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Growth and Development: A Schumpeterian Approach

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In this paper we present the so-called Schumpeterian approach to economic growth, in which growth is primarily driven by entrepreneurial innovations that are themselves influenced by the institutional environment. We argue that this more micro-founded approach both, questions the old divisions between growth and development economics, and also provides the analytical tools to design successful; strategies and appropriate institutions to achieve fast convergence and sustainable growth in countries at different initial levels of technological development.

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1. INTRODUCTION

Until very recently, development economists would commonly view growth theory as a subfield of macroeconomics[1]. Growth theory, would the argument go, focuses on the role of aggregate savings in fostering capital accumulation and thereby long-run growth, and on the rate of convergence to the long-run steady-state. Whilst also concerned with long-run growth prospects, development economics focuses much more on households and microenterprises, and on the role of institutions for insurance, credit, health, and education, etc, and on the successes and failures of those institutions in fighting poverty.

However, the emergence over the past twelve years of a new wave of growth models – in which growth is primarily driven, not only by capital accumulation and savings but more fundamentally by entrepreneurial activities or "innovations" that are themselves induced or facilitated by various aspects of the institutional environment– has changed the above

[1]See for example Ray (1998).

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perception. These new growth theories are more deeply rooted in microeconomics, and, in particular, in the theory of industrial organization, and their primary focus is on the role of institutions in inducing growth and facilitating convergence.

As we shall argue in this survey, not only does this new wave of growth models question the old distinction between growth and economic development, but it also provides analytical tools for new thinking on how to design successful strategies and appropriate institutions to achieve fast and sustainable economic growth in countries at different levels of technological development.

The survey is organized as follows. Section 2 discusses the growth models based on capital accumulation. Section 3 introduces the new growth paradigm, and shows how it can be used to analyze the issue of sustainable development and to explain the observed diversity of convergence or non-convergence patterns. Finally, the concluding Section 4 shows how new growth theories can be used to capture the notions of appropriate institutions and development strategies.

2. THE LIMITS OF GROWTH MODELS BASED ON CAPITAL ACCUMULATION

2.1. The neo-classical model

The idea that knowledge creation is critical for long-run economic growth, is certainly the most important proposition that emerges from the neo-classical theory of Solow (1956) and Swan (1956). More specifically, consider a closed economy in which final output Y is produced each period using the current capital stock K , according to the production technology:

$$Y = F(K, AL),$$

where: (i) A is a productivity parameter that measures the current state of knowledge; (ii) L is the current size of the labor force; (iii) the production technology F exhibits diminishing returns to capital accumulation, that is, the marginal productivity of capital F_K decreases as capital accumulates.

Capital accumulates according to the accumulation equation:

$$\frac{dK}{dt} = sY - \delta K, \tag{AC}$$

where s is the fraction of savings -assumed to be constant in the Solow-Swan model-, and δ is the depreciation rate of capital.

In the absence of population growth (i.e, if L remains constant) and of technical progress (i.e, if A too remains constant), such an economy cannot grow forever at a positive rate. Indeed, because of diminishing returns to capital, national income Y does not grow as fast as the capital stock, which in turn means that savings sY cannot grow as fast as depreciation. Eventually depreciation catches up with savings and at that point the capital stock stops rising and the economy stops growing. With population growth, and a production technology F that exhibits constant returns with respect to K and L, the same reasoning can be applied to output per capita $y = \frac{Y}{L}$ which is then a concave function of capital per capita $k = \frac{K}{L}$; we then obtain the proposition that knowledge creation, i.e a growing A, is necessary in order to sustain long-run growth of income per capita when final production exhibits decreasing returns to capital accumulation.

Thus, the neo-classical growth model cannot explain long-run growth of GDP per capita. However it can account for the observed phenomenon of "conditional" convergence, in other words the fact that among countries or regions that are initially sufficiently similar, those at a lower current level of ouput or capital stock par capita grow faster than countries that are closer to their steady-states (see Figure 2). For example, if:

$$Y = K^{\alpha} L^{1-\alpha},$$

then dividing both sides of equation (AC) by K, we immediately obtain:

$$\frac{K}{K} = s(\frac{L}{K})^{1-\alpha} - \delta,$$

which in turn is obviously decreasing in K. Therefore, the more capital has already been accumulated in a country, the lower the growth rate in that country. Cross-country convergence here is entirely due to the assumption of decreasing returns to capital accumulation. In section 3.4 below we develop an alternative theory of convergence based on the existence of cross-country knowledge spillovers.

2.2. The AK approach

Whilst knowledge creation, which determines the long-run rate of growth of income per capita, is taken as given by neo-classical growth models from Solow (1956) to Mankiw-Romer-Weil (1992), a main proposition shared by all so-called *endogenous growth* models, is that knowledge is generated by the economic system itself. There are two variants of endogenous growth theory.

The first variant of endogenous growth model, known as AK theory, was introduced in a long-neglected contribution by Frankel (1962) and then given its modern formulation in the celebrated articles of Romer (1986) and Lucas (1988). The AK model treats knowledge as little more than a particular kind of capital: namely, knowledge creation results directly from capital accumulation by the different firms in the economy, the basic idea being that capital accumulation by any individual firm contributes to a collective process of creation of new technological and organizational knowledge through learning by doing or learning by imitating. Such knowledge creation, in turn, will permanently offset the effect of the diminishing marginal productivity of capital and thereby enable the economy to sustain a positive rate of growth in the long-run under suitable assumptions on the learning externalities.

