The Italian Economy
Before Modern Growth

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(2011)

The paper presents a neoclassical, exogenous model of the development of the pre-modern Italian economy preceding the beginning of modernisation. Population plays a central role and conditions the evolution of the economy until the late 19th century. From then onwards, capital, together with technology replace population as the main driving force behind the economy. The statistical basis of the present paper is provided by P. Malanima, "The Long Decline of a Leading Economy. GDP in Central and Northern Italy 1300-1913".

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Over the last two centuries, the standard of living in western Europe, measured by output per head, has risen by 15-16 times. For the first time in the history of mankind, the production of goods and services has outpaced the rise in population over a long period of time. It is a common opinion that, although the availability of goods and services per head was scarce before 1800, slow growth did however occur. This view of slow or imperceptible growth is supported by the important example of England, which, poorly developed in the late Middle Ages, rose to the foreground in the early 19th century. The statistical reconstruction of British output, which is in progress, supports this view of slow rise from the late Middle Ages onwards.[1] Since economic historians deal primarily with England, the European trend is too often drawn on the basis of 5 per cent of the European population, that of England. Then, since the late Middle Ages, slow growth is also seen to characterize the European economy. However, as the case of Italy suggests, England is more of an exception than the norm against the background of the European economy; and Italy, we could add, is more normal than England, as a pre-modern economy.

Here I will consider the Italian case and try to analyse the long-term development of the Italian economy since the late Middle Ages.[2] The approach is based on the neoclassical model of growth. This model, however, in the elaboration primarily put forward by R. Solow (1956, 1970), assumes a stable rate of population growth, while capital is the dynamic variable and its evolution conditions long-term growth. In the following interpretation, by contrast, the rate of capital growth is low and stable, while demographic evolution is variable. R. Solow himself suggested that, when dealing with pre-modern growth, the central variable had to become population instead of capital (1970, chap. I).

[1] By S. Broadberry, B. Campbell, A. Klein, M. Overton, B. Van Leuven, British Economic Growth, 1270-1870: Some preliminary Estimates (presented in the University of Durham, March 2010, Congress of the Economic History Society).

[2] This topic has also been discussed in Capasso-Malanima (2007). I thank my friend Salvatore Capasso for the many conversations we had together on the topic developed in this paper.

I will recall, in the first section, the long-term trend of the Italian economy. I will examine, in the second, the availability of production factors and the main innovative changes taking place during the long epoch under investigation. A growth accounting of GDP in pre-modern Italy will be attempted in the third section. In the fourth, I will develop a model of pre-modern growth on the basis of the Italian experience. The start of the Italian modern growth, at the end of the 19th century, will be explained as mainly determined by the introduction of modern technology from abroad and especially by the change in the energy system. This is the reason why, looking at an economy such as the Italian one, an exogenous growth theory seems much more appropriate than an endogenous one.

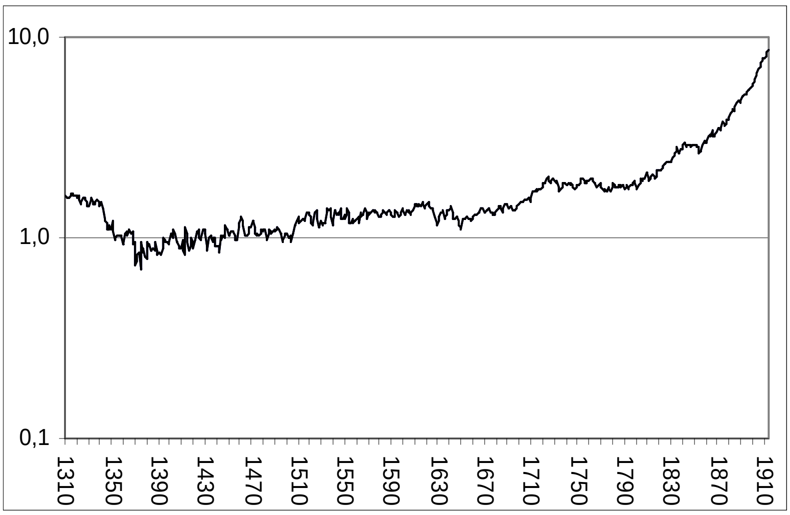
The present reconstruction is based on data concerning the centre and the north of Italy:[3] from the southern borders of the present regions of Tuscany, Umbria and Marche up as far as the Alps (161,000 km^2 out of the total of 310,000 km^2).

1. The trend

1.1. *Aggregate output*

Aggregate product dynamics show long-term stability in Italy, at least in the period we are dealing with. Taking the product in the years 1420-40 as the base of our index and then equal to 1, it varied within the range of 1 to 2 for half a millennium (Figure 1). The upper limit of 2 was only surpassed from 1820 onwards; 3 was reached in 1861 and 8 in 1912. If the base of our graph is set in the first decades of the 14th century, then 2 was reached only after 1870. In any case, a period of long stability was followed by rapid growth.

Figure 1. Index of GDP in Italy CN 1310-1913 (1420-40=1; vertical axis in log).



Source: Malanima, The Long Decline.

[3] I will refer to this part of Italy as north or centre-north (CN).

Long-term equilibrium of gross product characterizes any pre-modern agrarian economy. This equilibrium is maintained by falls in product per capita whenever population rises and increases in product per capita whenever population diminishes. This is the central point our model should address. The main differences between pre-modern and modern economies can be summarized by the two following features:

- in pre-modern economies gross product is stable in the long term, but unstable in the short term (because of the frequent famines and epidemics);
- in modern economies product is unstable in the long term (characterized as it is by high rates of growth), but ordinarily stable in the short term.

Long-term equilibrium, due to adjustments in product and population, is the central feature of our pre-modern Italian economy. The analysis of product per capita helps specify the trend of aggregate GDP.

1.2. *Per capita GDP*

The series of per capita GDP witnesses a decline of about 20-25 per cent from 1420-40 until the decade between 1860 and 1870 (Figure 2). If a comparison is made between the beginning of the series in 1310 and the first decade after the Unification, the decline is about 10 per cent. This long-term decline was interrupted by two periods of recovery, the 15th century, and, albeit more modest, the century between 1650 and 1750 (Table 1). During both periods, the urban sectors declined, while agricultural output per capita grew.

Table 1. Yearly rates of growth of per capita GDP 1360-1913 (%).

	% GDP
1360-1430	0.13
1430-1600	-0.20
1600-1760	0.11
1760-1855	-0.12
1855-1913	1.16

Note: rates of growth are computed from the Hodrick-Prescott trend.

Looking at the level of per capita GDP, the Italian economic evolution from 1300 until 1913 can be divided into three epochs:

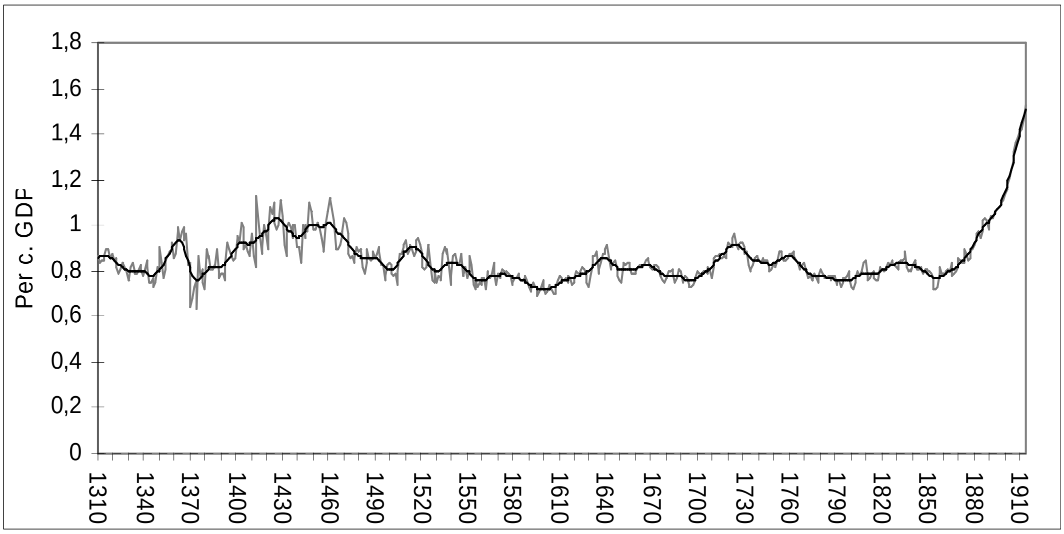
1. *from 1300 until the second half of the 16th century*: the period of the *Italian Renaissance*. The Italian economy enjoys a leadership in Europe. Its per capita GDP is high: between 1300 and 1570 the level is around 1,600 international 1990 PPP dollars;[4]
2. *from the second half of the 16th century until 1880*: the period of the *Italian decline*. The level is 10 per cent lower. It is about 1,400 International 1990 dollars in 1690-1710 (and therefore the same as that of the United Kingdom, but lower than that of Eng-

