for almost one thousand years[5].

Shortly after the Armada failure, England initiated its expansion in the new world establishing its first successful settlement in North America in 1607. By 1600, even before English settlements were established in the New World, the discovery had already transformed England significantly: London had already multiplied its size by a factor of more than three becoming the fourth largest city in Europe. By 1776, when England colonies in America declared independence and the industrial revolution was igniting, London was already the largest city in Europe and the second largest in the world. Trade was the engine of growth

[5] The last successful invation of England was in 1066 by Norman forces.

of England, and of London in particular:

> "As sugar plantations spread on Barbados, Antigua, Jamaica, and in the eighteen century, on St. Dominique, the volume of sugar exported to Europe skyrocketed. Shipments to London rose from very low levels in 1640 to an average of 17,200 tons in 1663-69, 19,0000 tons in 1699-1701 - when the price had fallen to half the 1640 level - and 46,000 tons in 1750-54... From 1600 to the American Revolution, New World sugar production grew tenfold, from 20 to 200 thousand tons. Tobacco production also grew enormously; after the initial glut in the 1640, demand grew to permit English shipments to increase from 9 million pounds in the 1660s to 38 million pounds in 1699, and 55 million pounds in 1750." (De Vries, 1976, p. 139).
> "London's wealth came from many sources, but its life-blood was trade, especially overseas trade. ..In the early seventeenth century, London handled around 70 per cent (by value) of English foreign trade, and in 1700 its share was around 76 percent, with an even bigger share of imports and re-exported colonial goods. ... There had been significant diversification since 1640, when woollens had been almost 90 percent of London exports... What changed the picture was the rapid growth since 1660 of colonial trade with the North American and West Indian planations, which sent molasses and sugar (London's second most valuable import in 1700, after linen), tobacco and dyes, and the East India Company's imports of calico, silk and pepper. London's exports to the colonies were mainly cloth and manufactures." (Inwood 1998, p. 317-18).

It is remarkable that London's diversification since 1640 coincides with the observation stressed by Clark (2005), who argues that England escaped Malthusian stagnation for the first time in 1640.

Figure 8.b. provides a rationalization for these events. For England, the discoveries acted as a positive and long lasting productivity shock to the urban sector. The higher productivity shifted the $c(N)$ curve upward to $c'(N)$ enough to eliminate stagnation from being a steady state. The model predicts that the economy would eventually sustain systematic economic growth once its population reaches the critical size $\overline{N}'$.

This theory is consistent with major developments of England during the three centuries following the great discoveries: a systematic increase in the urban population, explained by the positive urban productivity shock and the subsequent increase in population; an initial period after the discoveries during which the economy behaves as a Malthusian economy; and a break down from Malthusian predictions once the economy starts growing systematically.

This simple story could be enriched by adding a specific path of productivity that takes into account major developments during the colonization era such as the gradual colonization, the outcome of wars, and independence of the colonizes among others. A detailed quantitative analysis is left for future research.

7. Summary of Main Results

The analysis above produces four key contributions:

1. Population and growth. While dependency theories stress the effects of colonization, slavery and trade on *physical* capital accumulation in Europe, our theory suggests that the key channel is the accumulation of *human* capital in the form of larger population. This is a promising channel since in fact population growth was substantially larger after the great discoveries, and population growth is the key "parameter shift" hypothesized by North & Thomas. For example, according to Clark (2005), England's population did not grow between 1400 and 1500, but it multiplied by a factor of more than 3.5 between 1500 and 1800. The population channel is a powerful one and it has been overlooked by the critics who focus on profits or the size of industrial exports to the colonies but are silent on the flow of wages.

There are multiple ways the Great Discoveries stimulated population growth in Europe. Clearly, the discoveries opened new trade and exploitation opportunities that translated into new employment opportunities for Europeans in all kind of activities: military, trade, government, industry, religion, piracy, among many. As Inwood describes "international merchants were at the top of London's commercial world, but the system which they dominated depended upon the work of a far greater number of lesser traders, warehousemen, wholesalers, retailers, refiners, processors, drovers, travelling salesman, factors, middlemen, and dealers of all sorts" (1998 p 324). Furthermore, commodities from the New World such as sugar, high in calories, became an affordable and popular commodity in Europe.

Thus, the great discoveries not only provided new profit opportunities for European merchants, as dependency theories stress, but more importantly, new employment and wage opportunities for european workers. These opportunities allowed to support larger families and immigration, and expanded domestic markets. In particular, London experienced an unprecedented surge of immigrants in the centuries following the discoveries.

2. Economic Divergence Among European Powers. The model suggests that the arguments used by ES to explain the divergence among colonies after the discovery of the New World, say U.S. vs. Mexico, can also explain the divergence among colonizers, say England vs. Spain. Specifically, the model suggests that the initial prosperity and later stagnation of Spain was a case of "Dutch disease". By discovering the New World, Spain gained a first mover advantage over vast resources and a degree of monopoly power granted by the Pope. Its optimal strategy was to colonize the rich and highly populated areas of Latin America where they established extractive institutions. The bullion and resources arriving to the empire acted as an increase in the productivity of the primary sector, the rural sector in our model, that enriched Spain but shifted resources out of the industrial sector, delaying industrialization, urbanization, and growth.

In the other hand, England late arrival left her with a vast amount of territory sparsely populated in the New World, and with new trade opportunities in Africa, Europe, Asia and the New World. Its access to the exploitation of primary resources was limited compared to Spain, and the optimal colonizing and trade strategy was to open business opportunities for ordinary citizens, and to promote migration to the new world under favorable conditions. These new opportunities empowered ordinary citizens, lead to a more democratized and equalitarian society in the colonies but also at home. On the economic side, the new economic opportunities were analogous to an increase in the productivity of the "urban sector" (commerce and industry) which favored urbanization, industrialization, and eventual growth.