First introduced by Frankel (1955) to reconcile the assumption of diminishing returns to individual capital accumulation with the possibility of positive long-run growth as in the Harrod-Domar model, the AK model features a competitive economy with N firms. Each firm j ($1 \leq j \leq N$) produces final output according to the Cobb-Douglas production function:

$$Y_j = AK_j^{\alpha} L_j^{1-\alpha}, \tag{1}$$

where: (i) α is strictly less than one, so that there are diminishing returns to individual capital accumulation; (ii) A is a productivity parameter that reflects the current state of knowledge; whilst the dynamic evolution of A, i.e knowledge creation, is taken as given in the neo-classical model discussed above, the AK model endogeneizes knowledge creation by making it the *collective* outcome of capital accumulation by all firms in the economy. More formally, it assumes:

$$A = A_0 \Big(\frac{1}{N} \sum_j K_j\Big)^{\eta}, \tag{2}$$

where η measures the degree of externality in firms' learning by doing.

For simplicity let $L_j \equiv 1$ for all j; then, in a symmetric equilibrium where $K_j = \frac{K}{N}$ for all j, aggregate per capita income Y will satisfy the equation:

$$Y = A_0 N^{1-\alpha-\eta} K^{\alpha+\eta}. \tag{3}$$

This, together with the accumulation equation (AC) which still holds here if we assume a constant savings rate, will determine the entire growth path of the economy. We shall be particularly interested in the knife-edge case where $\alpha + \eta = 1$. Only then will the long-run rate of growth g be finitely positive, equal to:

$$g = sA_0 - \delta, \tag{4}$$

which is nothing but the Harrod-Domar growth rate.

2.2.1. The Mankiw-Romer-Weil criticism

An unfortunate prediction of the AK model of Endogenous Growth where knowledge is treated like nothing more than capital, is that positive long-run growth is simply inconsistent with the possibility of cross-country convergence. Consider indeed two countries or regions, each of them governed by the same kind of dynamic equations as above. Either these two countries (regions) share the same fundamental characteristics (in terms of savings rate, depreciation rate, production technologies,...), in which case from the start these two economies will grow at the same rate $g = sA_0 - \delta$; or these countries will have different characteristics, or may be subject to stochastic shocks, in which case their growth paths should simply diverge over time. In contrast, the neo-classical model immediately implies that, every thing else remaining equal, a richer country that has accumulated a larger stock of capital should grow more slowly than a poorer country with the same economic parameters but a lower capital stock. There, in fact, is strong evidence of a *convergence* pattern in per-capita income, not only across regions with different starting points but similar economic characteristics, like between different States within the US, but also between industrialized countries and emerging market economies, in particular in South-East Asia (see Barro and Sala-i-Martín, 1995). This cross-country evidence on income differences, has in turn been used to criticize endogenous growth theory as a whole.

Mankiw, Romer and Weil (1992) -henceforth MRW- have led this attack whilst arguing that the neo-classical growth model with exogenous technical progress and diminishing returns to capital (see subsection 2.1 above) can explain most of the cross-country variation in output per capita. The problem with the traditional Solow model is that with capital as the only cumulable factor and given that estimates of the coefficient on capital lie in the range of 0.3-0.6, the implied convergence rate is much higher than the one estimated from cross-country regressions, being around 0.02. In order words, there seemed to be excessively strong diminishing returns to capital. MRW tried to solve this puzzle by introducing (unbounded) human capital accumulation on top of physical capital accumulation. The augmented Solow model then postulates a production function of the form $Y = K^{\alpha} H^{\beta} (AL)^{1-\alpha-\beta}$. The joint coefficient on physical and human capital, $\alpha + \beta$, is still less than one, but necessarily greater than the estimated coefficient on capital. As a result the returns to cumulable factors diminish, but only very slowly, and the implied convergence rate is therefore lowered.

To summarize our discussion at this point, the main criticism to the AK approach, most forcefully put forward by Mankiw, Romer and Weil (1992), is that, unless $\alpha + \eta < 1$ (in which case, as in the neo-classical model where $\eta = 0$, the long-run rate of growth in output per capita is equal to zero), this model cannot account for conditional convergence, that is for convergence among countries with similar production characteristics, i.e. with the same values of the parameters A_0, α, δ and η.

2.2.2. AK models with exhaustible resources

As we shall now argue, another drawback of the AK approach, is that it cannot account for the possibility of sustained positive optimal growth in an economy in which capital accumulation requires the use of an exhaustible resource. That the issue of sustainable development might be more adequately analyzed using an optimal growth formulation a la Cass-Koopmans, has been convincingly argued by Dasgupta (1994) who defines "sustainable development" as development that maximizes the total (discounted) welfare of current *and* future generations, taking into account, not only the constraints imposed by the finiteness of natural resources but also all the possibilities for technological substitution between different kinds of capital goods, be they physical, natural, or intellectual.

We shall thus abandon the constant savings rate assumption and replace it by intertemporal utility maximization by a representative infinitely-lived consumer who incarnates a representative dynasty over time. The following variant of the AK model will thus be very similar to Romer (1986) except for the introduction of a limited natural resource which must be depleted in order to produce capital. As it turns out, this addition to the AK model will dramatically affect its ability to explain long-run growth.

More formally, consider the following AK model with limited natural resources. At each period, final output is produced using capital and a flow of natural resource services R according to the production technology:

$$Y = AKR^{\nu} \tag{5}$$

where $0 < \nu < 1$. The current stock of natural resources is denoted by S, and this stock depletes as resource services are being provided to the final sector, namely:

$$\dot{S} = -R \tag{6}$$

The optimal growth path is then one that maximizes intertemporal utility of the representative consumer, i.e which solves:

$$\max W = \int_0^{\infty} e^{-\rho t} u(c_t) dt$$

subject to (5), (6), and the resource constraints:

$$\dot{K} = Y - c \tag{7}$$

and:

$$S \geq 0. \tag{8}$$

The hamiltonian for this program is:

$$H = u(c) + \lambda(AKR^{\nu} - c) - \xi R, \tag{9}$$

where λ and ξ are the shadow prices associated with constraints (6) and (7). Now, taking isoelastic utility functions of the form: $u(c) = \frac{c^{1-\varepsilon}-1}{1-\varepsilon}$, the first-order conditions satisfied by the optimal solution to this program, are:

$$\dot{\lambda} - \rho\lambda = -\frac{\partial H}{\partial K}, \tag{10}$$

$$0 = \frac{\partial H}{\partial c}, \tag{11}$$

and

$$\dot{\xi} - \rho\xi = -\frac{\partial H}{\partial S} = 0.$$

The first two conditions together lead to the well-known Ramsey equation:

$$\frac{\dot{c}}{c} = \frac{1}{\varepsilon}(AR^{\nu} - \rho), \tag{12}$$

The unnumbered equation implies that the shadow price of the natural resource, ξ, grows exponentially at rate ρ over time. Thus, ξ converges to infinity in the long-run. Furthermore, equations (6) and (8) immediately imply that R must eventually converge to zero. This, together with the Ramsey equation (12), in turn rules out the possibility that optimal growth be positive in the long-run as this would lead to the contradiction: $\frac{\dot{c}}{c} \to -\frac{\rho}{\varepsilon}$.

In other words, unbounded growth cannot go on forever because the resource constraint will eventually reduce the marginal social value of capital below the discount rate ρ. And here, unlike in the AK model without limited resources, the accumulation of knowledge is of no help: indeed, to the extent that new knowledge is entirely driven by capital accumulation in this model, a faster rate of technical progress would require speeding up the depletion of the natural resource, which in turn can only lower the prospects for sustained long-run growth, i.e aggravate the problem that technical progress was supposed to alleviate!

In contrast, the Schumpeterian model developed in the next section, which treats technological innovations and capital accumulation as two separate processes, will be shown to accommodate the possibility of a positive optimal long-run rate of growth.

3. THE SCHUMPETERIAN FRAMEWORK

The second variant of endogenous growth theory is the Schumpeterian approach,[2] which revolves around the following set of ideas: (i) the main source of technological progress is innovation; (ii) innovations, which lead to the introduction of new production processes, new products, new management methods, and new organization of production activities, are created by self-interested firms, entrepreneurs, and researchers who expect to be rewarded with (monopoly) rents in the event that their innovation is successfully implemented;[3] (iii) in general, these monopoly rents are eventually dissipated, as the new processes or products introduced by current innovators become obsolete when new innovations occur that compete with the current technologies and thereby drive them out of the market; this is the Schumpeterian notion of "creative destruction".

Unlike its AK predecessors, the Schumpeterian model emphasizes the difference between R&D and knowledge on the one hand, and physical or human capital investments on the other hand. In Section 3.1 we provide a simple diagrammatic representation of the Schumpeterian framework, to help us distinguish it from previous theories based on capital accumulation and savings alone. Section 3.2 develops the basic Schumpeterian growth model and uses it to analyze the institutional determinants of (long-run) growth. Section 3.3 analyzes the role of R&D and innovations to sustain economic growth in an economy with limited natural input resources. Finally, Section 3.4 shows that in contrast to the AK models of endogenous growth, the Schumpeterian approach can be reconciled with existing evidence on cross-country convergence, in a way which outperforms the neo-classical approach developed by Mankiw, Romer and Weil (1992).

3.1. A simple diagrammatic representation

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[2] This approach, which builds on Aghion-Howitt (1992), is developed at length in Aghion-Howitt (1998). See also Romer (1990) for an R&D based model of growth which does not embody the Schumpeterian notion of creative destruction; and Grossman-Helpman (1991) for a quality-ladder model with unit elastic demands that combines Aghion-Howitt (1992) with Segerstrom, Anant and Dinopoulos (1990).

[3] Of course, knowledge creation also depends on progress in basic science, which often is driven by curiosity rather than profit. Yet, much of the research that has led to fundamental breakthroughs in basic science has been conducted by private for-profit business firms, as shown by Rosenberg (1982).

Three main ideas underlie what we now commonly refer to as the new growth theories:

• growth is primarily driven by the rate of technological innovations, in the form of new products, new methods, and new ways of organizing production processes.

• most innovations are the result of entrepreneurial activities or investments –typically, investments in R&D – which involve risky experimentation and learning.[4]

• the incentive to engage in innovative investments is itself affected by the economic environment.[5]

The following diagram may help illustrate such new paradigm which, unlike previous growth models, it is not at all based on capital accumulation and aggregate savings. The horizontal axis shows the steady-state amount of capital per efficiency unit of labor, k , whereas the vertical axis depicts the steady-state rate of productivity growth, g.[6] The downward-sloping curve SS represents the steady-state level of capital per efficiency unit of labor as a function of the rate of productivity growth. For example, as it results from the capital accumulation equation in the Solow model.[7]The higher the rate of productivity growth, the faster the capital-per-efficiency-

[4]A case in point is the green revolution or the boost in grain production associated with the scientific discovery of new hybrid seed varieties of wheat, rice, and corn that have resulted in high farm yields in many developing economies. (See, Todaro (1994)).

[5]For example, a higher probability of imitation, i.e., a lower protection of property rights, will tend to reduce the expected profits to a successful innovator and thereby discourage innovative investments. Another example are the high interest rates that result from macroeconomic volatility. Such rates will also reduce the present discounted value of rents to a successful innovator, and will thus also discourage innovative activities. In the last section we shall complete this list by spelling out what we perceive to be main obstacles to entrepreneurship in poor areas.

