Abstract

Following a phase of near-constant living standards lasting from Stone Age until the onset of the Industrial Revolution, a large number of countries have experienced growth takeoffs, in which stagnation gives way to sustained economic growth. What causes some countries to enter a growth takeoff, while others remain poor? We discuss three mechanisms that can trigger a growth takeoff in a country previously captured in a poverty trap: fertility decline, structural change, and accelerating technological progress.

Growth takeoffs

Viewed on a historical time scale, economic growth in the world economy is characterized by a long phase of stagnation in living standards, followed in many, but not all countries by a growth takeoff, i.e., a transition to steady and sustained economic growth.

Figure 1 illustrates the basic facts. Before 1800, GDP per capita was low and near-constant in all world regions, with little cross-country variation in income levels. The first country to experience a growth takeoff was Britain with the start of the Industrial Revolution, closely followed by other Western European countries and the "Western Offshoots" such as the United States. More recently, a number of Asian and Latin American countries have undergone a transition to rapid economic growth as well. In much of Africa, however, income per capita continues to stagnate. What causes some countries to enter a growth takeoff, while others remain poor?

Explaining stagnation

Before one can account for a growth takeoff after a phase of stagnation, it is essential to understand why economies stagnated in the first place. The explanation suggested by one of the earliest writers on the subject, British economist Thomas Malthus in his "Essay on the Principle of Population" of 1798, is widely accepted to the present day. The Malthusian model relies on two key ingredients: an agricultural production function that uses the fixed factor land, and an income-population feedback where the population growth rate is an increasing function of income per capita.

Consider an aggregate production function of the form

$$Y_t = A_t N_t^{\alpha} Z^{1-\alpha}, \tag{1}$$

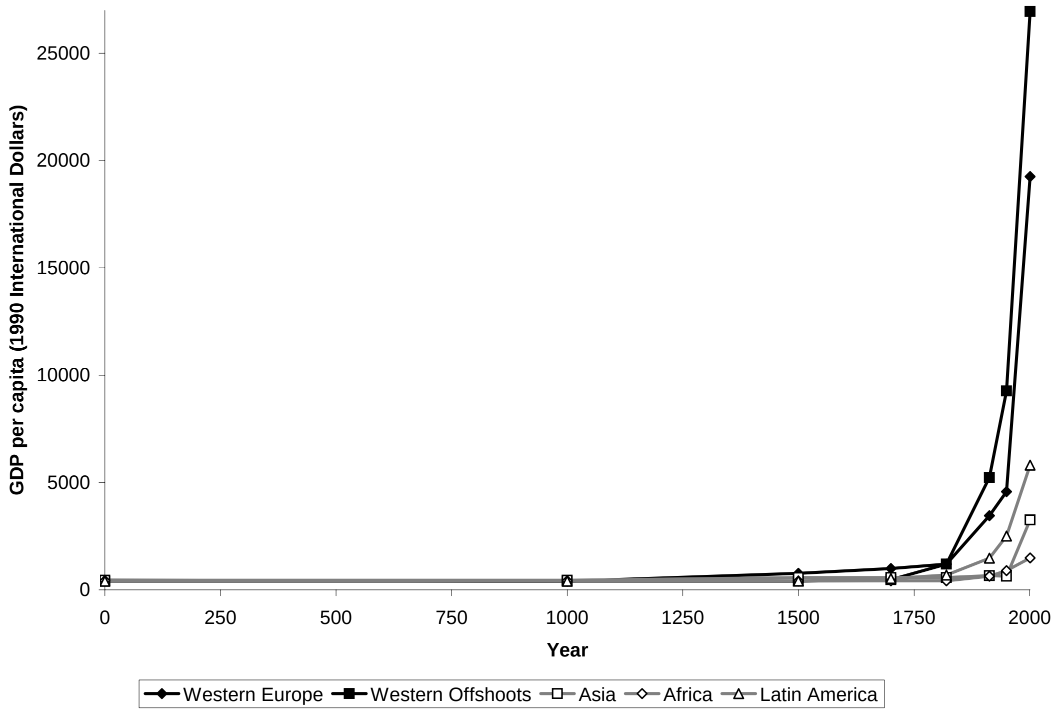

Figure 1: The evolution of income per capita across world regions, years 0–2001 (Source: Maddison 2003, Table 8c. The "Western Offshoots" are defined as the U.S., Canada, Australia, and Nea Zealand. "Asia" excludes Japan.)

