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Population, land, and growth ☆

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ABSTRACT

This paper suggests a new explanation for changes in economic and population growth with a long run perspective, emphasizing the role of land in the development process. Starting from a pre-industrialization state called the "Malthusian regime", land and labor are the main production factors. The size of population is limited by the quantity of land available for households and by incomes. Technical progress driven by a "Boserupian effect" may push the economy towards a take-off regime. In this regime, capital accumulation begins and a "learning-by-doing" effect in production takes over from the "Boserupian effect". If this effect is strong enough, the economy can reach an "ultimate growth regime". In the different phases, land plays a crucial role.

1. Introduction

This paper is a contribution to the unified growth theory emphasizing the role of land and technological progress in economic and population growth. In a long run perspective, land seems a very important variable in the growth process that deserves a particular study. Our approach is particularly related to two recent articles that have made a breakthrough on the theory of population evolution and growth: Galor and Weil (2000) and Hansen and Prescott (2002).

Galor and Weil (2000) develop a growth model that may explain the joint historical dynamics of education, population, and technology. They are able to reproduce changes in economic growth and population through three regimes: Malthusian, Post-Malthusian, and Modern Growth. Our approach differs from theirs in two key ways. First, land plays a limited role in their model: they assume that the return on land is zero and that the ownership of land is public. Secondly, their model allows population to increase with no bound and population density is not a brake on population growth. We depart from Galor and Weil (2000) by including a true land market with endogenous rent and prices. This true market, combined with a congestion effect on the use of land, induces an upper bound on population size. This is consistent with the usual long run scenario on population from the United Nations (2004).

Hansen and Prescott (2002) give an explanation of fertility behaviors during the industrialization process that emphasizes the role of land. This process is due to the substitution of capital to land in production, driven by biased technical progress in favor of the less land-intensive technology. In their story, population growth is based on an inverse U-shaped functional form of consumption inspired by Malthus (1798). Their model includes a true land market, but both sectors have technologies based on specific exogenous technical progress. Our approach complements Hansen and Prescott (2002) in two ways. First, we introduce endogenous fertility behaviors. The fertility decisions depend on different parameters of cost including a cost in time for parents and a housing cost related to the price of land. Secondly, we also depart from Hansen and Prescott (2002) by incorporating endogenous technical progress. This technical progress results from the increase in population density, that stimulates innovations, and from learning-by-doing. It induces a substitution of capital to land as in Hansen and Prescott (2002).

Our approach can also be related to Kremer (1993) who developed a model emphasizing interactions between technology and population. This model leads to a testable law of population dynamics that is not rejected by the data on a very long historical period. Our model develops the microfoundations of behaviors that underlie the

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interactions between technology and population. This allow us to generate a demographic transition without Kremer's assumptions that the population growth rate increases with the level of population at low levels of income and decreases with the level of population at high levels of income.

We develop an overlapping generations model in which fertility is endogenous. The utility of the parents is a function of good consumptions, of the number of their children, and of the consumption of a fixed asset: land. Each child implies a financial cost and induces a congestion effect on the utility of land. In our analysis, land can be used both as a production factor and as housing services for households. As a production factor, land is an income source for households. Under the form of housing services, land gives utility to households. Moreover, as the demand for housing services depends on the number of children, land is also related to fertility behaviors.

To complement our model we introduce two types of survival probabilities: a child survival rate and an adult survival rate. As shown in Aghion et al. (2010), improvement in life expectancy has a significantly positive impact on per capita GDP growth.

The production technology uses three factors: capital, land, and labor. The productivity of capital benefits from technical progress. Technical progress is driven by two effects: a "Boserupian effect" and a "learning-by-doing effect".

The first effect follows Boserup (1965, 1976), for whom the density of population may stimulate the incentives to innovate, in order to increase productivity. Boserup has studied the early stages of development, and was concerned with innovations in agriculture. She claims that "sustained demographic growth among primitive peoples does not always result in deterioration of the environment, because the possibility exists that the population, when it outgrows the carrying capacity of the land with the existing subsistence technology, may change to another subsistence system with a higher carrying capacity. Sometimes this change is even facilitated by the transformation of the environment, for instance, by the replacement of forest by bush or grassland, which forces the population to shift to bush fallow or grass fallow instead of forest fallow and to introduce types of tools that can cope with grassy weeds." This idea of a positive effect of the density of population on innovation has also been emphasized by several authors. Kremer (1993), incorporating ideas of Kuznets (1960), argues that "even if each person's research productivity is independent of population, total research output will increase with population due to the nonrivalry of technology".