[6]Formally:

$$k = \frac{K}{AL},$$

where K is the stock of capital, L is the labor force employed in the final good sector, and A is the current productivity of labor. And the steady-state rate of growth of A is

$$g = \frac{A}{A}.$$

[7]We know that in the Solow model –or in the Euler equation from the Ramsey model– that output flow is given by an equation of the form:

$$Y = K^{\alpha}(AL)^{1-\alpha},$$

where the net accumulation of capital results from the difference between savings, sY, and depreciation, δK, so that:

$$K = sY - \delta K,$$

unit-of-labor depreciates and therefore the lower the steady-state amount of capital per efficiency unit of labor. The upward-sloping curve RR represents the steady-state rate of productivity growth as a function of the steady-state amount of capital per efficiency unit of labor.[8] Intuitively, the higher the amount of productivity-adjusted capital per head, the larger the amount of income per capita, and, therefore, the larger the size of the monopoly rents that reward a successful innovator. Thus, the bigger the incentives to engage in innovative activities. And, hence, the higher the rate of productivity growth, since such rate is driven by the rate of innovations.

The intersection between the two lines, SS and RR, determines an equilibrium rate of long-run productivity growth, which depends *not only* upon the aggregate rate of savings. In particular, and as in previous growth models based upon capital accumulation, a higher rate of savings would shift the SS line to the right. However, a whole range of institutional and policy features play a crucial role here –via de RR line. For example, intellectual property rights protection, subsidies to innovative activities, product market competition, macroeconomic volatility, the supply of educated labor and/or the efficiency of research activities, amongst others. All these parameters affect growth through their effect on the RR line. Typically, a better protection of intellectual property rights, higher subsidies to innovative activities, higher efficiency of research, and/or a higher supply of educated workers moves the RR curve upwards, thereby enhancing productivity growth. Likewise, a higher level of macroeconomic volatility and/or tighter credit ceilings would move the RR curve downwards, thereby reducing productivity growth.

3.2. Basic model

In this section we formalize the conceptual framework represented in figure 3. We consider first a closed economy that produces a single final

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we have:

$$k = sk^{\alpha} - (\delta + n + g)k,$$

where n denotes the rate of population growth and g is the rate of productivity growth. Thus, in steady-state:

$$k = (\frac{\delta + n + g}{s})^{\frac{1}{\alpha - 1}},$$

which is indeed decreasing in g.

[8]More formally, this RR curve summarizes two relationships: first, a growth equation which says that the steady-state growth rate is an increasing function of the innovation rate and thus of the staedy-state investment in innovative activities; second, a "research arbitrage equation" which relates innovative investment to various characteristics of the economic environment, in particular to the scale of the economy as measured by the steady-state amount of capital per head, but also the interest rate, the productivity of R&D, the probability of imitation, product market competition, etc.

good, which can be used both for consumption purposes and in the production of intermediate inputs. This final good is produced according to the production technology:

$$Y = L^{1-\alpha} \int_0^1 A_i x_i^{\alpha} di, \tag{13}$$

where L is the labor flow used in final good manufacturing, x_i is the quantity of input i currently used to produce final output, and A_i is a productivity parameter measuring the quality of the latest version of input i (for simplicity, we omit the time subscript t in this equation).

Intermediate inputs are all produced using capital, according to the production function:

$$x_i = \frac{K_i}{A_i}, \tag{14}$$

where K_i is the input of capital in sector i. Division by A_i reflects the fact that successive vintages of intermediate input i are produced by increasingly capital-intensive techniques.

Knowledge creation, i.e technological innovations, are targeted at specific intermediate goods. An innovation in sector i will give rise to an improved version of intermediate good i, and at the same time it will allow the innovator to replace the incumbent monopolist until the next innovation occurs in that sector. [9]The incumbent monopolist in each intermediate sector i, operates with a price schedule given by the marginal productivity of input i, namely:

$$p_i = A_i \alpha x_i^{\alpha-1} L^{1-\alpha},$$

and a linear cost function equal to:

$$C(x_i) = (r + \delta - \beta) K_i = (r + \delta - \beta) A_i x_i,$$

where r is the current interest rate (again, for notational simplicity we omit the time subscript t); δ is the fixed rate of depreciation; and β is the rate at capital accumulation is subsidized . Thus, if for simplicity we normalize the aggregate supply of labor L to one, the incumbent monopolist in sector

[9]In this model, as in Aghion-Howitt (1992), no innovations are done by incumbents; this, in turn, is a direct consequence: (i) of new knowledge becoming immediately accessible to non-incumbent researchers; (ii) of the Arrow (or replacement) effect: namely, the incremental post-innovation profit of an incumbent firm is less than that of a non-incumbent firm since the incumbent firm already enjoys positive monopoly rents; (iii) the research technology is linear.

i will choose x_i to maximize:

$$\max\{A_i \alpha x_i^{\alpha-1}.x_i - (r+\delta-\beta)A_i x_i\} = \pi_i$$

It is immediate to see that the solution x to this maximization program is independent of i; that is, in equilibrium all intermediate firms will supply the same quantity of intermediate product. This in turn implies that for all i :

$$\frac{K_i}{A_i} \equiv x \equiv \frac{K}{A} = k,$$

where $K = \int K_i di$ is the aggregate demand for capital which in equilibrium is equal to the aggregate supply of capital; and $A = \int A_i di$ is the average productivity parameter across all sectors, and therefore $k = \frac{K}{A}$ is the capital stock per effective worker. The first order condition for the above maximization program can then be simply rewritten as:

$$\alpha^2 k^{\alpha-1} = r + \delta - \beta. \quad \text{(K)}$$

We shall refer to this first equilibrium condition as the *capital equation*, and denote it by (K). The second condition will be an analogue of the research-arbitrage equation in Aghion-Howitt (1992,1998), which we now derive as follows.

As in AH (1992), innovations result from R&D investments, but here we suppose that instead of using labor as a unique input the R&D sectors use final output, or equivalently they use labor and capital services according to the same Cobb-Douglas technology as in the final-good sector. An innovation in sector i at date t will bring this sector's productivity parameter A_i up to the current leading-edge productivity level $A^{\max} = \max_j A_j$ at that date. This implicitly assumes that the leading-edge technology, once discovered, is automatically disclosed and consequently becomes immediately accessible to all potential innovators. Thus, whilst the incumbent innovator in any sector, has monopoly power over the use of his innovation, the knowledge embodied in this innovation is publicly accessible to all producers engaged in R&D activities aimed at generating further innovations.