[4] I refer here to the nominal currency ordinarily used by Maddison in his research on world per capita output. See especially Maddison (2001 and 2007).

land and Wales).[5] It is, however, about 30 per cent less than that of England in 1820;[6]

3. *from the 1880s:* the beginning of *modern growth* in Italy. While per capita GDP is about 1,400 1990 international dollars in 1850-80, it exceeds 2,000 in 1900; is 3,500 immediately after World War II and reaches 20,000 in 2005.

Figure 2. Per c. GDP Italy CN 1310-1913 (1420-40=1).



Source: Malanima, The Long Decline.
Note: the trend is represented by the Hodrick-Prescott filter (λ=100).

1.3. *The start of modern growth*

When did modern growth start in Italy? As we have seen, the series of per capita GDP shows a clear upward trend from the 1880s onwards, as recently stressed by G. Federico (2003a, 2003b) and S. Fenoaltea (2002, 2006), in contrast with the opinion of previous scholars, according to which modern growth only began in Italy from 1896 on. However, if a longer period is considered, the upturn of the declining trend of per head output is already apparent from the 1820s, as it is in other western European countries; although in Italy this is hidden by stochastic events. During the first half of the 19th century wine and silk were among the most important agricultural products. Vineyard diseases drastically reduced wine production and, from 1850 onwards, the silkworm disease virtually put an end to silk production for two decades, thus resulting in a dramatic fall of the agricultural product and an interruption in the rising trend. Bad cereal harvests between 1853 and 1856 exacerbated the hardship of Italian agriculture.[7] For this reason only after 1880 did a true rise occur in Italy thanks to the introduction of new technology, notably in the field of energy (Malanima 2006a, 2006b). From then until the eve of World War I, product per head

[5] Crafts, Harley (1992) and Maddison (2001), p. 247. In 1700 the urbanisation rate was also the same in England and Italy (Malanima –forthcoming a-).
[6] See the similar declining trend in Alvarez-Nogal, Prados de la Escosura (2007a and 2007b).
[7] See in the following Figure 6 the mortality crises determined by the bad harvests.

rose by 98 per cent in the centre and north, and by 89 per cent on the national scale. A disparity was taking place between north and south as the industrialisation of the country got underway. The level reached by per capita GDP in the 15th century was surpassed around the year 1900.

The following Table 2 helps in setting Italy in the western European context between 1870 and 1911.

Table 2. Per capita GDP in Italy and Western European nations in 1870 and 1911 (Geary-Khamis 1990 PPP International dollars).

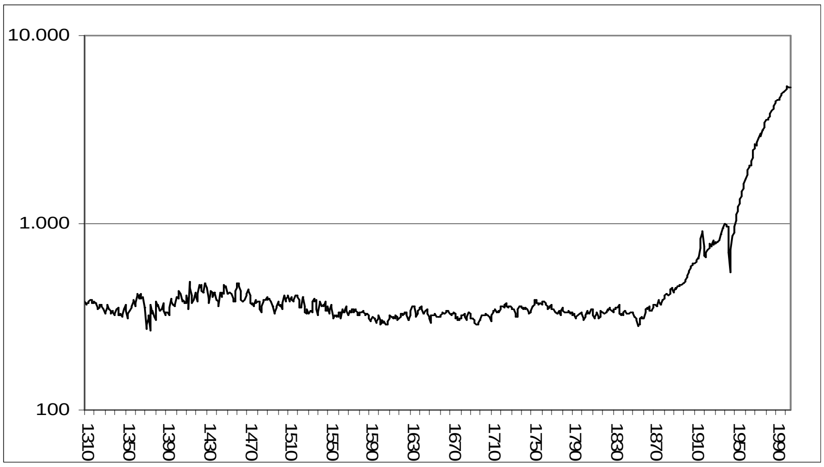
	1870	**1911**
United Kingdom	3,190	4,709
Netherlands	2,757	3,888
Belgium	2,692	4,148
Switzerland	2,102	4,378
Denmark	2,003	3,857
France	1,876	3,250
Austria	1,863	3,365
Germany	1,839	3,408
Sweden	1,662	3,002
Italy	1,649	2,557
Norway	1,360	2,255
Finland	1,140	1,939

Source: the source of the Table is Maddison (2003). Data for Italy are those of App. III, of Malanima, The Long Decline. The position of Italy in the hierarchy is hardly different using the database by Prados de la Escosura (2000).

1.4. *Two epochs*

We are now able to distinguish the two main epochs of the long history from 1300 until today (Figure 3): the long decline of the Italian economy since the Renaissance, and the rise in the productive capacity in the 150 years preceding 2000.

Figure 3. Per c. GDP 1310-2005 in CN Italy (1911 prices; vertical axis in log).



Source: Malanima, The Long Decline.

Between 1861 and 2005, per capita GDP rose 16 times in the centre and north, 14 times on the national scale, and 9.5 times in the south and the islands.

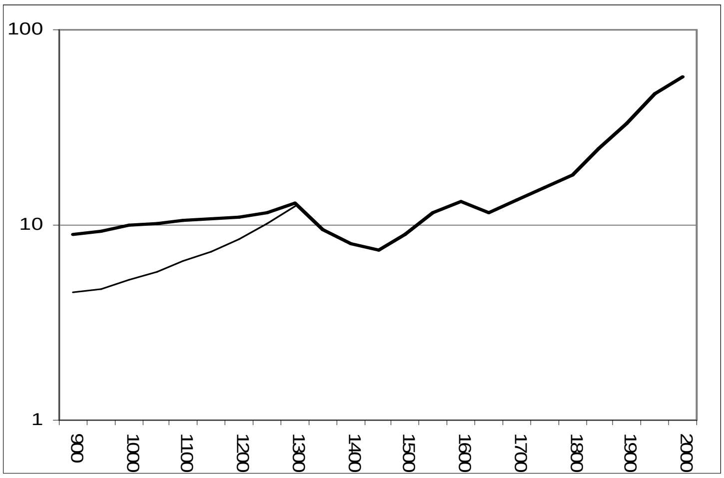
In the following analysis, I will be concerned only with the first of these two epochs and with the start of the second. Since the production factors are the main protagonists of this long development, I will primarily devote my attention to these.

2. Production factors

2.1. *Population*

For Italy as well as for other European regions margins of uncertainty exist regarding the level and trend of the late medieval and early modern population. In the case of Italy, however, these margins are narrower than for other countries, at least from 1300 onwards (Figure 4).

Figure 4. The Italian population between 900 and 2000 (with two plausible trends for the period 900-1300 (log scale).



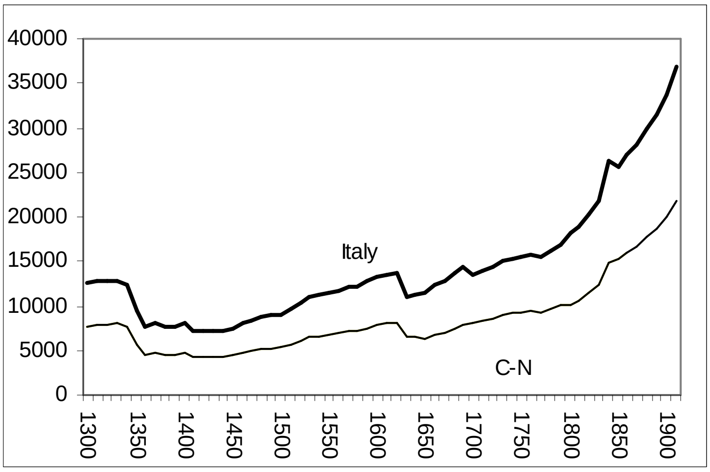
Sources: Del Panta, Livi Bacci, Pinto, Sonnino (1996), Malanima (2002), App. I; Lo Cascio-Malanima (2005).