where Y_t denotes output in period t, A_t is productivity, N_t is the size of the population, and Z is the fixed amount of land.[1] In what follows, we will use lower-case letters to denote per capita variables ($y_t = Y_t/N_t$ etc.), and the growth rate of a variable x will be written as $\gamma(x)$. Output per capita is given by $y_t = A_t z_t^{1-\alpha}$, so that its growth rate $\gamma(y_t)$ satisfies:

$$\gamma(y_t) = \gamma(A_t) + (1-\alpha)\gamma(z_t).$$

Since land Z is constant, we have $\gamma(z_t) = \gamma(Z) - \gamma(N_t) = -\gamma(N_t)$. Using this relationship, the growth equation can be rewritten as

$$\gamma(y_t) = \gamma(A_t) - (1-\alpha)\gamma(N_t). \tag{2}$$

Growth in income per capita is thus an increasing function of productivity growth and a decreasing function of population growth. The negative effect of population growth reflects that land is a fixed factor: when the size of the population increases, there is less

[1]The results outlined below can be generalized to the case where physical capital also enters production.

land for each person to work with, which lowers income per capita.

To turn the growth equation (2) into a theory of stagnation, one needs to specify how productivity A_t and population N_t evolve over time. Assume for now that productivity growth is constant, $\gamma(A_t) = \bar{\gamma}_A$. The main assumption underlying the Malthusian theory of stagnation is that population growth is an increasing function of income per capita y_t:

$$\gamma(N_t) = f(y_t), \tag{3}$$

where $f'(y_t) > 0$. A number of different justifications can be given for this relationship. One possibility is that children enter the utility function of parents as normal goods. A rise in income would then increase the demand for children, leading to higher population growth. Alternatively, the mechanism could also work through mortality. If higher income leads to better nutrition and, as a consequence, lower mortality rates, a positive relationship between income per capita and population growth follows. As an empirical matter, the assumption of a positive relationship appears to fit the experience of most pre-industrial economies rather well.

Using (3), the growth equation (2) reads:

$$\gamma(y_t) = \bar{\gamma}_A - (1 - \alpha) f(y_t). \tag{4}$$

According to this equation, the *growth rate* of income per capita is a decreasing function of its *level*. If the detrimental effect of population growth is sufficiently strong, this mechanism leads to stagnation as the only possible long-run outcome. In a country where income per capita is initially rising, population growth will accelerate until it fully offsets productivity growth, $(1 - \alpha) f(y_t) = \bar{\gamma}_A$, resulting in stagnation.

The Malthusian model is remarkably successful in terms of explaining economic growth (or the lack thereof) until Industrial Revolution. However, we now know that ultimately many countries managed to escape from the Malthusian trap. In these countries, living standards today are far superior to what almost any human alive before 1800 could have experienced. How can this drastic change in the economic fate of countries be explained?

Endogenous population growth

Given the growth equation (4), one scenario that could lead to a growth takeoff is a reversal of the income-population feedback. If the positive relationship described by the equation $\gamma(N_t) = f(y_t)$ breaks down, and subsequent population growth is low,

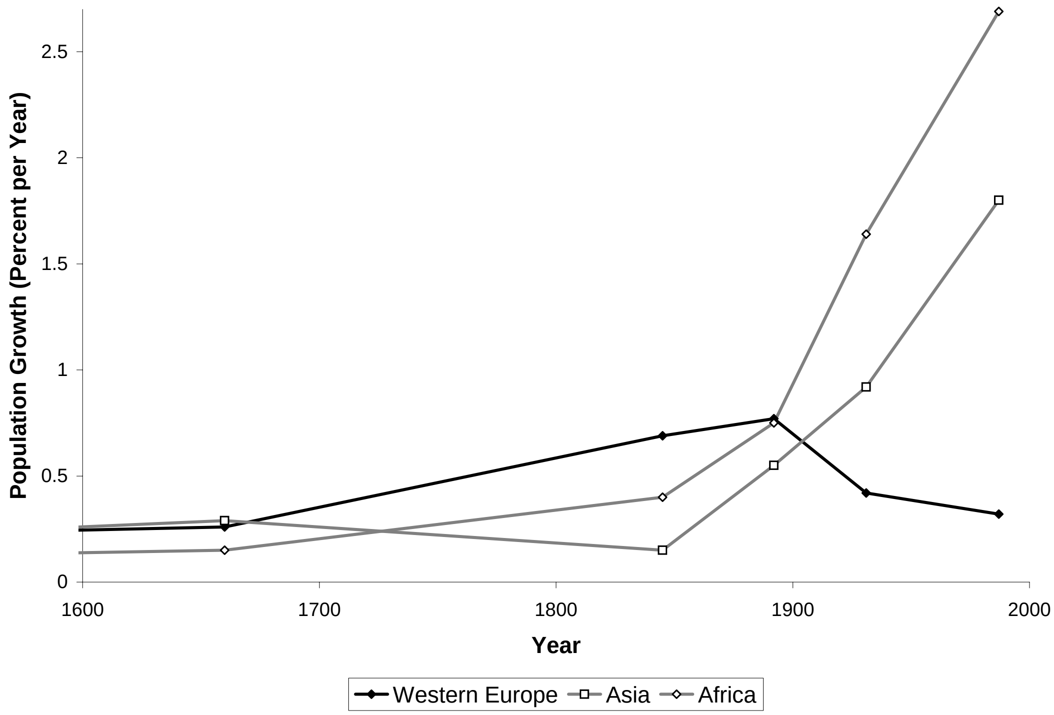

Figure 2: The evolution of population growth across world regions, years 1600–2001 (Source: Maddison 2003, Table 8a. "Asia" excludes Japan.)