3. Institutional Divergence Among European Powers. The model also suggests that the institutional divergences between England and Spain also obeyed to the underlying economic conditions. The boom in the primary sector of the Spanish economy shifted resources toward that sector weakening the urban and industrial sector and also weakening our measure of institutions, as a lesser number of varieties needed to be produced. This is the model's rationalization for the increase in the absolutist power of the Spain Crown.

In contrast, Britain late arrival to the colonization era acted as a positive shock to the urban and industrial sectors. This shock shifted resources toward the urban sector, and improve our measure of institutions, the number of varieties produced. Our interpretation is that the new opportunities offered to Britain by the great discoveries favored commerce and entrepreneurial activities, as well as strengthen property rights, making Britain gradually more democratic, weakening the monarchy.

4. Accounting pitfalls. The analysis also uncovers potential pitfalls in using static calculations of the type employed by O'Brien (1982), De Vries (1976), or Bairoch (1995) when assessing the role of colonies for industrialization. They argue that the impact of colonies on Britain was minor since most resources for capital accumulation originated domestically.

In the model, a temporary but sufficiently lasting shock may induce enough population growth to allow the economy scape stagnation. Once the shock disappears, the economy is self-sustaining. Simple accounting calculations would assign all the subsequent growth to domestic conditions and none to the shock. However, without the shock the economy would have remained stagnated. Specifically, the model suggests that the population growth of London was ignited by the Great Discoveries, but once London reached certain size, growth there was self-sustaining even after the colonies were lost.

To further illustrate the point, consider a reverse question, the influence of Europe on U.S. output. Simple static calculations would assign most of the U.S. growth during the last five centuries to domestic factors, little to the effect of Europe. However, if one is interested in ultimate determinants, it is very plausible that U.S. output today would be similar to the one 500 years ago had not the discoveries yet occurred. If so, the role of Europe on current U.S. output is fundamental.

8. Concluding Comments

The role of the Great Discoveries at the end of the XV century in igniting the industrial revolution and the rise of the western world remains a controversial issue, particularly among historians. Unfortunately, most of the discussion lacks formal models that spell out the assumptions, the channels, and their quantitative implications. The contribution of this paper is to provide a model suitable for the period of analysis that formalizes existing arguments and sheds lights on new avenues.

By any measure the discovery of the New World in 1492 by Christopher Columbus is still one of the major macroeconomic shocks in history, if not the major[6]. Almost overnight the territorial size of the western world was multiplied by a factor of 4. The New World was around three times larger than Europe, similar to the size of Asia, rich in natural resources and fertile lands, and relatively easy to subdue by the superior military technology of the Europeans. Equally impressive, the discovery of the passage by Cape of Good Hope shifted the patterns of trade in the old world from the Mediterranean to the Atlantic. It is hard imagine better luck for the Atlantic economies, and in particular England, a natural fortress situated in an enviable position in front of the Atlantic.

These facts motivate the theory explored in this paper. The working hypothesis is that the Great Discoveries ignited major events that have occurred since, in particular, economic

[6] Earlier encounters by the Vikings remained largerly unkown to the rest of the world.

growth and institutional changes. We study a model of growth where major shocks can ignite perpetual economic growth. The model rationalizes the connection between population and institutional change, and allows to disentangle some relevant channels at work.

We show that early critics pointing out the implausibility of the hypothesis based on the weakness of the capital accumulation channel have overlooked other key channel, population, and that their static method may be invalid for the dynamic question at hand. The paper also shed some light on the endogenous institutional development themselves ignited by the discoveries. Our analysis suggests that the biggest legacy of the Great Discoveries was an expanded market size that took time to be built but that eventually enabled an industrial revolution.

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Appendix

Proof of Proposition 1 Given the symmetry of the problem regarding intermediate inputs and the restriction $\gamma \leq 1$, any efficient allocation entails $x_i = x$ for i. Thus, total urban production is given by

$$Y_u = xI^{1/\gamma} - \psi I = z_I F^u(\frac{L_u}{I}, \frac{N_u}{I})I^{1/\gamma} - \psi I \tag{11}$$
$$= z_I F^u(L_u, N_u) I^{\frac{1-\gamma}{\gamma}} - \psi I$$

Futhermore, since the cost and benefits of the number of varieties only impact urban output, Y_u, the efficient number of varieties is the one that maximizes Y_u. The first order optimality condition for I is given by $\frac{1-\gamma}{\gamma} I^{\frac{1-\gamma}{\gamma}} z_I F(L_u, N_u) = \psi I$,which can also be written as:

$$I = \left(\frac{1-\gamma}{\gamma} \frac{z_I F^u(L_u, N_u)}{\psi} \right)^{\frac{\gamma}{2\gamma - 1}}.$$

Substituting this expression into (11) and simplifying produces:

$$Y_u = z_u F^u(L_u, N_u)^{\mu}$$

where $\mu \equiv \frac{\gamma}{2\gamma-1} > 1$ (by Assumption 1) is the degree of increasing returns and $z_u \equiv \left(\frac{2\gamma-1}{\gamma}\right) \left(\frac{1-\gamma}{\gamma}\frac{1}{\psi}\right)^{\frac{1-\gamma}{2\gamma-1}} z_I^{\frac{\gamma}{2\gamma-1}}$. Thus, an efficient allocation in this environment is one that maximizes aggregate (and percapita) consumption, or:

$$C(N) \equiv \max_{\substack{0 \leq L_r \leq L \\ 0 \leq N_r \leq N}} G\left[z_r F^r(L_r, N_r), z_u F^u(L - L_r, N - N_r)^{\mu}\right] \tag{12}$$