If we look at the last millennium of Italian demographic history, three phases of about 3-4 centuries each can be singled out:

1. slow progress of the medieval era, starting in the 9th-10th centuries and ending in the first half of the 14th. There is no certainty about the rate of growth during this long epoch; rates between 1 and 2.5 per thousand per year being equally plausible at the present state of research;
2. long stability between 1300 and 1660. If we compare the population in these two years, the rate of growth was negative: Italy lost 0.35 inhabitants per thousand per year;
3. from 1660 until 2000 population grew in Italy at the astonishing rate of 4.5 per thousand per year. Taking into account migration from Italy, the Italian population grew much more.

The period under investigation, 1300-1913, includes the second of the three phases just examined and the start of the third: we could call the first of these two periods pre-modern stability and the second the start of modernization or demographic transition (Figure 5).

Figure 5. Population in Italy and the centre and north (CN) 1300-1910 (000) (log scale).

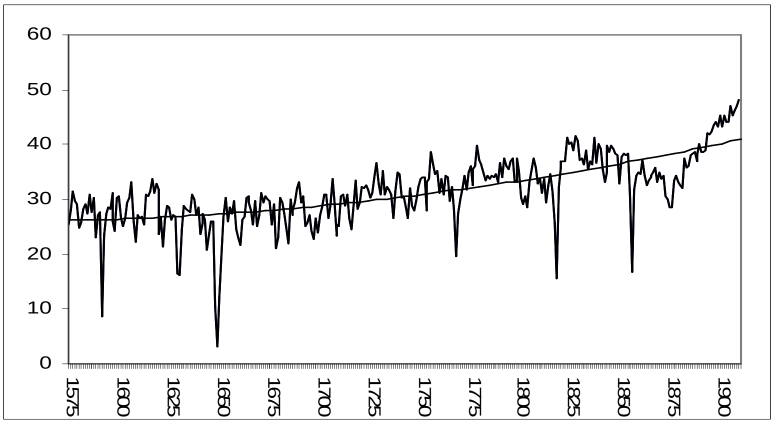


Sources: Del Panta, Livi Bacci, Pinto, Sonnino (1996), Malanima (2002), App. I.

2.2. *The short period*

Over the long term, data referring to Italy show the occurrence of sizeable drops in population size, due to plagues and especially to the three big epidemics striking a wide part of Italian territory at the same time: 1348-49, 1629-30, 1656-58.[8]

Figure 6*.* Life expectancy in Tuscany 1575-1910.



Source: Breschi-Malanima (2002).

[8] In Fig. 6, however, we also notice the fall between 1645-48, caused by a typhus epidemic. While the first two plagues hit the area we are dealing with (the centre and north), the last one involved only the south. The 1629-30 plague, however, hit Tuscan population less than that of the Po Valley, as Fig. 6 shows.

Long-term figures, however, hide short-term fluctuations caused by local epidemics and famines. Short-term movements in population are apparent in the demographic history of Tuscany, which is better known than that of other Italian regions. The graph of life expectancy in Tuscany in the long period 1575-1910 clearly shows short-term fluctuations due to mortality crises. The sharpest falls are caused by epidemics, while the lesser ones are mainly due to cereal shortages. We see that the rise in life expectancy was a relatively late event in Tuscany (as in Italy on the whole). At the end of the 19th century serious crises were still relatively frequent (Breschi-Malanima 2002) (Figure 6).

2.3. *Labour*

Although researchers do not know very much about the structure of employment in late medieval and early modern centuries, some estimation of its main features can be drawn from the data of the first national censuses held in 1861, 1871 and 1881.[9] Indeed, modern growth only started in Italy in the 1880s (Fenoaltea 2006), and up until then the structure of the labour market and population, remained virtually unchanged. In the first decades after the Unification, population in working age was 60 per cent of the total and labour force 55 per cent. Around 60 per cent of the labour force was employed in agriculture. Hence, with a certain degree of confidence, it is possible to deduce that the labour force in late medieval and early modern centuries was also about 50-60 per cent, out of which 55-75 per cent[10] was employed in agriculture:

	% of labour force	*% of population*
Agriculture	55-75	30-40
Industry and services	25-45	15-25

For the sake of simplification, we will describe this economy as one in which labour represents a fixed percentage of population; not forgetting, however, that, in pre-modern economies, the participation rate (the labour force employed or in search of employment on total population) varied notably. In fact, this percentage was higher in epochs of food shortage and low wage rates, when the density of population was higher, and lower in periods of low population density and high wages.[11] Similar behaviour of the labour market has been noted in modern underdeveloped agricultural economies (Berg 1962). An inverse relationship existed between supply of labour and wage rate at low levels of wage, especially for women. By contrast, in modern economies, there is a positive relationship between labour supply and wage rate. In Italy, during the centuries with which we are dealing, there was a true *intensification of labour* in agriculture, while, as we will see later, wage rates were diminishing.[12] Arboricul-

[9] Data is from *Sommario* (1958) and (1976); and, for 1881, Vitali (1970). See also Daniele, Malanima (forthcoming) for a statistical reconstruction of labour force in Italy from the Unification until 2001.
[10] This estimate is based on the first Italian censuses of population in 1861 and 1871 per region. See Daniele, Malanima (forthcoming)
[11] The problem is more widely discussed in Malanima, The Long Decline.
[12] On this topic see the important book by De Vries (2008), although the problem of labour intensification is set in a different perspective from that proposed in this paper.

ture –especially vineyard and mulberry tree cultivation– spread from the late Middle Ages onward. The diffusion of maize, as from the late 16th century, implied the employment of a much greater labour force in spring, which was previously a slack season for the peasant family. Later, from the 18th century on, proto-industrial activities also progressed.[13] The idea of an intensification of labour and intensification of land is actually supported by direct and indirect evidence, as will subsequently be illustrated.[14]

2.4. *Natural resources*

An initial, although imperfect, indicator of the available resources is provided by the population density. A comparison with the other European regions reveals the high Italian density (Table 3)[15].

Table 3*.* Density of population in Europe 1300-1870 (inhab. per km^2).

	Italy	**Italy Centre-North**	**Europe**	**Europe (without Russia)**
1300	41.5	48.1	9.0	15.8
1400	26.6	29.3	6.5	11.4
1500	29.9	33.0	8.2	13.6
1600	44.2	48.6	10.3	18.3
1700	44.9	50.0	11.7	20.4
1800	60.1	63.4	18.2	30.8
1870	93.0	103.0	29.9	50.4

Sources: Malanima (2002), App. I; Malanima (2009), chap. 1.

With the exceptions of Belgium and The Netherlands, Italy is among the most inhabited areas of Europe. In terms of arables the density of the Italian population is even higher. In Italy, hills (between 300 and 6-700 metres above sea level) cover 40 per cent of the surface; another 40 per cent is mountainous (more than 700 metres above sea level). Only 20 per cent is made up of plains. All in all, arable land covered 45 per cent of the Italian territory in the traditional agriculture of the past: that is all of the plains and part of the hilly terrain (Svimez 1961a).

If we simply assume that arable land constituted 38 per cent of the whole surface in the centre and north (Svimez 1961b) and divide it by the only existing estimate of the agricultural workers (Federico-Malanima 2004) –around 35-40 per cent of the population--, arable land per worker halved from the 15th century until 1800 (Table 4).

Table 4. Hectares per worker in Italy 1300-1870.

1300	2.2
1400	3.6
1500	3.2
1600	2.1

[13] The topic is discussed in Malanima (2002).
[14] As more widely discussed in Malanima, The Long Decline, App I.
[15] Data on population and their sources are quoted in Malanima (2009).