The second effect is inspired by the Romer (1986) model: the knowledge that was acquired in production in the past increases current productivity. As in Romer (1986), this knowledge can be measured by a proxy variable which is the capital stock.

The economy in our model experiences different stages of development as suggested by Rostow (1959). The analysis firstly focuses on a country starting from a pre-industrialization state. Land and labor are the main production factors. The size of population is limited by the quantity of land available for households and by incomes. This pre-industrialization state is called the "Malthusian regime".

During this phase, some innovations can appear, driven by the "Boserupian effect". If this technical progress is marked enough, the economy can jump out of this Malthusian regime, to undergo a take-off phase. But in the converse case, the economy remains trapped in the stationary "Malthusian regime".

In the take-off regime, the economy begins to accumulate physical capital. The role of land in production becomes less important. A "learning-by-doing" effect in production takes over from the "Boserupian effect". Productivity increases as incomes and population rise. If this "learning-by-doing" effect is strong enough, the economy can reach an "ultimate growth regime".

In the "ultimate growth regime", the economy grows at a constant positive rate. Population converges towards a constant size, as its expansion is limited by land.

In the different phases, land plays a crucial role.[2] In the "Malthusian regime", a high population density gives incentives to innovate by the "Boserup effect". Therefore, starting with a lower endowment of land or with a higher population size allows a country to reach the take-off phase earlier. In the second phase, when the "learning-by-doing" effect becomes the engine of growth, the size of land has a positive effect on development and thus on the possibility of reaching the third phase. For given technological parameters, a minimum endowment of land is required to reach the ultimate growth regime associated with a positive growth rate. In the third phase, the value of the long run growth increases with the land endowment. The interpretation of this result is that our production technology exhibits the usual property of a scale effect, as in many endogenous growth models. As returns to scale are increasing, the size of population has a positive effect on the long run growth rate. But population size is bounded by land endowment in our model.

Mortality rates also play a key role in take-off. Mortality is introduced in the model through two survival rates: the survival rate of children and the survival rate of adults. An increase in the survival rate of children reduces the cost of a surviving child. An increase in the survival rate of adults increases their propensity to save, and thus favors capital accumulation. Historically, the Malthusian demographic regime had been characterized by high levels of both fertility and mortality. A decrease in mortality rates can induce both transitions: from the Malthusian to the take-off regime and from the take-off to the ultimate growth regime.

Numerical examples of transition from Malthusian stationary state to the ultimate growth regime are provided at the end of the paper. These examples emphasize the role of the learning-by-doing effect and of the different mortality parameters in demographic transition and in economic take-off.

Our analysis is related to several strands of literature. First, different authors have stressed the importance of an unbalanced growth process. Galor and Moav (2004) develop a growth theory that describes the replacement of physical capital accumulation by human capital accumulation as a prime engine of growth along the process of development. Kongsamut et al. (2001) propose a model of unbalanced growth, in which the growth process leads to a massive reallocation of labor from agriculture to manufacturing and services.

Secondly, other papers give a crucial role to land in the growth process. Galor et al. (2009) suggest that inequality in the distribution of land ownership may postpone or prevent take-off. Landowners affect the political process and postpone the implementation of education. Brunt and Garcia-Penalosa (2010) study the interactions between industrialization and urbanization. They point out a new mechanism that could drive technological change: the population density in cities may trigger the creation and diffusion of knowledge. Their paper provides another interpretation of the "Boserup effect" introduced in our framework: a high density of population leads to more innovation and technological progress.

Section 2 presents the model. Section 3 analyzes the dynamics of the intertemporal equilibrium. Section 4 shows how the dynamics allow us to isolate different phases in the development process. Section 5 presents a parametrization of the model that generates "realistic" numerical solutions. Section 6 concludes. A last section is devoted to technical appendixes.

2. The model

We develop a two-period overlapping generations model *à la* Diamond (1965) where fertility is endogenous. The life of an agent

[2] Allowing for capital accumulation and property rights over land considerably complicates the model, compared to Galor and Weil (2000). The quantity of capital has to be set to equalize its marginal product to the equilibrium interest rate, whereas the price of land has to follow a path such that the total return on land (rent plus net price appreciation) is also equal to the interest rate.