Consider first an interior solution. It satisfies:

$$L_r: \; G_1 z_r F_L^r = G_2 \mu z_u F^{u(\mu-1)} F_L^u;$$

$$N_r: \; G_1 z_r F_N^r = G_2 \mu z_u F^{u(\mu-1)} F_N^u.$$

Dividing the second condition by the first one obtains $l_r = \phi l_u$. Moreover, since $L = L_r + L_u$ then $l = l_r(1 - n_u) + l_u n_u$ where $n_u \equiv \frac{N_u}{N}$. From these last two equations it follows that:

$$l_u = l_u(n_u) = \frac{l}{\phi\left(1 - n_u\right) + n_u} \tag{13}$$

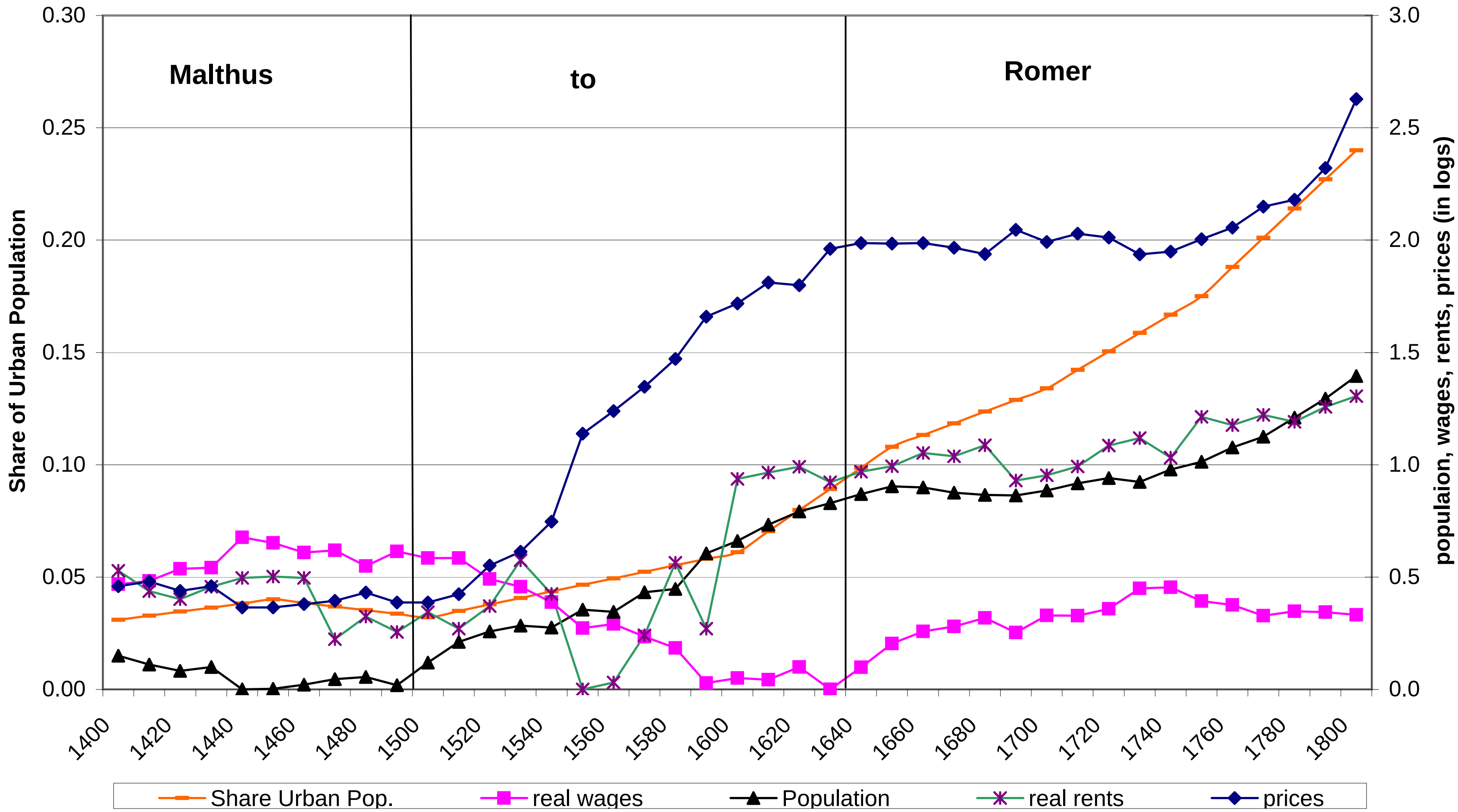
$$l_r = \phi l_u(n_u) \tag{14}$$

One can now rewrite (12) as

$$\begin{aligned} C(N) &\equiv \max G\left[z_r F^r(l_r,1)N_r, z_u F^u(l_u,1)^{\mu} N_u^{\mu}\right] \\ &= \max G\left[z_r F^r(l_r,1)\left(1-n_u\right)N, z_u F^u(l_u,1)^{\mu} n_u^{\mu} N^{\mu}\right] \\ &= \max G\left[z_r f^r(l_r)\left(1-n_u\right)N, z_u f^u(l_u)^{\mu} n_u^{\mu} N^{\mu}\right] \end{aligned}$$