growth will ensue. Consider, for example, the case where population growth ceases altogether, $\gamma(N_t) = 0$. According to equation (2), growth in output per capita is then equal to productivity growth. Thus, as long as productivity keeps increasing, income per capita will grow indefinitely.

Historically, the Malthusian relationship between income and population growth did indeed break down in every single country that experienced a growth takeoff. In a pattern known as the *demographic transition*, the high fertility and mortality rates of the preindustrial era gave way to a new regime in which fertility, mortality, and population growth are low. In modern data, the relationship between income per capita and population growth is negative (both in a cross section of countries and in the time series for most rich countries), which is the opposite of what the Malthusian model assumes.

Figure 2 illustrates the demographic transition by comparing population growth in Western Europe (the first region to experience a takeoff) with Asia and Africa (the regions that stagnated the longest). In Western Europe, population growth reached a peak at the end of the nineteenth century and has been declining since, despite rapid growth in income per capita. In Asia and Africa, in contrast, population growth accelerated throughout the last 150 years, and is now much higher than in Western Europe.

A number of authors have developed theories that integrate models of economic growth and the demographic transition to explain growth takeoffs. In this literature, fertility decline is usually interpreted as a substitution of child "quantity" (a large number of children) by child "quality" (fewer children in which parents invest in terms of education or human capital). As an example of a model capturing this tradeoff, consider the decision problem of a parent with preferences

$$u(c, n, h) = (1 - \beta) \log(c) + \beta \left[\log(n) + \gamma log(h)\right]$$

over consumption c, the number of children n, and the children's human capital h, where $\beta > 0$ and $0 < \gamma < 1$. The parent has to spend fraction ϕ of its time to raise each child, and can choose to spend an additional per-child fraction e on educating the children. The total child-rearing time is then given by $(\phi + e)n$, and the budget constraint for the parent is $c = (1 - (\phi + e)n)wH$, where H is the parent's human capital, w is the wage per unit of human capital, and the time endowment is normalized to one. A child's human capital depends on the parent's human capital H and education time e:

$$h = 1 + \mu H e,$$

where μ is the productivity of the education technology. Notice that a child receives at least one unit of human capital even if education e equals zero, which represents basic productive skills (such as physical strength) that do not rely on education. Lastly, the parent also has to observe a subsistence consumption constraint, $c \geq \bar{c}$, where $\bar{c}$ is the minimum amount of consumption required for survival.

In this model, the relationship between income and fertility depends on whether the optimal choices for education and consumption are at a corner. Assume that, initially, the wage w and the education productivity μ are so low that the subsistence constraint is binding and the parent chooses zero education ($e = 0$). The number of children is then constrained by the need to earn at least $\bar{c}$ units of consumption:

$$n = \frac{1}{\phi}\left(1 - \frac{\bar{c}}{wH}\right).$$

In this regime, the relationship between income wH and fertility n is positive, as assumed by the Malthusian model.

The outcome changes substantially if, through an increase in the wage w and the education productivity μ, the economy enters a regime where the subsistence constraint is no longer binding, and education is positive: $e > 0$. In this regime, parents spend a fixed fraction of their time on child rearing. The balance between child quality and quantity depends on parental human capital H. The optimal decision rules are:

$$n = \frac{\beta}{\phi + e} \quad \text{and} \tag{5}$$

$$e = \frac{1}{1-\gamma}\left(\gamma\phi - \frac{1}{\mu H}\right). \tag{6}$$

Equation (5) captures the tradeoff between child quality and quantity: the number of children is a decreasing function of education e. Intuitively, investing a lot in each child renders children expensive, which reduces demand. Education e, in turn, depends positively on parental human capital H. An increase in income per capita (through a rise in H) therefore lowers fertility n, the opposite of the Malthusian assumption.