Innovations in any intermediate sector are assumed to follow a Poisson Process with arrival rate:

$$\lambda n,$$

where λ is a parameter which measures the productivity of R&D; n is the productivity-adjusted quantity of final output devoted to R&D, or more precisely the amount of R&D expenditure per intermediate good divided by the leading-edge productivity level $A^{\max}$;[10] we divide by $A^{\max}$ to reflect the fact that, as technology advances, the resource cost of further advances increases proportionally.[11].

The research-arbitrage condition determining the equilibrium level of R&D, simply says that the net marginal cost of R&D - namely, $1-\psi$, where ψ is the rate at which R&D is subsidized (or taxed, if $\psi < 0$)-, is equal to the expected productivity-adjusted value generated by *one* unit of final output being invested in R&D; this expected value is equal to $\frac{\lambda}{A^{\max}}$ times the value of an innovation in any intermediate good sector, which in turn is equal to:

$$V = \frac{\pi}{r+\lambda n}, \tag{15}$$

where $\pi = \max_{x_i}\{A_i \alpha x_i^{\alpha-1}.x_i - (r+\delta-\beta)A_i x_i\} = A^{\max}.\widetilde{\pi}(k) = A^{\max}\alpha(1-\alpha)k^{\alpha}$ (here, we implicitly use the fact that the innovation pushes productivity A_i in sector i up to the *current* leading-edge level $A^{\max}$). The denominator of (15), is the discount rate on incumbent innovations; it is equal to the interest rate plus the rate of creative destruction λn, i.e the flow probability of being displaced by a new innovation occurring in the same sector. Hence the following simple research-arbitrage equation, which we refer to as (R):

$$1-\psi = \lambda\frac{\widetilde{\pi}(k)}{r+\lambda n}. \tag{R}$$

Equations (K) and (R) together determine the equilibrium steady-state level of R&D as a function of the parameters of the economy. In particular, taking the interest rate as given[12], equilibrium R&D will be encouraged both, by an increase in the subsidy rate of R&D ψ, or by an increase in the subsidy rate of capital β; it will also increase with the productivity of R&D,λ; it will be discouraged by an increase in the cost of capital (e.g, following an increase in the depreciation rate δ); finally, it will respond positively to patent legislations aimed at protecting innovators against the risk of imitation (if innovations could be imitated at Poisson rate p, then the denominator on the RHS of (R) should be replaced by $r+\lambda n+p$).

[10]Obviously $A^{\max}$ remains proportional to the average productivity A in steady-state.

[11]This "diminishing opportunities" hypothesis is discussed and analyzed in detail by Kortum (1997).

[12]In equilibrium, assuming iso-elastic preferences for the representative consumer, we also have the Ramsey equation:

$$r = \rho + \delta + \varepsilon g$$

where ρ is the rate of time-preference.

Now, to go from R&D to growth, we assume the existence of cross-sector knowledge spillovers which cause the leading-edge productivity $A^{\max}$ to grow at a rate proportional to the flow of innovations in the economy, that is:

$$\frac{\dot{A}^{\max}}{A^{\max}} = \lambda n \sigma = g, \tag{16}$$

where $\sigma > 0$ measures the size of cross-sector spillovers. Then, the above comparative statics on equilibrium R&D will immediately carry over to the equilibrium growth rate g, which in steady-state is also the growth rate of *average* productivity, i.e : $\frac{\dot{A}}{A} = g$, as the distribution of productivity ratios $\frac{A_i}{A^{\max}}$ is then stationary.

3.3. Schumpeterian growth and sustainable development

Having thus determined the equilibrium rate of knowledge creation and growth as a function of the basic parameters of the economy, we may now reconsider the issue of sustainable development using this Schumpeterian framework instead of the AK approach. Thus, suppose that final output is produced each period according to:

$$Y = L^{\eta} R^{\nu} \int_0^1 A_i x_i^{\alpha} di, \tag{17}$$

where R denotes again the current flow of services from the natural resource, and $\alpha + \nu + \eta = 1$. In equilibrium, we know that all intermediate sectors will produce the same amount of intermediate goods $x = \frac{K}{A}$, so that we simply have:

$$Y = A^{1-\alpha} K^{\alpha} L^{\eta} R^{\nu}. \tag{18}$$

The optimal growth path is one that maximizes intertemporal utility of the representative consumer subject to the same constraints as in the above subsection but with this modified expression for Y, and also the spillover equation:

$$\frac{\dot{A}^{\max}}{A^{\max}} = \frac{\dot{A}}{A} = \lambda n \sigma.$$

Again, let us normalize aggregate labor supply at $L = 1$. Then, assuming isoelastic preferences for the representative consumer, with $u(c) = \frac{c^{1-\varepsilon}-1}{1-\varepsilon}$, the Ramsey equation corresponding to this optimal growth problem, can be written as:

$$\frac{\dot{c}}{c} = \frac{1}{\varepsilon}\left(\frac{\partial Y}{\partial K} - \rho - \delta\right) = \frac{1}{\varepsilon}\left(\alpha \left(\frac{A}{K}\right)^{1-\alpha} R^{\nu} - \rho - \delta\right). \tag{19}$$