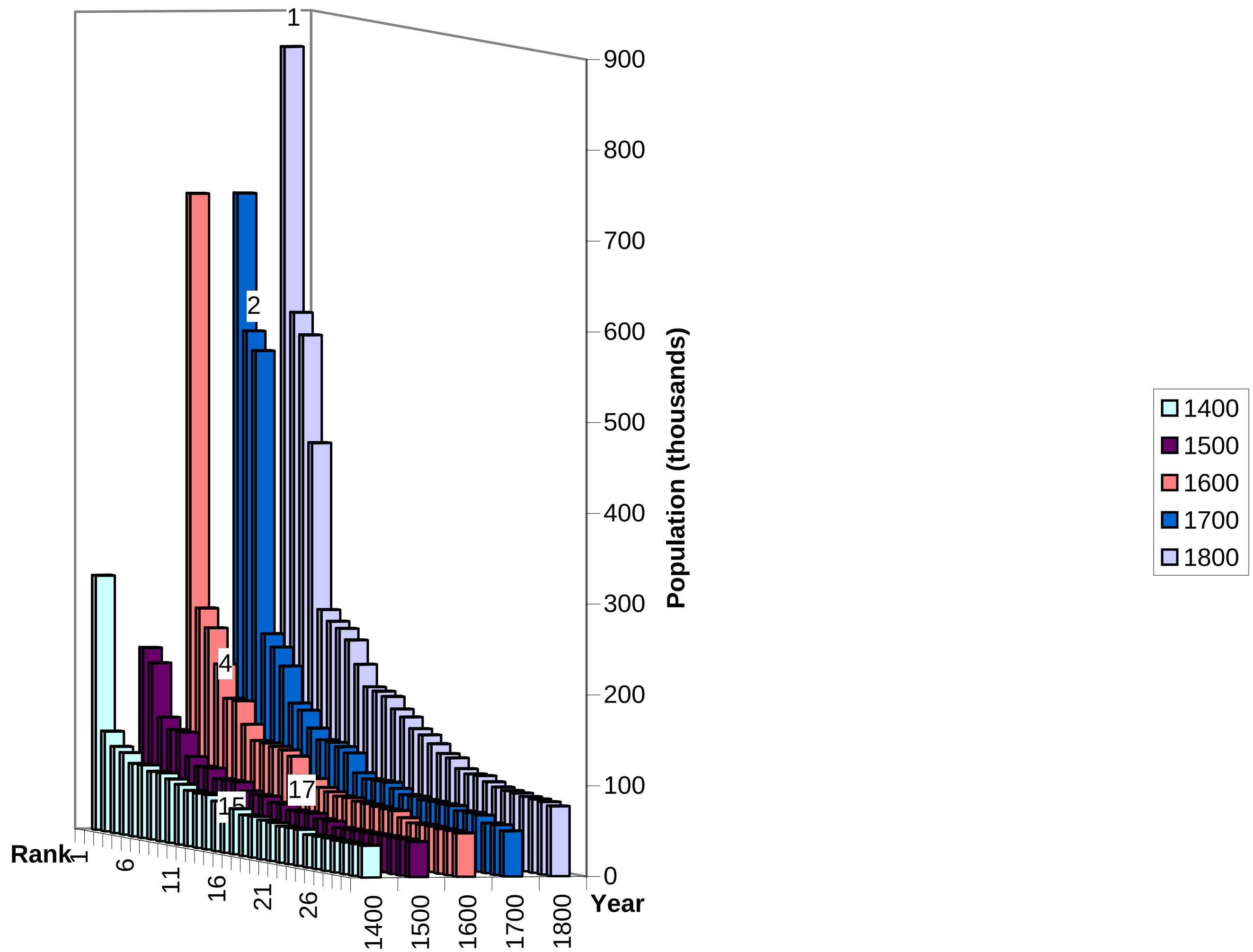
Finally, using (13) and (14), one obtains (7). Finally, consider corner solutions. In those cases, (13) and (14) does not need to hold, as assumed by (7). However, in those cases, (13) and (14) become an irrelevant normalization. To see this, consider a case in which $N_r^* = 0$ in (12). This is idential to the solution in which $n_u = 1$ in (7). In both cases, $C(N) = G\left[z_u f^u(L,N)^{\mu}\right]$. Similarly for $N_r^* = N$.

Figure 1
England 1400 - 1800
Wages, Population, Prices and Urban Population



(*) Sources: Prices, wages and Population, Clark (2005) Urban population, Wrigley (1985), Bairoch et. al. (1988) and author computations.

Figure 2
Population of London and Its rank among the 30 Largest Cities of Europe
1400-1800



Sourcer: Chandler (1987)