1700	2.0
1750	1.7
1800	1.6
1870	0.9

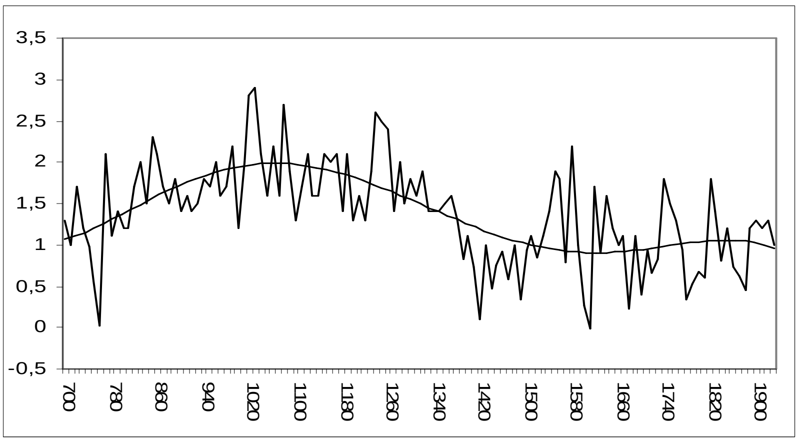
Source: Federico, Malanima (2004).

We know that arables increased at the expense of woods and marshes through investment of capital and labour time, especially in periods of demographic growth. During the 15th century, lands previously under cultivation were abandoned whereas in the following centuries the reverse took place. By the end of the 19th century, woodland areas were reduced to their lowest extent under the pressure of rising population. Large investment was directed to land reclamation especially in the second half of the 16th century and then throughout the 18th century.[16]

As clearly shown by many recent paleoclimatological studies, remarkable changes in temperatures occurred in Italy in the period with which we are dealing and these changes influenced the availability of agricultural land. Figure 7 represents the change in decadal temperatures during the long period from 700 to 1930. We see that after the so-called Medieval Climatic Optimum, which lasted from the 9th century until the end of the 13th century, the level of temperatures dropped sharply for a long period by about 1 degree. It was the beginning of the so-called Little Ice Age. Recent studies show that a recovery and rise in temperatures began in Italy from about 1820-25 (Brunetti, Maugeri, Monti, Nanni 2006).

Although apparently insignificant, a change of only 1 degree in the average temperature is likely to displace the altitude of wheat cultivation by about 100 metres above sea level and to have a strong impact on the agricultural surface (Galloway 1986). Considering the whole extent of Italy – 31 million hectares – lands between 600 and 700 metres cover more than 2 million hectares (Svimez 1961a). Hence, following a decrease of 1 degree, cultivation drops from 700 to 600 metres with the immediate consequence that wheat production becomes insufficient for 1-2 million people.

Figure 7. Temperatures in Northern Italy 700-1900 (decadal data).



Source: Mangin et al. (2005).

[16] Land reclamations and land-population ratios are recalled in Malanima 2002, chaps. 1 and 3.

Of course, an analysis of the correlation population-climate would require the investigation of many other variables. Among these, of utmost importance is precipitation variability, on which quantitative data only exist from 1800 onwards (Brunetti, Maugeri, Nanni, Auer, Böhm, Schöner 2006). However, on such variables, no information is available for Italy before 1800. What is certain is that for a long part of the period we are dealing with climatic conditions negatively influenced the availability of natural resources for Italian populations.

2.5. *Investment*

A simple workers-arables ratio is, however, far from a complete and satisfactory measure of per capita resources availability. The extent of the arables is not a stable percentage of the total available soil in the period with which we are dealing. Natural resources were not constant. They could be augmented by exogenous factors, such as climatic changes, and by endogenous factors, that is investment by landowners and peasants. This point requires further consideration.

Although in agricultural societies the potential for capital formation was high, given the unequal distribution of income, the actual productive investment was relatively low (Malanima 2009, chap. 7). This has two alternative, though not exclusive, explanations. On the one hand, the low formation of new capital was due to the high level of capital depreciation. In agricultural societies the short physical life of capital goods required a high proportion of savings in order to meet the yearly depreciation.[17] On the other hand, part of the investment was destined to generate totally unproductive, or low productive, fixed capital – buildings, palaces, churches etc.-- Given technical stability and low returns to capital in the agricultural sector, investments in this sector were low. To the question, often asked by historians, if capital formation was low because rich Italian families employed their incomes in palaces, churches and art we could answer that, since the productivity of investment was low, rich families spent their incomes in a more socially attractive way.[18] Buildings and art may thus be considered not the cause of low capital formation, but the consequence.

We know that arables increased at the expense of woods above all in periods of demographic growth. While, during the 15th century, lands previously under cultivation were abandoned, in the following centuries the reverse took place. At the end of the 19th century, woodlands were reduced to their lowest extension under the pressure of rising population. Substantial investment was directed to land reclamation, especially in the second half of the 16th century and throughout the 18th century.[19] Overall, however, the assumption of a low and stable rate of investment in pre-modern agrarian economies is quite plausible. Only in the industrialising economies of the 19th century did capital begin to play a wider role. When taking into account the high percentage of saving utilized to replace the depreciating capital in agrarian pre-modern economies, we may wonder if any net capital creation did actually occur.

[17] Kuznets (1968), p. 48.
[18] On the topic, see especially the important works by Goldthwaite (1987) and (1993).
[19] Land reclamations and land-population ratios are recalled in Malanima (2002), chaps. 1 and 3.

2.6. *Innovation*

Following A. Wrigley, the Italian economy, during these centuries, can be described either as a vegetable-based, or as a biological, or as an organic system (Wrigley 1988, 2004). Its main feature consists in the fact that the amount of energy employed in the production of goods and services is ultimately based on the metabolism of vegetable goods through biological engines i.e. both human beings and working animals. In other terms, what is lacking, in such a technical system, is the capacity to performing work with the aid of modern machinery. This lack represents the main constraint to the increase in the level of production. Economies such as the Italian one during the centuries we are analysing can thus be defined as *mature agrarian economies*.

Growth can only be achieved by introducing a new technical system and not by means of internal adjustments of the vegetable-based system. From what we know about the relationship between economy and population in late medieval-early modern Italy, this basic technical change is exogenous and took place in the last decades of the 19th century, just when modernization of the Italian economy was beginning (Malanima 2006).

Another exogenous factor was the introduction of maize from America, which proved to be the main innovation in agriculture (Coppola 1979). Its diffusion in northern Italy since the end of the 16th century is well known. Maize was to Italy what the potato was to some northern European countries, such as Flanders, England, Ireland…

In Italy, from the late Middle Ages until the introduction of modern fertilizers at the end of the 19th century, yield ratios of wheat reveal a long stability of around 4-5 quintals per hectare. However, in terms of calories per hectare, the spread of maize implied the doubling of yields to 10 quintals and even more. In terms of value, however, it was different since its price was half that of wheat for the same weight (De Maddalena 1974). Its progress was rapid especially in the Po Valley where, in the second half of the 19th century, it was by far the dominating cereal. In central Italy its diffusion was less important, and even less so in the south, where climatic conditions were unfavourable to its cultivation as in the wet soils of the Po Valley. The progress of rice in the north was less important in terms of calories per head and its price far higher than that of wheat.

Another important innovation, less immediately related to demographic trends was the spread of the mulberry tree from the south towards the north. It widened the possibility of producing raw silk and silk textiles. In the centre and north, the silk sector accounted for about 5 percent of the gross product in the 18th and 19th centuries (Battistini 1992, 2003, 2007). Its export could finance importation of cereals from abroad.

3. Growth accountancy

3.1. *Pre-modern growth accountancy*

Growth accountancy has become the ordinary tool of economists and economic historians dealing with modern growth. Because of the lack of series of data on capital, and ordinarily also on product, until now this method has never been utilised for pre-modern epochs. Labour can be proxied as a percentage of total population. For pre-modern times, furthermore, we also lack information on natural resources, today ordinarily excluded when dealing with modern epochs, but important to include when examining past agrarian economies. Our series allow a parsimonious utilisation of growth accountancy. The results we obtain, however, can not but single out orders of magnitude of the variables at play. The following analysis is aimed at establishing realistic relationships among the variable of our model, as developed in the following section 4.