Now, unlike in the above subsection, the marginal social value of capital $(\alpha(\frac{A}{K})^{1-\alpha}R^{\nu}-\delta)$ can remain constant and strictly positive over time even if we impose a finiteness constraint on natural resources. Indeed, whilst in the AK model, knowledge A was bound to grow at exactly the same rate as the supply of capital K, so that $\frac{\partial Y}{\partial K}\approx R^{\nu}$ would necessarily become eventually less than ρ, here instead, by adequately adjusting the growth rate of R&D spending, i.e by adjusting n, one can hope that knowledge A will grow sufficiently faster than K in order to offset the effect of a falling R on long-run growth. For example, suppose that the government aims at a depletion rate of the natural resource, equal to some positive q, that is:

$$\frac{\dot{R}}{R}=-q. \tag{20}$$

Then, in order to maintain the growth rate of consumption constant at some level g_0, it suffices to target the growth rate of R&D spending n at a level such that $\left(\frac{A}{K}\right)^{1-\alpha}R^{\nu}$ remains constant over time, or equivalently, using the fact that in steady-state $\frac{\dot{A}}{A}=\lambda n\sigma$ and $\frac{\dot{K}}{K}=\frac{\dot{c}}{c}=g_0$ and taking logarithmic derivatives:

$$\frac{d(\ln(\left(\frac{A}{K}\right)^{1-\alpha}R^{\nu}))}{dt}=(1-\alpha)(\lambda n\sigma-g_0)-\nu q=0. \tag{21}$$

In particular, when λ and σ are sufficiently large, there will always exist a feasible rate n^* , that is an equilibrium which can be achieved through a suitable policy choice (β,ψ), i.e of capital and R&D subsidies, which satisfies equation (21).

Thus, whilst the stock of natural resources is bound to deplete, knowledge creation and adequately "green" innovations, should allow us to postpone doomsday for a very long time.

3.4. Cross country convergence and knowledge spillovers

Their emphasis on institutions makes it quite obvious that new growth theories can do more than just focusing on long-run growth and advanced R&D activities in OECD economies. In particular, new growth theories can shed light on why some regions that were initially poor – in terms of their GDP per capita– as in, for example, Asia, have managed to emerge out of poverty and eventually catch up with the levels of GDP per capita of industrialized countries, whereas other poor regions in, for example, Africa, have remained exceedingly backward.

The explanation put forward by new growth theories for this “club convergence” phenomenon, is simple:[13] it basically consists in adding on top of the above framework a “knowledge spillovers” assumption whereby any sector in less advanced countries can catch-up with the current technological frontier whenever it “innovates”. Here, the term ”innovation” also refers to the adaptation of technologies or products first invented in more advanced countries for the local market –or geographical conditions. The knowledge spillover assumption, in turn, implies that the further behind the frontier a country initially is, the bigger the average size of innovations in such a country and, therefore, the higher this country’s growth rate for a given innovation intensity. What now distinguishes the countries that converge from those that stagnate is, again, institutional: (i) poor countries where, for example, macroeconomic conditions, the legal environment, and the education system are sufficiently favorable that entrepreneurial activities can nevertheless take place, will benefit from knowledge spillovers and thereby converge towards the technological frontier; (ii) poor countries where formal credit markets are basically absent, where there is a very poor enforcement of property rights, with a high incidence of economic and political instability, and/or where illiteracy levels are high, will deter entrepreneurial activities altogether. Such countries are bound to stagnate and remain poor.[14].

More formally, we consider a world economy composed of m countries, indexed by $j \in \{1, 2, ...m\}$. Each country produces according to the production technology specified in (13). The main difference lies in the assumption of *world-wide* technological spillovers: that is, at any date there is a world-wide leading-edge technology parameter $A^{\max}$, where:

$$A^{\max} = \max\{A_{ij}; i \in [0, 1], 1 \leq j \leq m\}, \tag{22}$$

where A_{ij} denotes the current productivity level in sector i of country j; we then assume that an innovation occurring in sector i of a country results in a new vintage of that country’s intermediate input i, whose productivity parameter is equal to the current world-wide leading-edge level $A^{\max}$.

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[13] See Quah (1996).

[14] The framework can be further developed, for example, by assuming that while the size of innovations increases with the distance to the technological frontier (due to technological spillovers), the frequency of innovations depends upon the ratio between the distance to the technological frontier and the current stock of skilled workers. This enriched framework (see Howitt-Mayer (2002)) can explain, not only why some countries converge while other countries stagnate, but also why different countries may display positive yet divergent growth patterns in the long-run.

In each country, the innovation technology is the same as in the one-country model in subsection 2.3, but now all innovating countries will grow in the long-run at the same world-wide rate:

$$g = \frac{\dot{A}^{\max}}{A^{\max}} = \sum_{1 \leq j \leq m} \sigma_j \lambda_j n_j, \tag{23}$$

where the σ_j's are non-negative spillover coefficients, λ_j's measures the productivity of R&D in country j, and n_j measures the R&D intensity in country j.

Let A denote current average productivity in a particular country (we omit the subindex j for notational simplicity). This parameter will grow over time as a result of domestic innovations, each of which moves the sector in which it occurs up to the current leading-edge level $A^{\max}$. Since innovations are equally likely to occur in any sector of the domestic economy, average productivity growth is governed by the differential equation:

$$\dot{A} = \lambda n (A^{\max} - A). \tag{24}$$

In particular, a country with a higher rate of innovations λn will be more productive on average because a larger fraction of its sectors will have recently innovated and thereby moved their productivity parameters up to the current leading-edge. Now, let: $a \equiv \frac{A}{A^{\max}}$ denote the domestic country's average productivity relative to the leading-edge. Dividing both sides of the above differential equation by $A^{\max}$ and using the fact that $g = \frac{\dot{A}^{\max}}{A^{\max}}$, we obtain the following differential equation for a :

$$\dot{a} = \lambda n (1 - a) - ag. \tag{25}$$

This equation describes the mechanism whereby knowledge transfers generate convergence to the global growth rate. An increase in R&D will temporarily raise productivity growth, but as the gap $(1 - a)$ narrows between the country's average productivity and the world-wide leading-edge, innovations will raise productivity by less and less, which in turn will slow down the growth rate of the country's average productivity. This equation, together with the dynamic equation for capital accumulation and the research arbitrage equation (15) which determines the equilibrium R&D intensity as a function of the capital stock, will fully characterize the dynamic evolution of this multi-country economy starting from initial values a_0 and k_0.