Figure 3
Malthus to Romer Model: θ=1

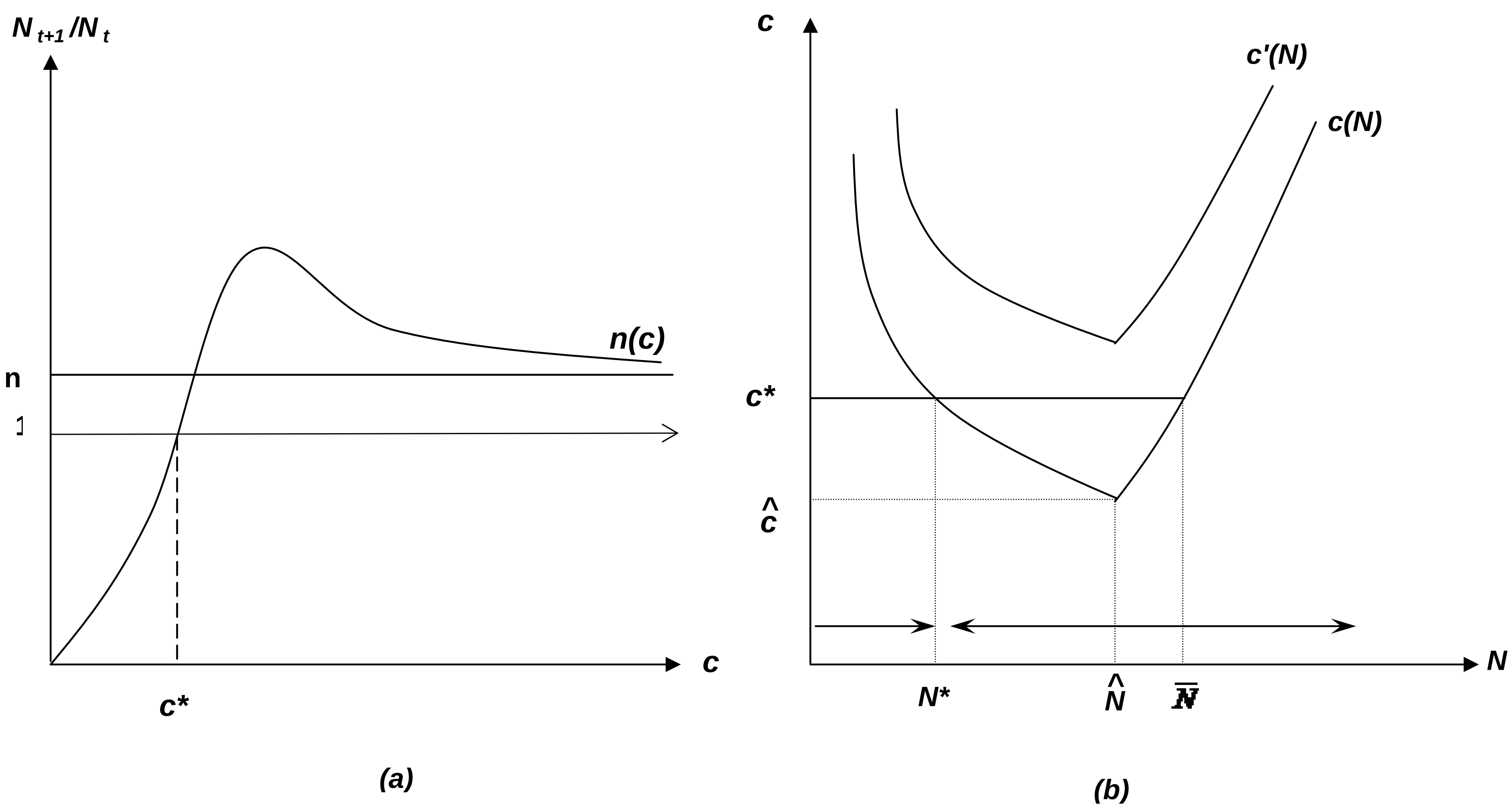


Figure 4
$M(n_u;N)$ for different levels of N and θ