Given these results, an escape from the Malthusian trap is possible if some change in the economy generates increased investment in child quality. The literature proposes different candidates for the underlying cause of such an event. In Galor and Weil (2000), the takeoff is ultimately a consequence of technological progress. Accelerating productivity growth increases the return to education (the parameter μ in the model outlined above), which eventually triggers the quantity-quality substitution and the growth takeoff. Galor and Moav (2002), in contrast, suggest that evolving parental preferences (through an increase in the parameter γ) are the driving force behind fertility decline. Yet other authors have emphasized the role of declining mortality rates (Boucekkine et. al. 2002, Cervellati and Sunde 2005, Doepke 2005, Kalemli-Oczan 2002, Lagerlöf 2003a, Soares 2004), increasing female labor-force participation (Galor and Weil 1996, Lagerlöf 2003b), changes in the provision of old-age security (Boldrin and Jones 2002), changes in child-labor and education laws (Doepke and Zilibotti 2005), and the introduction skill-intensive production technologies that raise the return to education (Doepke 2004).

Structural change

Apart from endogenous population growth, the Malthusian model also relies on the presence of the fixed factor land to generate stagnation. A second potential trigger for a growth takeoff is therefore *structural change* that decreases the role of land. In pre-industrial economies, agriculture was the main mode of production. In contrast, in modern industrial economies the share of agriculture in output is small, and consequently land is less important. Translated into the growth equation (4), structural change amounts to a shift in the parameter α. In particular, an increase in α lowers the detrimental effect of population growth on income per capita. In the limit case of $\alpha = 1$, income per capita is independent of the size or growth rate of the population, and is solely driven by productivity growth.

In Hansen and Prescott (2002), a decline of the role of land is generated endogenously in an environment where two competing technologies can be used for production.[2] In addition to the production function (1) above, an "industrial," constant-returns technology is also available:

$$Y_t^I = A_t^I N_t^I,$$

where Y_t^I is industrial output, A_t^I is productivity, and N_t^I is the amount of labor employed in the industrial sector. Productivity A_t^I is assumed to grow at a constant rate. The total amount of labor is allocated optimally between the traditional sector and the industrial sector. Given the linear production technology, output per worker in the modern sector is given by A_t^I. Early in development, when A_t^I is still low, it is optimal to allocate all workers to the traditional sector. During this phase the economy behaves just like a Malthusian economy where the modern technology does not exist at all. Ultimately, however, the modern technology becomes sufficiently productive to be introduced. If w_M is the (constant) marginal product of a worker in the Malthusian regime, the technology will be introduced once $A_t^I > w_M$. From this point on, population growth no longer affects output per worker, since land is not used in the industrial sector. Output per worker therefore starts to grow at the rate of technological progress. Viewed through the lens of the Hansen-Prescott model, what initially appears as a structural break in economic history is merely the outcome of an optimal sectoral allocation decision in an otherwise stable economic environment.

Endogenous technological progress

Starting once again from the growth equation (4), a third potential trigger for a growth takeoff is a sustained increase in productivity growth that is large enough to "outrun" population growth. Clearly, population growth cannot increase indefinitely, as there are physiological constraints on child bearing. Let $\bar{\gamma}_N$ be an upper bound for population growth that cannot be exceeded for biological reasons. If now productivity growth satis-

[2] Related contributions include Matsuyama (1992), Laitner (2000), Kögel and Prskawetz (2001), Gollin et. al. (2002), and Ngai (2004).

fies

$$\gamma_A > (1-\alpha)\bar{\gamma}_N,$$

even at maximum population growth the detrimental effect of increasing population density does not suffice to negate productivity improvements, and improving living standards ensue.

A potential cause for accelerating productivity growth is scale effects in the production of ideas. An increase in world population implies that there are more people who might invent new, productive technologies. An increase in world population should therefore imply an acceleration of productivity growth. Scale effects of this kind underlie the take-off models of Kremer (1993), Jones (2001), and Tamura (2002).

Conclusions

The three potential triggers for a growth takeoff presented here should not be regarded as mutually exclusive alternatives, but rather as complementary explanations for a joint phenomenon. From an empirical perspective, there is little doubt that all three explanations are relevant: every country that underwent a growth takeoff also experienced a demographic transition, a sectoral shift from agriculture to industry and services, an an acceleration of productivity growth. Reflecting these observations, many papers in the literature already incorporate more than one of the mechanisms. For example, a number of authors propose models where accelerating endogenous productivity growth triggers a fertility transition. This is true, for example, for the seminal paper of Galor and Weil (2000) and, in a framework driven by human-capital externalities, for de la Croix and Doepke (2003). Similarly, Greenwood and Seshadri (2002) and Doepke (2004) integrate models of structural change with theories of fertility decline.

Building on the different mechanisms behind growth takeoffs that have been proposed in recent years, a major challenge for future research is to understand why in many countries these mechanisms fail to work to the present day. Conceivably, a better understanding of the mechanisms that allowed some countries to overcome economic stagnation 200 years ago might help us learn how the same feat could be accomplished in poverty-stricken developing countries today.

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