Assuming the same constant savings rate s for all countries, and letting $k = \frac{K}{AL} = \frac{K}{A}$, capital accumulation in each country j is simply governed by the equation:

$$\dot{k} = sk^{\alpha} - \left(\delta + \frac{\dot{A}}{A}\right) k = sk^{\alpha} - (\delta + \lambda n(a^{-1} - 1))k. \tag{26}$$

This is identical to the equation for capital accumulation in the neo-classical model, except that the rate of technological progress $\frac{\dot{A}}{A}$ is now endogenous.

The multi-country model is now fully specified and we can use it to vindicate our three claims, respectively on club convergence, on accounting for the positive correlation between per-capita income levels and investment rates/productivity/R&D intensities across countries, and on convergence rates.

Club convergence

When deriving the research arbitrage equation in section 2.3, we have implicitly restricted the analysis to the case where the equilibrium research intensity n is strictly positive. More generally, the research arbitrage condition is expressed as:

$$1 - \psi \geq \lambda \frac{\widetilde{\pi}(k)}{r + \lambda n}; n \geq 0, \text{ with at least one equality.}$$

In particular, a country j with very low R&D productivity λ_j and/or low R&D subsidy ψ, and/or low appropriability of innovation rents (i.e, low $\widetilde{\pi}(k)$ for given k), or high interest rate r, will remain in a no-innovation/no-growth trap with $n = 0$ in steady-state; on the other hand, countries with higher R&D productivity, higher rent appropriability, and lower interest rates, will undertake R&D and thereby converge to the common growth rate g. Hence, only "club" members will converge, whereas the poorest countries will remain on the sidewalk in the absence of public and/or foreign aid.

Cross-country regressions

The steady-state corresponding to the differential equations (25) and (26), is simply given by:

$$a = \frac{\lambda n}{g + \lambda n}, \tag{27}$$

and:

$$sk^{\alpha - 1} = \delta + g, \tag{28}$$

where the equilibrium R&D intensity n is determined by the above research arbitrage condition. Now, using the latter equation to substitute for k, and reexpressing per-capita income as:

$$\frac{Y}{L} = ak^{\alpha} A^{\max}, \tag{29}$$

we obtain the steady-state equation:

$$\ln \frac{Y}{L} = \ln A^{\max} + \ln a + \frac{\alpha}{1-\alpha}(\ln s - \ln(\delta + g)). \tag{30}$$

This equation is almost identical to that in MRW, except for the additional term "$\ln a$". However, unlike MRW, the residual term $\Omega = (\ln A^{\max} + \ln a)$ is positively correlated with the regressor $(\ln s - \ln(\delta + g))$; in particular, countries with a higher savings rate s are also those countries that do more R&D and therefore display a higher ratio between the average and the leading-edge levels of productivity in steady-state, i.e a higher level of a. Ignoring this correlation, in turn leads MRW to a biased estimate of the capital coefficient α, and more specifically to overestimate the direct contribution of capital to growth.

Convergence rates

From equation (24) we immediately get:

$$\frac{\dot{A}}{A} = \lambda n(a^{-1} - 1). \tag{31}$$

In other words, countries that are closer to the leading-edge should experience lower spillovers and therefore lower rates of productivity growth. Unlike MRW we do not need to introduce (unbounded) human capital accumulation on top of physical capital accumulation in order to reconcile the observed evidence about the convergence rate with that on the capital coefficient.

Having shown that the Schumpeterian approach to endogenous growth can be reconciled with the evidence on cross-country per-capita income levels and growth rates, we can ask ourselves whether the existing empirical evidence is more supportive of the neoclassical or the Schumpeterian convergence approach.

In a recent paper, Desdoigts (2000) specifies a general convergence equation that incorporates both the neoclassical and the Schumpeterian model, along the lines of equation (**??**) above. Growth is thus, in principle, determined by both the accumulation of human and physical capital and by technological spillovers, where the capacity to absorb these spillovers is determined by either human capital stocks or investment rates. Using this unified framework it is possible to estimate growth equations and let the data choose between the various nested models. Desdoigts finds that, as far as education is concerned, the MRW specification can be improved upon if a country's absorption capacity is proxied by human capital measures. Moreover, the explanatory power of the model improves substantially when the technology gap term is interacted with a country's share of equipment investment in output. He then undertakes an interesting exercise: taking 1960 as the initial point, Desdoigts calculates the world distribution of incomes in 1985 using the two estimated models, and compares it to the actual distribution of incomes in 1985. The results are striking. The income levels obtained from the MRW model bear little resemblance to those that actually prevailed, while the distribution generated by the technological-catch up model exhibits the same double hump that we observe in the actual distribution. Figure 1 presents the difference in densities between the actual and the two simulated distributions. It clearly implies a much more satisfactory performance of the Schumpeterian approach (dotted line) than of the neo-classical model (solid line).

4. CONCLUSION: NEW GROWTH THEORY AND ECONOMIC DEVELOPMENT

Thus, unlike previous growth models based upon capital accumulation, new growth theories can deliver an explanation for both, cross-country differences in long-run growth rates and convergence or non-convergence patterns. To the extent that they emphasize the importance of *institutions*, these theories are not so distant from what development economists have always been concerned with. Yet, development economists may argue, first, that new growth theories remain of little help for development policy: all they seem to be doing is advocating macroeconomic stability, property rights enforcement, a sound education system, and financial development to encourage savings and risk-taking: otherwise stated, new growth theories' prescriptions are simply a mild version of the so-called "Washington Consensus". Second, that new growth theories are quite orthogonal to the issue of individual poverty traps and poverty alleviation which is so central to development economics. We shall now conclude the survey with a brief and informal discussion of these two objections[15].

[15] This section borrows unrestrainedly from joint work with Daron Acemoglu and Fabrizio Zilibotti. See Acemoglu-Aghion-Zilibotti (2002).