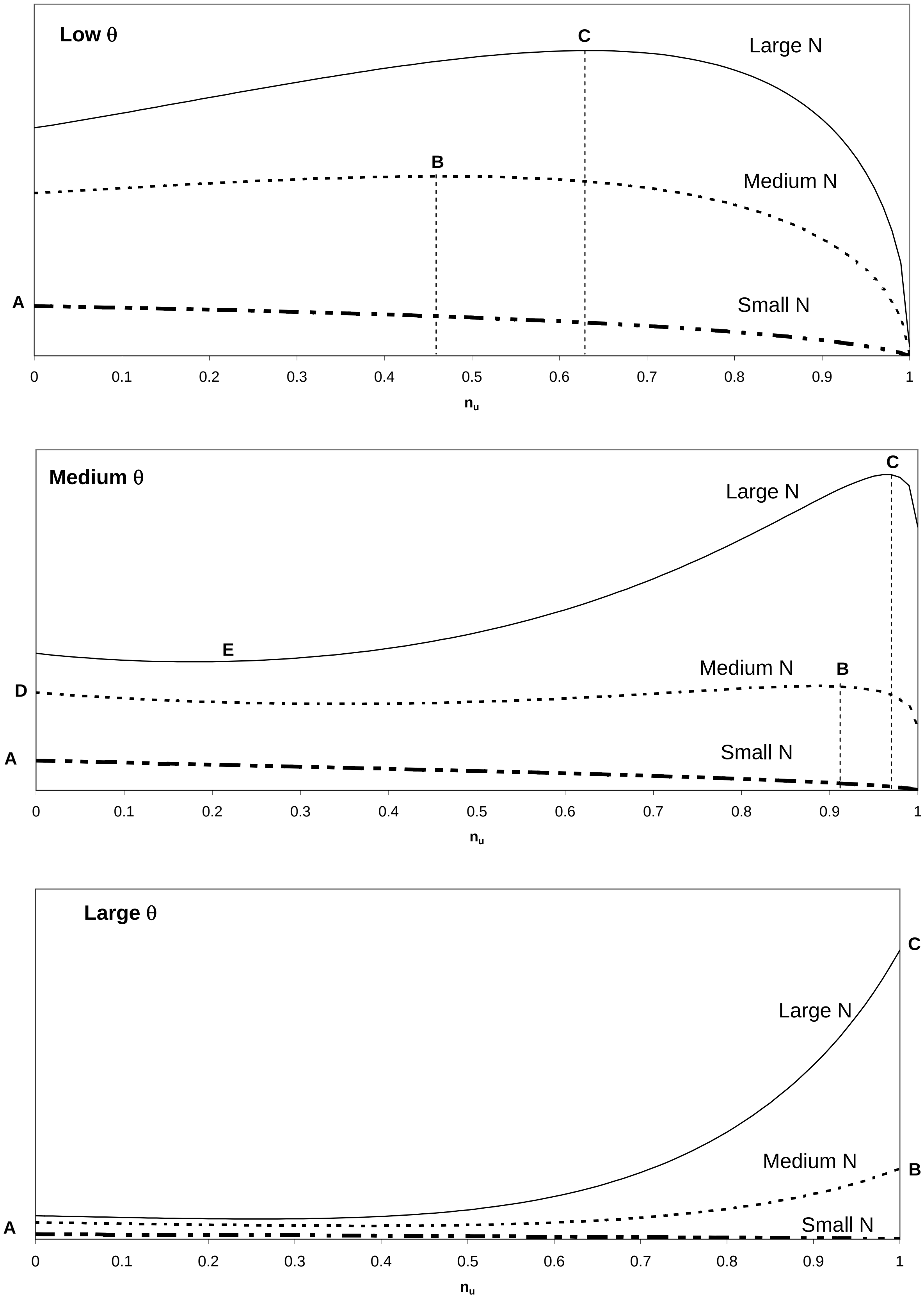
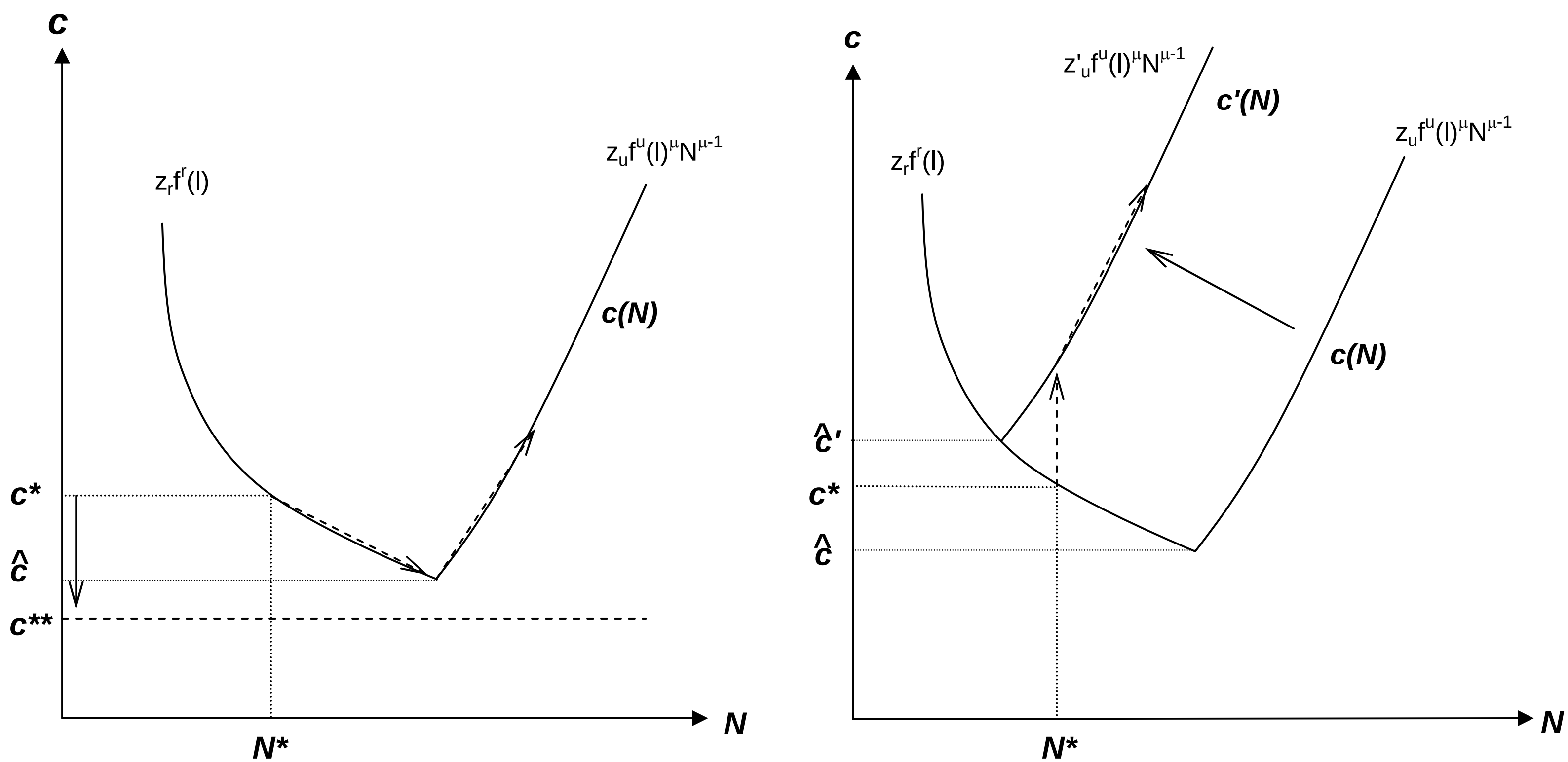
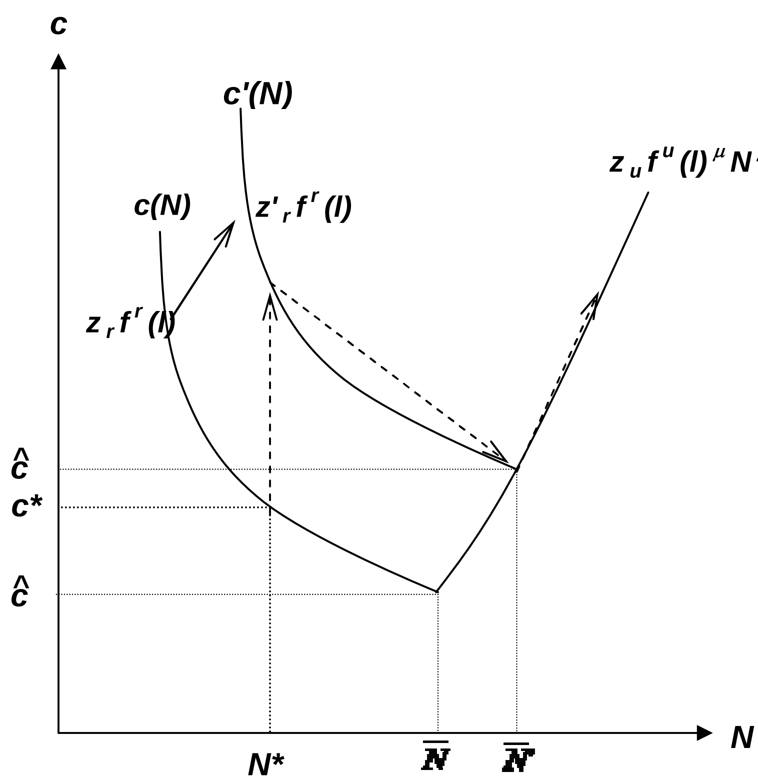