As always, we start with a Cobb-Douglas production function, where output is the dependent variable and natural resources, capital and labour are the independent variables. The value of lands and natural resources must be included in a pre-modern Cobb-Douglas function since they were main production factors. Natural resources were more important than produced resources, that is, capital goods. In Italy, in the half century between 1861 and 1913, lands and rural buildings accounted for half the total wealth of the country. Their relative value diminished fast, with the modernisation of the country. In 1970, it was 20 per cent (Goldsmith, Zecchini 1999, pp. 3-20). Our Cobb-Douglas production function is therefore:

$$Y = A(L^{\alpha} R^{\beta} K^{1-\alpha-\beta}) \quad [1]$$

where:

Y GDP;

A total factor productivity;

L number of workers;

R value of natural resources;

K value of fixed capital (building included);

α, β relative share of output produced by any factor on aggregate output (or the elasticity of output as regards the change of a factor).

3.2. *Assumptions*

As usual, I assume constant returns to scale. Rate of growth is weighted through the marginal contribution of any factor according to eq. [2]:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \alpha\frac{\dot{L}}{L} + \beta\frac{\dot{R}}{R} + (1-\alpha-\beta)\frac{\dot{K}}{K} \quad [2]$$

where the dot on the symbol indicates the derivative as regards time. If *R* and *K* are jointly considered, the number of coefficients diminishes to two: α for *L* and (*1*-α) for (*R*+*K*). Then eq. [1] becomes:

$$Y = F(L,R,K) = A\left[L^{\alpha}(R+K)^{1-\alpha}\right] \quad [3]$$

In order to specify the weight of *A*, or Total Factor Productivity (*TFP*), for modern economies, eq. [2] is then developed in the following way:

$$\frac{\dot{A}}{A}=\frac{\dot{Y}}{Y}-\left[\alpha\frac{\dot{L}}{L}+(1-\alpha)\frac{(R\dot{+}K)}{(R+K)}\right] \quad [4]$$

In this form we can not solve eq. [4], in the case of pre-modern economies, for lack of information on *R* and *K*. A possible development is, however, the following one:

$$\frac{\dot{A}}{A}+(1-\alpha)\frac{(R\dot{+}K)}{(R+K)}=\frac{\dot{Y}}{Y}-\alpha\frac{\dot{L}}{L} \quad [5]$$

Since we estimated the value of *Y* and some plausible estimate is also possible for *L* as a percentage of total population, we are thus able to estimate, from the subtraction on the right side of the equation, the importance of technical knowledge (*A*) together with resources, both natural (*R*) and produced (*K*). The left side of the equation includes all the determinants of output with the only exclusion of the mere number of workers, on the right side. Not only technical progress is included in the right side of the equation as a capital-augmenting variable, able that is to increase the effectiveness of resources, but also improvements in human capital, which are not comprised in *L*. Labour intensification, that is the increase in working time, is often included whenever we deal with modern economies, since *L* is estimated as the hours worked in a year. It is not included in *L* in our equations. Then, while on the right side of eq. [5] we have only the difference between the aggregate product and the product indicated by the mere number of workers, on the left side we find the product of capital and resources, which incorporate the rising effectiveness of these factors thanks to technical improvement and the employment of more workers. Even today, it is hard to specify the coefficients for *L* and *K*, or, as in our case, (*R*+*K*). For modern economies, coefficients of production factors (*α* and *1-α*) are mainly comprised in the range between 0.60 and 0.75 for *α* and 0.25-0.40 for *1-α.*[20] Our calculations would suggest, for pre-modern Italy, the coefficient 0.70 for labour and 0.30 for the rest (capital plus resources);[21] which seems plausible for a pre-modern economy where labour is ordinarily supported by modest fixed capitals. We thus accept these last values. We use the following equation in our calculations:

$$\ln\frac{A_{t+n}}{A_t}+(1-\alpha)\ln\frac{(R+K)_{t+n}}{(R+K)_t}=\ln\frac{Y_{t+n}}{Y_t}-\alpha\ln\frac{L_{t+n}}{L_t} \quad [6]$$

3.3. *The results*

Total product is heavily influenced by population trend from 1300 until the end of the 19th century. It may be noted that, when considering the 5 centuries between 1370 and 1870, the contribution of labour to output was by 50 per cent more important than that of resources, capital, human capital, technology and

[20] See Barro, Sala-I-Martin (1995), chap. 10.
[21] See the calculations in Malanima, The Long Decline of a Leading Economy, App. 1.

changes in labour time (Table 5). If we divide the 5 centuries into two phases – 1370-1630 and 1630-1870 --, we again notice the higher importance of labour in the second period much more than during the first. While in 1370-1630, its importance is half that of labour, in 1630-1870 it is less than a third. Finally, dividing the 5 centuries into 4 phases, we can notice the higher importance of resources and productivity whenever population diminishes, as during the phases A and C, and the higher importance of labour during the phases B and D. The negative sign of *A(R+K)* during phase B could be explained as the consequence of worsening climatic conditions and decline in the availability of arables.

Table 5. Yearly rates of growth between 1370 and 1870 in GDP (*Y*), and contribution to growth of labour (*L*), natural resources (*R*), capital (*K*) and *A* (%).

		(1) ***Y***	**(2)** ***L*** **(α=0.70)**	**(3)** ***A(R+K)*** **(1-α=0.30)**
	1370-1860	0.25	0.15	0.10
	1370-1630	0.23	0.15	0.08
	1630-1870	0.35	0.27	0.08
A	**1350-1450**	-0.10	-0.17	0.07
B	**1450-1600**	0.16	0.26	-0.11
C	**1600-1760**	0.22	0.10	0.13
D	**1760-1860**	0.43	0.37	0.06

In a pre-modern economy such as the Italian one, the central driving force is population (that is labour). Capital accumulation, natural resources, human capital and technique play a secondary role.

This intensive production function can be represented through a graph based on our previous figures for growth; although data in our previous Table 6 include not only natural and produced resources, that is (*R+K*), but also technical advance and labour intensification. The yearly rate of growth of non labour inputs is equal to the left member of eq. 5 divided by *(1-α).*

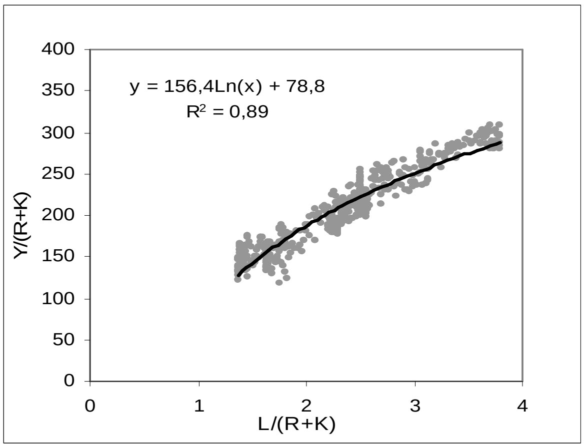
We now use this rate of growth to calculate the annual variation in the denominator of our eq. 8, assuming that (*R+K)* were, in 1350, 5 times the yearly output, such as estimated for 1427 Tuscany by R. Goldsmith (1987, pp. 145 ff.). Labour is always assumed equal to 60 per cent of total population.[22] It is apparent that neither the calculation of (*R+K)* nor that of *L* provide precise figures. An approximation is, however, enough as a basis for our graphical representation of the main relationships of our model.

Our intensive production function is drawn in Figure 8. It may be noted that a log function represents the relationship between *Y/(R+K)* and *L/(R+K)* quite well. Although it is important to start from actual figures whenever we simplify the reality geometrically, our formalisation will follow the graph only partially. As will be seen, the main difference in our formalisation is that the denominator (*R+K*) will not include technical advance and labour intensification.

For simplicity's sake *K* has replaced (*R+K*) and we analyse in section 4 *Y/K* as a function of *L/K.*

[22] As explained in Malanima, The Long Decline, App. I.