During the past two decades there has been an intense debate regarding the institutions and government policies that are most conducive to economic development and technological catch-up. Among policy makers and advisers at the World Bank as well as other International Financial Institutions, the initial enthusiasm about investment-based strategies of the kind pursued in countries like Korea and Japan, has basically disappeared. Instead, and since the early 1980s, a wholehearted belief in a more market-oriented and laissez-faire strategies of the kind followed by countries like Honk Hong or the UK during the 19th century has taken place. (Such a widespread belief is also –and very often – referred to as the Washington Consensus). The debate over the appropriate development strategy has been mirrored in universities, with a clear divide between the views of academics such as Joseph Stiglitz (1995, 2002) or Ricardo Hausmann and Dani Rodrik (2002) versus Andrei Shleifer and Robert Vishny (1999). The former ones would strongly advocate government intervention and subsidies in backward countries where externalities and market failures are pervasive, whilst the latter ones would argue that backward countries are not only plagued with market failures but, also, and perhaps more importantly, with government failure, and a higher scope for political capture, which in turn increases the danger of interventionist policies.

This debate has been fueled by cross-country experience over the past fifty years. Specifically, by the contrasted results of interventionist policies both, across different countries until the late 1970s and across countries when comparing between, before, and after the 1980s. In particular, while investment-based strategies have been growth-enhancing in countries like South-Korea, Japan, Peru and Mexico between the 1950s and the 1970s, similar policies have failed in numerous instances, e.g. throughout Africa. Furthermore, since the 1980s countries like Peru and Mexico who pursued import-substitution and infant-industry protection policies have been leap-frogged by countries like Honk Hong that had always adhered to full market openness and liberalization.[16]

Can new growth theories contribute to this debate? Recent work by Acemoglu-Aghion-Zilibotti (2002) suggests that they can, provided they rely on a more detailed description of the process whereby productivity im-

[16]After growing at average rates of between 3.5 and 4% between 1950 and the mid-1970s, Brazil and Peru had achieved a level of GDP per worker equal to 35% of the US level. Then, both these countries stagnated at that level. On the other side of the spectrum we find countries such as Honk Kong, where the level of GDP per worker was no more than 17% of the US level in 1960, but surpassed Brazil and Peru during the 1980s and 1990s achieving 70% of the US level in 2000 (see Acemoglu et al.).

provements are generated in countries (or sectors) below the "technological frontier". The basic idea in Acemoglu-Aghion-Zilibotti (2002)-henceforth AAZ- is that productivity improvements in sectors below the technological frontier, involves both: *imitation* of leading-edge technologies and *innovation* upon previous local technologies. Whilst imitation can take advantage of the experience of existing firms and managers: more experienced managers can use their accumulated knowledge "on the job" to manage investments of increasing size over time; innovation requires the selection of the best possible managers and the best possible matching between managers and firms. (Note that when discussing the convergence issue in the previous section we did not distinguish between these two dimensions of the process of technological diffusion).

This dichotomy between imitation and innovation in the process of technological diffusion implies that different policies (or institutions) will maximize growth at different stages of development. For example, in sectors or countries that differ in terms of their distance to the technological frontier: in economies or sectors that are further below that frontier, imitation of leading-edge technologies is what maximizes the average rate of productivity improvement; an investment based strategy that relies on bank finance and protection/ subsidies may then be growth-enhancing. Imitation in such economies encourages longer-term contractual relationships and experience building. And in economies or sectors that are closer to the technological frontier, growth should be better enhanced by an "innovation-based" strategy which emphasizes the competitive market mechanism that will in turn select the most innovative managers.

But the AAZ view is basically suggesting a dynamic approach to development policy, with at least some elements of investment-based strategy for countries far below the frontier, and a more pro-market strategy for countries closer the frontier. Such a view is in turn opening the scope for a narrowing gap between the above mentioned interventionist versus laissez faire approaches to economic development. However, isn't such a "closing the gap" prescription easier said than done? It is. First, we need to understand why investment-based strategies have failed to generate any growth in so many instances. Second, an obvious question is whether poor countries can replicate the Korean strategy of the 1950s-1970s in the current globalization context. Third, as pointed out by Shleifer-Vishny (2000)– and analyzed more formally in AAZ– investment-based strategies often have the side effect of creating vested interests which are opposed to the necessary switch from an investment-based to more pro-competition policy. Put simply, it seems to be exceedingly hard to design investment-based policies that are truly temporary.[17] Fourth, even those countries that have been successful in achieving high growth rates through investment-based strategies have not had uniform success in alleviating poverty, and in eliminating poverty traps. In particular, there is a huge discrepancy between countries like Korea and Japan where income inequality has remained under control and education is widespread and countries like Mexico, Brazil or Peru where poverty traps have remained, income inequality has not been eradicated, and high illiteracy rates have prevailed.[18]Analyzing these and other related issues in formal models of the type developed in this survey, constitutes a challenging research agenda.

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[17]Yet, the existence of vested interests have not prevented middle-income countries in Central Europe or China to trade liberalize and endorse globalization. A key role in this respect appears to be that of the emerging middle class. For example it is largely under the pressure of middle class individuals that countries like Mexico have initiated pro-market reforms. This in turn suggests that an investment-based strategy that would not succeed in reducing the polarization of wealth, is more likely to fail in the long-run than one that trickles down to the poor and facilitates the rise of a large and powerful middle class. This brings us to our next point.

[18]In Aghion-Armendariz (2002) we investigate some of the reasons why top-down investment-based strategies may fail to trickle-down and eliminate poverty, thereby delaying the emergence of a middle-class that is favorable to competition and openness, a middle class that would be strong enough to counteract the vested interests generated by investment-based policies; then, we argue that trickle-down can be more effectively achieved through combining subsidized or non-subsidized microcredit with government support.

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