Figure 5
Malthus to Romer Model: θ=1

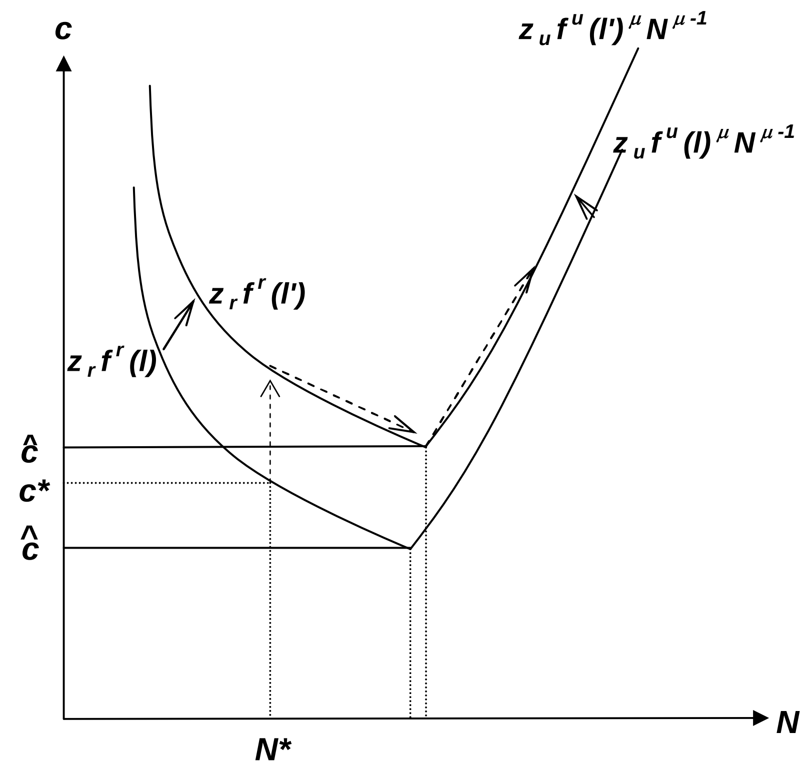


(a) Demographic Change (b) Change in Urban Technology

Figure 6
Malthus to Romer Model: θ=1

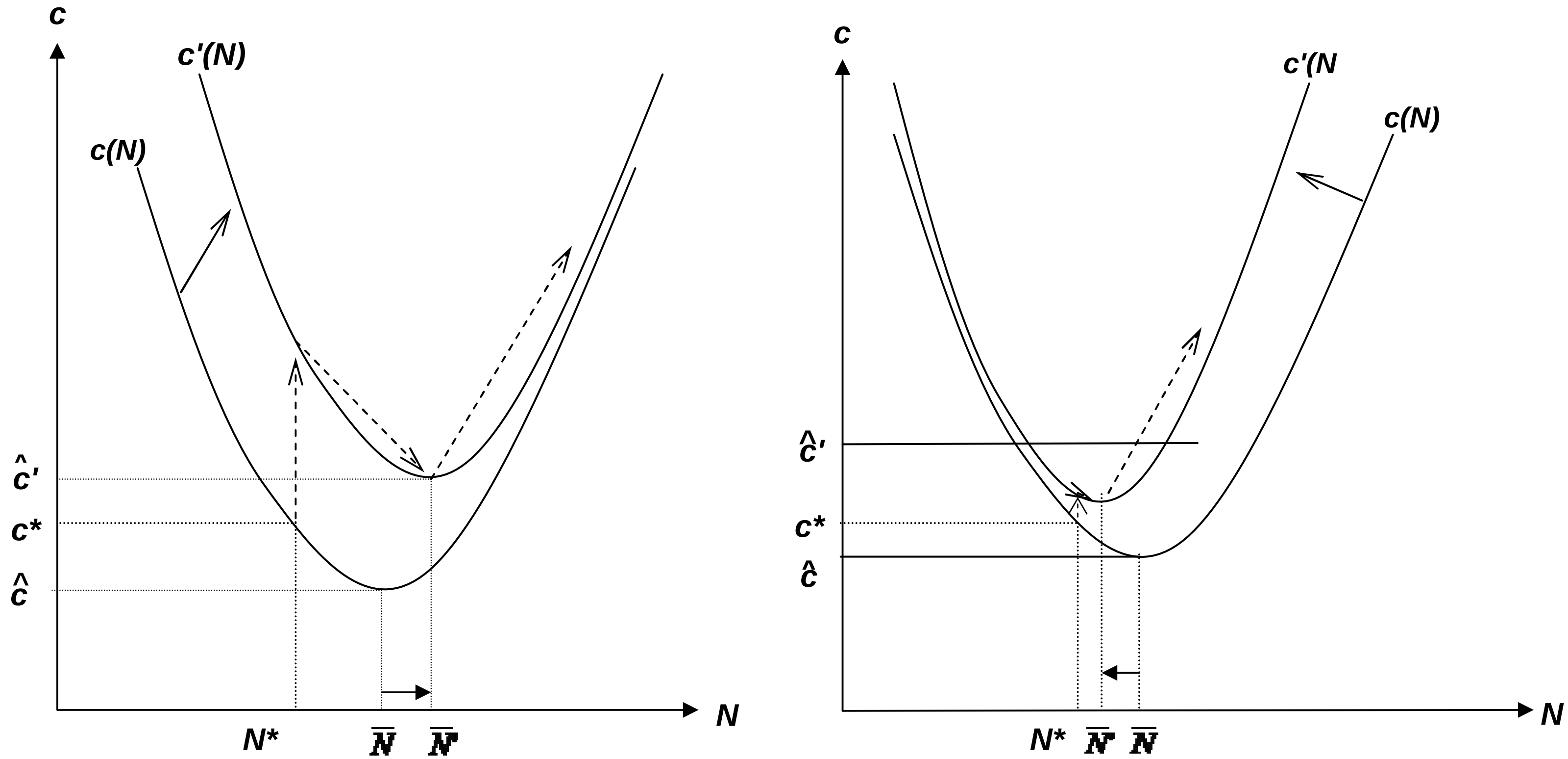


(a) Change in Rural Technology



(b) Land Discovery

Figure 7
Malthus to Romer θ<1



(a) Change in Rural Technology

(b) Change in Urban Technology

Figure 8
Malthus to Romer: The Great Discoveries

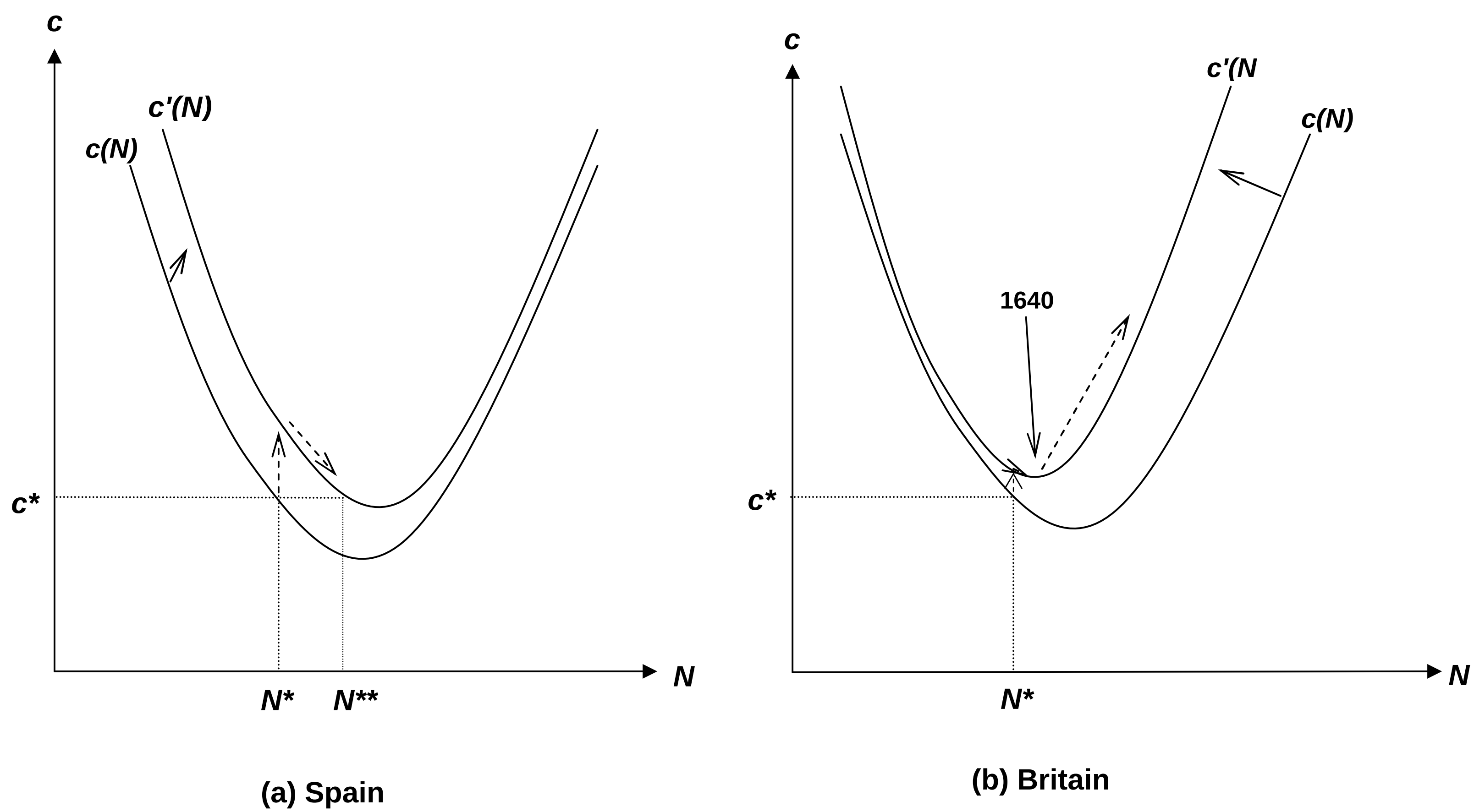


Table 1
Population, GDP Percapita and Urban Population
Spain and Britain

YEAR	1400	1450	1500	1550	1600	1650	1700	1750	1800
Spain									
Population (Thousands)	6008	6392	6800	7485	8240	8505	8770	9579	13026
Population (Annual Growth)		0.12%	0.12%	0.19%	0.19%	0.06%	0.06%	0.18%	0.62%
GDP Percapita (1990 International $)	698	698	698	793	900	900	900	965	1034
GDP Percapita (Annual Growth)		0.00%	0.00%	0.25%	0.25%	0.00%	0.00%	0.14%	0.14%
Share of Urban Population	26.3	22.4	18.4	19.9	21.3	20.8	20.3	21.4	19.5
Britain									
Population (Thousands)	2640	2600	2560	3240	4400	5610	5510	6260	9170
Population (Annual Growth)		-0.03%	-0.03%	0.47%	0.61%	0.49%	-0.04%	0.26%	0.77%
GDP Percapita (1990 International $)	714	714	714	834	974	1129	1250	1423	1621
GDP Percapita (Annual Growth)		0.00%	0.00%	0.31%	0.31%	0.30%	0.20%	0.26%	0.26%
Share of Urban Population	3.1	4.0	3.2	4.7	6.1	10.8	13.4	17.5	24.1

Sources: Population for Britain is from Clark (2005) and correspond to England only.
Population for Spain for the years 1400, 1750 and 1800 is from Bairoch et al. (1988, Table B5).
The remaining GDP and Population figures are from Maddison (2003), and blanks are filled
using simple interporlations except Britain 1650, which uses the growth rate of Clark's real wage.
Rates of urbanization for England after 1500 are from Wrigley (1985, Table 5). The remaining figures
are from Bairoch et al. (1988, Table b5). All remaining blanks are filled using simple interpolation.