Figure 8. Intensive production function in the period 1350-1860 (*Y* per thousands *R+K* and *L* per thousands *R+K*).



Note: *Y* and *R+K* are in 1420-40 constant Florentine lire. The ordinates have to be read as output of 1,000 lire of *R+K* and abscissae as workers for 1,000 lire of *R+K*.
Source: see text.

4. The production function

4.1. *Characterising features*

In order to build a simple stylised representation of a pre-modern economy one needs to briefly recall its main characterising features.[23] The economy with which we are dealing is essentially agrarian. The agricultural sector is indeed the most relevant both in terms of the share of employed labour and final output. Urban population is quite a small fraction of total population, ordinarily representing less than 20 per cent of the inhabitants. Yet, the percentage of the non-agricultural population is higher: around 35 per cent in the long period we are dealing with.[24] Although we do recognise the presence of an urban population and non-agricultural product, for simplicity's sake we will compress our model into a single sector. After all, looking at a pre-modern economy and especially at its relationship with population, agricultural product should be the central focus. From agriculture it accrues the support for the living population and the possibilities for its multiplication. Agricultural product and productivity generally govern the potential for non-agricultural growth.

Our starting point is again the production function:

$$Y = AF(L,R,K) \quad [7]$$

The state of technology, captured by the parameter *A*, incorporates the technical content of tools, as well as the stock of knowledge, expertise and skills employed in the process of energy conversion (production): that is all those fac-

[23] In order to present a more realistic outline of the relationships among the variables, I developed the growth accountancy presented in the Appendix.
[24] Daniele, Malanima, Labour-Force in Italy 1861-2001 (forthcoming).

tors that are able to increase the efficiency of an energy converter (the ratio of the output of useful energy as to the total energy input).

4.2. *The intensive production function*

Following a standard practice in economics, we will assume specific features for this production function:

1. constant returns to scale in its two arguments (R+K) and L: doubling the quantities of (R+K) and L, with A held fixed (that is technique and human capital), doubles the amount produced;
2. marginal product of both factors, (R+K) and L, is positive, but decreasing. Marginal returns to L and (R+K) are diminishing.

These features of the production function, among others, offer the clear advantage of permitting us to express variables in intensive form. In fact, equation [7], dividing both members by (R+K), can be rewritten as:

$$\frac{Y}{R+K} = AF\left(\frac{L}{R+K}\right) \quad [8]$$

where $Y/(R+K)$ is the amount of output per unit of capital plus resources and $L/(R+K)$, the amount of labour per unit of capital plus resources.[25] This intensive form of the production function is similar to the one employed primarily by Solow (1956, 1970). However, as already mentioned, in this model, and following the classical tradition, population depends on economic variables and is not assumed to be a constant.

In the following pages, in order to simplify, $(R+K)$ is replaced by K.

4.3. *Mouths*

It is now useful to provide a simple formal representation of the movements of population and the relationship of these with output. Output is produced according to the production function in [7]. This produce, as already argued, is destined to sustain the population – pure consumption – and to replace or expand the stock of capital. In fact, capital includes animal stock and the amount of natural resources, land included, used in production.

First, the system has to cover the immediate needs of the population. Hence, very simply, we can show the output needed for the mere survival of existing population as:

$$\beta L \quad [9]$$

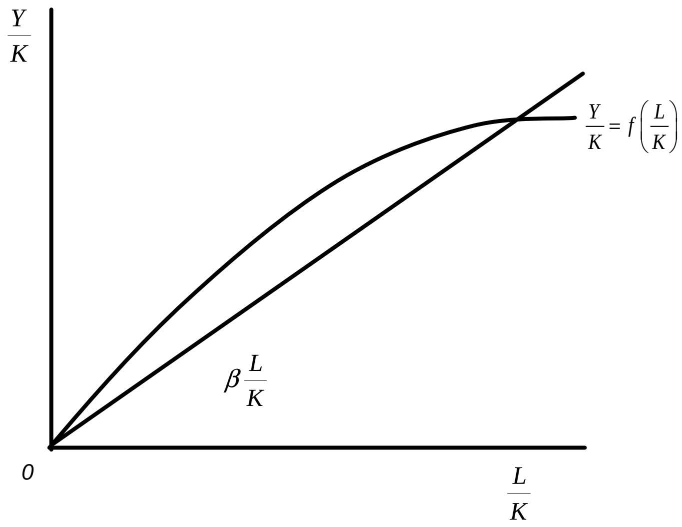
where β is the per capita amount of output required to keep population constant at L. Dividing the latter by K, we obtain the minimum amount of output the system requires merely to sustain itself in terms of capital and resources:

[25] This possibility was already put forward by Solow (1970), chap. 1.

$$\beta \frac{L}{K} \quad [10]$$

This can be represented as a straight line in a diagram in which we measure *L/K* on the horizontal axis (Figure 9). The *βL/K* line shows the minimum amount of energy to keep the population stable. Using a metaphor, we could call this the "mouths" of the economy.

Figure 9. The intensive production function.



4.4. *Hands*

Whenever the economic system is able to produce more than is required for simple reproduction, population can grow. Therefore the equation [9] may be rewritten in the following way:

$$\beta(L + \Delta L) \quad [11]$$

where *L* represents the population existing in the year *t-1* and *ΔL* represents the increase in population in a specific year *t* (that is the net increment of population from time *t*-1 to time *t*). Since in our model population increase depends on the possibilities of consumption and since consumption is a function of product, *Y*, the latter will ultimately modify the dynamics of population and of the economy.

Production is represented by the *Y* function as given by eq. 7 and, in terms of capital, by eq. 8 that is *Y/K* (where, as said, *K* replace (*K*+*R*). Because returns from labour are decreasing, this is a concave and upward sloping curve. This curve represents the total output per unit of capital. Hence, by using an analogous metaphor, we can define this energy as the product of the "hands" of the economy. It is now clear that the dynamics of the economy is modified by the relationship between the needs and the resources of the economy: the mouth and the hands. The system can grow and develop in terms of population (capital is constant) only if there is sufficient output. In graphical terms, this implies that population can only grow if the concave production function is above the straight line in Figure 8.

Vice versa, population will decrease when the straight line is above the concave production function. Having said that, we need to make some further specifications before proceeding to analyse the dynamics of the Italian economy within this model,

4.5. *Equilibrium*

Following a standard assumption in the neoclassical growth model, we take output per unit of capital, *Y/K*, as being divisible into two parts both representing a fixed percentage of the aggregate product: consumption and capital formation. Indeed, we know that in a pre-modern agricultural economy consumption represents about 90 percent of the total product[26] and this percentage remains constant over time.

On the face of this empirical evidence, we will assume that a fixed fraction of output, *c*, is destined to feed population. Hence, it can be written:

$$\beta(L + \Delta L) = cY \quad [12]$$

This equation implies that a fixed fraction of output, *cY*, is employed to provide the minimum level of energy in order to permit the survival of the population and in some cases allow for growth, *ΔL*. This also implies that the complement fraction of output, (*1-c*)*Y*, is employed in capital formation.[27]

As already discussed, capital formation (*1-c*)*Y/K* is partly destined to replace depreciating capital and is partly employed in non productive or scarcely productive investments. “Unproductive” refers to the fact that these activities are not strictly connected to the process of production of agricultural goods. These activities include the construction of buildings, palaces and churches for example, or the financing of wars and other similar undertakings (such as works of art). As such, these are not activities which allow the system to grow and develop. Indeed, as outlined above, this economy only grows when agricultural productive factors increase, i.e. labour and capital. The fraction of agricultural output, which is not employed in sustaining labour or capital, is in this sense, a waste of energy for the economy and the system. Hence, in order to determine the actual dynamics of the economy, we need to specify how much of the agricultural output is employed in these unproductive activities, rather than in the accumulation of labour and capital.

Population can expand or diminish depending on the amount of available resources. Expressing variables in terms of capital, we can represent the working of the economy graphically in the following way. When population is constant (long-term equilibrium), i.e. *ΔL* =0, the amount of output employed in agriculture is just sufficient to allow the population to survive. If this is the case, eq. 12 can be written as:

[26] See, for Italy, in 1861, Ercolani (1969), p. 422.

[27] In the following Figure 10, capital formation is represented by the area between the curves *Y/K* and *cY/K*.

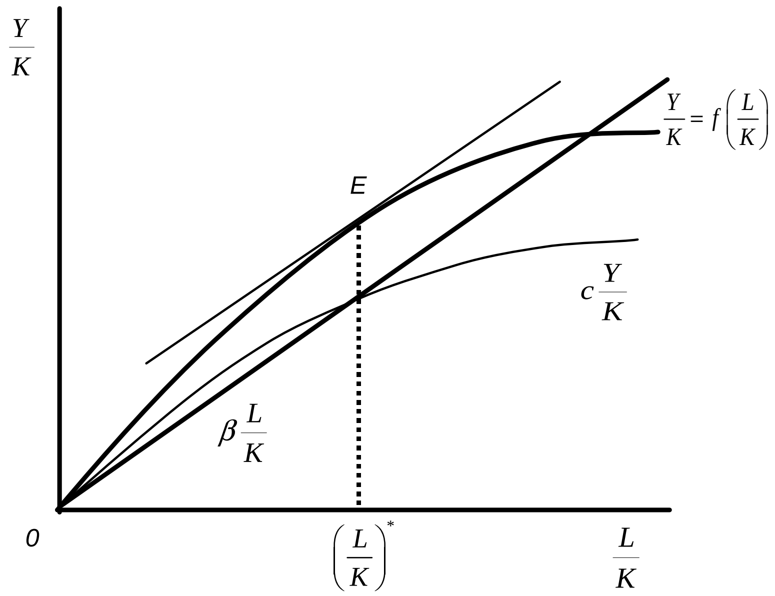
$$\beta \frac{L}{K} = c\frac{Y}{K} \quad [13]$$

Given the concavity of the production function *Y/K*, the fixed fraction *cY/K* is also represented by a concave curve. The relationship between this curve and the line of survival, $\beta L/K$, determines the dynamics of the population.

4.6. *The dynamics of the economy*

The workings of the economy are the following (Figure 10).

Figure 10. The production function: the general framework.



It is a geometrical representation of the real trend as ascertained by our previous growth figures. When labour per unit of capital, *L/K*, is below the level that keeps population at its survival level (eq. 16), the *cY/K* curve will be above the survival line *βL/K*. This implies that there will be sufficient resources to sustain the existing population and to allow demographic growth. In this case the workers or “hands” are very productive and can more than sustain the living “mouths”. Population and labour will then grow as will the *L/K* ratio, until equilibrium in the equation is re-established. The opposite occurs if the number of workers is too high.

4.7. *Factor productivity and long-term equilibrium*

Marginal labour productivity, though not explicitly represented in the previous diagrams (Figures 9 and 10), corresponds to the slope of the production function (*dY/dL*), represented in the graph by the tangent to the *Y/K* curve. Given concavity, labour productivity (hence wage) diminishes on the production function, while the average product of K (and then the average land productivity), on the vertical axis, increases thanks to the intensification in the use of land, capital and labour time. The graph combines the decreasing returns to labour (the concavity of Y/K) dear to classical economists with the increasing productivity of land and time (the values of the ordinates) dear to followers of the Boserupian view.

What determines a shift in the economy, and thus equilibrium $(L/K)^*$, creating increase or decrease in population? The production function depends on many factors, endogenous as well as exogenous. Shocks in the production function, for example in A (technique and human knowledge) or in the given stock of capital K, will shift the production function and determine a temporary surplus or deficit in the amount of resources required to sustain the system. When this occurs, the economy will move towards long-term equilibrium in the way we have described above. For example, particularly good climatic conditions will generally allow the productivity of land and rural capital to increase (hence K rises). The L/K ratio will shift to the left and the cY/K function will be higher than the level of subsistence. More resources will be available and population will increase, at least temporarily.

The other features of long-term equilibrium will now be determined.

4.8. *A general framework*

This simple model is able to depict many features of the Italian economy during the analysed period, such as the occurrence of epidemics, the flourishing Renaissance economy, or the decline in the early modern age.

One well known fact of pre-modern economies is indeed that wages were often close to the survival rate. If this is the case, one can argue that the equilibrium level of labour must be such that the wage rate, that is the slope of the production function, $Af'(L/K)$, equates the slope of the survival line, $\beta L/K$. This can be clearly seen in Figure 10. In the long run, the equilibrium level of labour per unit of capital, $(L/K)^*$, is such that the slope of the production function in E is β, that is the slope of $\beta L/K$. We are assuming that the yield of labour per unit of capital, the wage rate, is just enough to sustain survival.

We can also determine how the economy adjusts when it is outside the equilibrium. For lower levels of labour per unit of capital, that is for $L/K<(L/K)^*$, the slope of the production function increases and so does the wage rate. When this occurs more resources can be devoted to increase population, the L/K ratio will increase until we reach long-term equilibrium. Of course the opposite will occur for higher than equilibrium levels of L/K. An important feature of the model is the convergence towards a steady state which occurs when $cY/K=\beta L/K$. In a state of steady long-term equilibrium, the amount of output destined to consumption is just sufficient to cover the needs of a stable population. Decreasing returns to factors of production (the concavity of the production function) ensure convergence towards a steady labour/capital level $(L/K)^*$.

Despite long-term stability, this agrarian system is also characterized by frequent short-term "perpetual oscillation between happiness and misery",[28] as Malthus wrote. Given the great fluctuations in agricultural output year by year,

[28] Malthus (1798), Chap. 1.

one also needs to argue that the production function and therefore the *f*(.) function is not stable over time. This can indeed shift upwards or downwards depending onperiods of abundance and shortages in agriculture. Correspondingly, the yield of labour and the amount of available resources to sustain the economy will increase or decrease, as will population (although the modification of population due to the rise of fertility are not equal to the crises as a consequence of shortages).

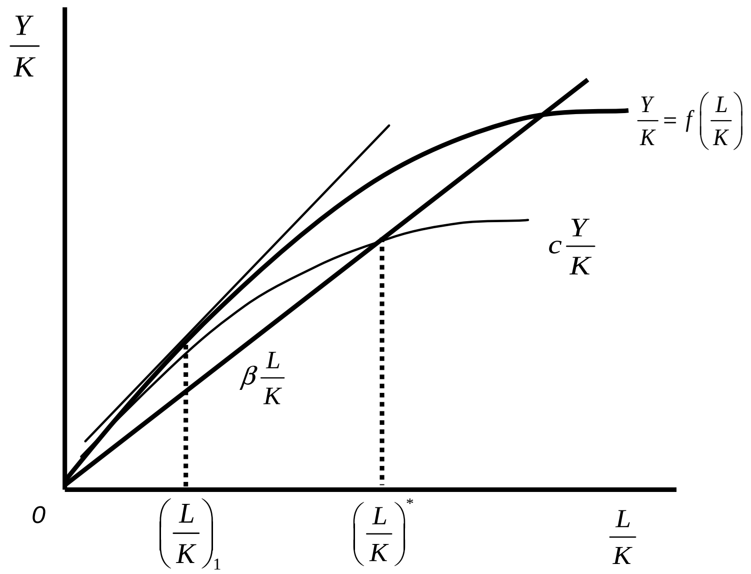
Although in this model population growth is endogenous and depends on the difference between *cY/K* and *βL/K*, a fall in population is only favoured by the rise of the *L/K* ratio. In fact, epidemics are more probable whenever the density of population increases. However, they are not simply determined by the rising ratio. Many epidemics do not depend on nutritional stress. There is a lot of chance in their occurrence. We can only say that the vicinity of the *L/K* ratio to *L/K** increases the probability or enhances the spread of epidemic mortality. We could call them *endogenous stochastic shocks*.

Some well-known historical patterns, which have characterised the period we are studying can now be analysed.

4.9. *The Renaissance*

During the Renaissance, the economy flourished (Figure 11).

Figure 11. The production function: the Renaissance.



A particularly high level of product per unit of labour allowed population growth, as well as providing the resources to enable a boost in artistic production and the construction of buildings. This occurred because the population per unit of available capital was particularly low. In other terms, there was an abundance of capital and, hence, both the productivity of labour and per capita product were higher. Following the theoretical framework we have just developed, this can be described as a situation in which the long-term equilibrium has not been reached: $L/K_1 < (L/K)^*$. If this is the case, labour productivity and the slope of the production function (represented by the tangent to the *Y/K* curve) is higher than the slope of the survival line. An excess of resources can be devoted to population increase and to unproductive activities (for example arts). As population per unit of capital grows the economy slowly moves towards the long-term equilibrium.

4.10 *The decline*

As the economy grows, the yield of labour decreases. Population increased from 7 million people (4.7 in CN) between 1400 and 1450 to more than 13 million people (7.8 in CN) from 1600 to 1700 and to 17 million people (10.2 in CN) in 1800. In 1600 and during the 18th century, population reached long-term equilibrium. At this stage, the yield of labour per unit of capital was just sufficient to sustain the population. The relative stability of gross product entailed, in this case, a fall in per capita income. Wages, given the level of capital, were near the subsistence level (with the exception of some periods during the 17th century) and population was striving to survive let alone increase. In graphical terms we can argue that the labour/capital ratio is very close to, or coincides with, the long term value, $L/K = (L/K)^*$.

We can also argue that, in some periods, the Italian economy was even below this level; especially in the last decades of the 16th century and in the years between 1790 and 1818. The consequence was that, in order to secure the subsistence of the population (βL), the substitution of the depreciating capital by the peasant families was lower than was required to ensure the simple reproduction of the system.[29] It was a period of ecological crisis.[30]

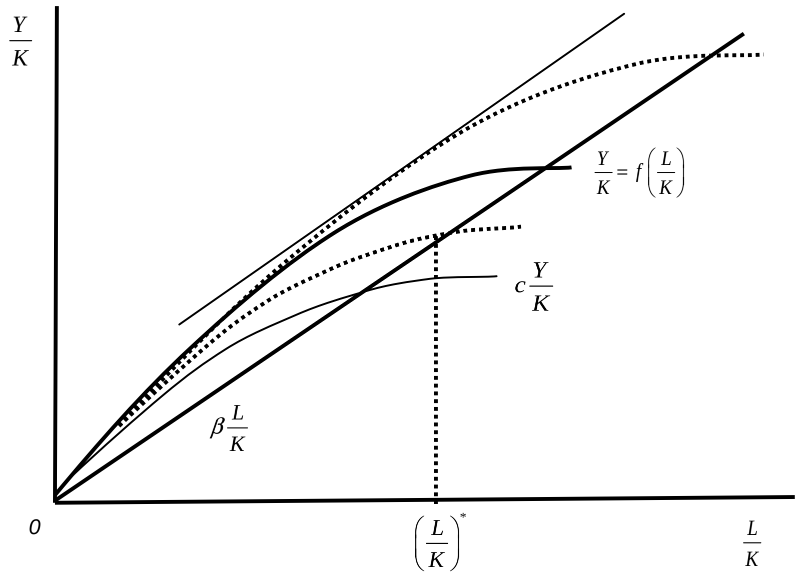
Things did not change with the spread of maize between 1650 and 1850. In fact, maize which involves a return in terms of calories double that of wheat, but which is worth half of what wheat is worth, allowed the population to expand even more. Per capita calories rose due to the effect of the introduction of maize in an upwards shift of the production function (Figure 12). The *cAf*(.) curve would also shift upwards and the equilibrium level of labour/capital ratio increase. After the introduction of maize, therefore, there are sufficient calories to allow the population to increase. Since the slope of the survival curve does not change, the new long-term equilibrium level of population/capital must determine an invariable wage and the slope of the production function must be the same as before the introduction of maize. However, since output is measured in energy as is labour productivity and the wage rate, this implies a decrease of wage in terms of value. That is exactly what happened during this period.

As revealed by recent research on the Italian economy (Fenoaltea 2006) it was only from the 1880s that the true modern growth also took place in Italy. The displacement of *Y/K* to the left became a lasting change in the shape of the production function because of technical change and the increase in capital formation. The consequence was a rise in labour productivity and in GDP per capita. This change continues to characterize the economy and to distinguish it from the pre-modern epoch.

[29] Examples could be the overexploitation of forests, decline in livestock, diminution of seed per hectare, neglect of the maintenance of farms…

[30] We agree with the concept of “ecological crisis” put forward some years ago by Pomeranz (2000) in a global perspective.

Figure 12. The production function: the 18th and 19th centuries.



4.11. *The start of modern growth*

Growth figures for the first half century after Unification witness a notable change taking place in the Italian economy. Data in Table 6 have been computed using different coefficients and including natural resources. No attempt has been made either to use standard labour units and working hours or to disentangle human capital. Then *L* represents the labour force.

Table 6. Rates of growth of labour (*L*), natural resources (*R*) and capital (*K*), and *TFP* 1861-1913 using different coefficients.

	(1)	**(2)**	**(3)**
	R+K 0.40	*R+K* 0.50	*R+K* 0.60
	L 0.60	*L* 0.50	*L* 0.40
L	0.21	0.18	0.14
R + K	0.63	0.79	0.95
TFP	1.00	0.87	0.75

Source: Malanima (2006a).

Although no comparison can be made with our calculations for the pre-modern economy, it can be seen that the role of labour in the first modernisation of the Italian economy is modest, whatever coefficient we use (Table 7).

Table 7. Estimate of the role of labour (*L*), resources plus capital (*R+K*) and TFP in the rate of growth in Italy 1861-1913 (%).

	%
L	7-10
R+K	43-51

PTF	41-47

Source: Malanima (2006a).

While the role of natural resources is diminishing during the period we are dealing with, that of capital is rising fast. It can also be seen that the role played by total factor productivity is remarkable and very similar to that of resources and capital. Capital formation, together with the technology of the first and second industrial revolution, were determining a deep break with the past traditional, agricultural economy.

Conclusions

In the previous pages we have tried to adapt Solow's neoclassical model to the population-economy (or, better, economy-population) interrelationships. While in Solow's framework the growth rate of population is assumed to be exogenous and the rate of capital accumulation endogenous, in our framework the reverse occurs: the rate of growth of capital is exogenous and the rate of growth of population endogenous. This is not the first attempt in this direction. It has been argued (by economic historians and by many economists, among these Lucas, 2002), that the main difference between economic systems prior to the industrial revolution and the modern ones is that, in the former, technological improvements and increase in the amount of per capita resources translated into increase in population and not into increase in per capita income. In these frameworks, the rate of population growth is not exogenously given and depends on many variables, such as individual choice, the amount of available resources, and the prevailing technology. We simply followed this line of thought. Lucas, Becker (1960) and other economists have modelled these facts by "endogenising" the rate of population growth: as well as standard variables such as labour and consumption, agents which dictate the number of children. The idea is that children increase parents' utility but they are also costly to raise. If this is the case, an optimal number of children might exist, which could be a function of the level of income.

Chance, however, plays an important role in pre-modern economies and in our framework. While increase in population is favoured by a positioning of the variables near the intersection of the axes in our geometrical description, death, and especially epidemics such as plague, primarily, depend on the density of population but are not determined by population pressure or decline in living standards[31]. Density favours the spread of epidemics, but in many cases does not determine them. Usually, in these cases, the system is around the L/K^* level in our figures. The same happens with short-term falls, caused primarily by meteorological conditions, which become famines whenever population pressure is high and living conditions are near the subsistence line and where starvation is already creeping in. Chance, however, plays a role in this case as well. This is the reason why we called these events *endogenous stochastic shocks*. Deterministic evolution only prepares the background.

[31] See especially the important remarks on living conditions and epidemics and diseases in Livi Bacci (1987).

We have tried to look at the Italian population in this perspective and to establish some connections among the many variables involved and have discovered that the explanatory value of this attempt helps combine different approaches. Boserup's view is not excluded. However, this is only a detail in a larger framework where "land and labour intensification" play an important role more as the result of a declining path rather than as the foundation of a rising one. Italy, as well as many other traditional societies – but not England, on which many economists and economic historians focus -- followed this declining path from the Renaissance onwards.

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