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DEBATE EN LAS TEORÍAS MODERNAS DE CRECIMIENTO REGIONAL

THE DEBATE OF THE MODERN THEORIES OF REGIONAL ECONOMIC GROWTH

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RESUMEN

¿Cómo podemos explicar las diferencias en el crecimiento económico en las distintas regiones del país y del mundo en los últimos sesenta años?

El objetivo del estudio es el de realizar una revisión de la literatura tradicional de los principales modelos del crecimiento económico regional. La literatura del crecimiento económico regional nos propone varias respuestas en los modelos neoclásicos, al igual que en los modelos endógenos que enfatizan la acumulación de capital mediante externalidades, el aprendizaje y el capital humano, y el progreso tecnológico endógeno. El estudio se centra en el debate empírico y de las teorías recientes del crecimiento económico regional.

Palabras clave: modelo de solow, modelo keynesiano, modelo de crecimiento neoclásico, nueva teoría del crecimiento, la geografía económica, las economías de aglomeración, los modelos de ciclo real de negocio.

SUMMARY

How do we explain the differences in economic growth in different parts of the nation and the world during the last sixty years?

The objective of the study is to survey the traditional theories and models of regional economic growth. The growth literature to date has proposed several answers, included in the neoclassical models, exogenous technological progress and recent endogenous models that emphasize capital accumulation through externalities, learning by doing, or in conjunction with human capital. The paper looks at the recent theoretical and empirical debate related to the theory of regional economic growth.

Key Words: solow model, keynesian model, neoclassical growth model, new growth theory, economic geography, economies of agglomeration, real business cycle models.

INTRODUCTION TO CLASSICAL AND NEOCLASSICAL GROWTH

Although most contemporary economists would trace the birth of the modern theory of economic growth to the 1950's, the great classical economists such as Adam Smith, David Ricardo, and Thomas Malthus were the first ones to discuss many of the basic parts of modern growth theory. The work of the classical economists, with emphasis on competitive behavior, equilibrium dynamics, and the impact of diminishing returns on the accumulation of labor and capital are integral elements of what is called the neoclassical approach to growth theory. In the neoclassical tradition, Solow (1956), Swan (1956), Cass (1965) and Koopmans (1965) formulated the basic framework and assumptions of the growth model. The framework of the neoclassical model states that the productive capacity of the economy can be adequately characterized by a constant-returns-to-scale production function with diminishing returns to capital and labor. Firms are price-takers in a competitive market place, which means that no individual firm has any influence over market prices and individual firms do not possess any market power. Technological change and productivity growth is entirely exogenous (independent of the actions of the consumers and producers) and is available to all countries at no cost. The first implication is that sustained increases in per-capita income can be supported only by sustained increases in total factor productivity. In this model, output per worker can rise only if the ratio of capital per worker increases or total factor productivity increases. Since this model assumes diminishing returns to capital, there is a limit to how much capital accumulation can add to output per capita. The only way to increase output per worker in the long run is to have sustained productivity growth. This is a

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major weakness of the neoclassical growth model, since long-run growth is exogenous or determined by an element that is entirely outside of the model.

The neoclassical growth model predicts that the growth rates of various countries will ultimately converge. In a free market environment, each country will have access to similar technologies and mobile factors of production will be drawn to the areas where they are able to earn the highest rate of return. Poorer regions, given their initial position, are in a better position to exploit the gains from more capital since they have a relatively low capital-labor ratio. In other words, given the usual neoclassical assumptions, countries with less capital will have higher returns to this capital and any investment in capital will exhibit higher marginal returns. Thus, income convergence should occur over time as the increase in the capital stock takes hold in capital-poor regions. Regions with high rates of population growth should exhibit slower per capita GDP growth. This is due to the fact that any capital stock would be spread out among larger numbers of people, thus decreasing the capital-labor ratio. The increasing rate of investment will increase the stock of capital and therefore capital-deepening will occur, resulting in higher growth rates.

Economic growth in the solow model

To understand the role played both by education and externalities in the new growth theories it is necessary to begin with the simple Solow (1956) model. Consider a firm's output, Y, as a function of three variables: capital, K, labor, L, and knowledge or the effectiveness of labor, A_t. Thus, for output can be described by the following equation:

$$Y = K^a(A_tL)^{1-a} \quad \text{where } 0 < a < 1 \qquad (1)$$

Knowledge production is assumed to be independent of both the capital and labor inputs and to be freely available to all firms, but notice that it appears multiplicatively with labor in indicating that knowledge operates by augmenting labor (making it more effective) rather than via capital. The exponents measure the relative contribution of the two inputs, capital and effective labor. By summing to unity they capture the assumption that there are constant returns to scale in production.

The Solow equation describes the determinants of the level of output but can readily be transformed into an equation describing the growth of output. In the Solow model, we were only concerned with steady-state growth, but the steady-state capital-labor ratio is dependent on three parameters, savings rate, s, the population growth, n, and the rate of technical change, q. But what is the optimal savings rate for an economy, which seeks growth? Frank Ramsey (1928) and Edmund S. Phelps (1961) were the first ones to ask the question. Recall that C = Y - S. As S = sY, then c = Y - sY. Thus dividing by L and recalling that Y/L = y = f(k), then c = f(k) - sf(k) where s is the propensity to save, c = C/L and k = K/L. This equation merely states that the difference between the curves y = f(k) and i = sf(k) would be c or consumption per capita. Phelps (1961, 1966) proposed that s was a choice variable and that we should seek to maximize consumption per capita by choosing s (and thus the i = sf(k) curve) such that at the steady-state growth (where i = i*) will ensure that we have the highest consumption per capita possible for all future generations. The constraint is that we are in steady state, i.e. sf(k) = nk (ignoring technical change). Thus, maximizing the term c = f(k) – nk with the first order condition for a maximum is merely: dc/dk = f'(k) - n = 0. In other words, we are at the optimal k* when the steady state, k*, will be where f'(k) = n. If we interpret f'(k) as the rate of return on capital, r, and n as the natural growth rate, then f'(k) = n is equivalent to r = g, similar to the Golden Rule growth condition of Von Neumann (1937).

Maximum consumption will be at the point where the difference between y = f(k) and the necessary investment (i* = nk) is greatest. Thus, we choose s such that the steady-state k* will be at the highest point of difference between these two curves. The highest point of difference can be found simply by placing a line parallel to $i^* = nk$ at its tangency with $y = f(k)$ curve. Thus, the Golden Rule growth, $f'(k) = n$, is the condition for optimal growth. Koopmans (1965, 1967a;b) and David Cass (1965) agreed that it was a Golden Rule, but they disagreed that it was optimal, because we should be seeking to maximize utility, and not merely consumption. The underlying reasoning for imposing a time preference is more a mathematical one than a logical one, which is necessary for solving an intertemporal optimizing program. In the Cass-Koopmans version, the objective of the representative agent is to maximize utility over an infinite horizon. Let us suppose that the utility function at any time t is hedonistically defined as a positive function of consumption per capita at time t, $U(c_t)$. Given an infinite horizon and continuous time, consumption will thus be infinite and continuous. The present value of future utility gains from individual consumption at any time period t is then: $U(c_t)e^{-pt}$ where p is the subjective rate of time preference. The objective of the representative agent is therefore to maximize this intertemporal stream of utility subject to economy wide constraints. The constraint is obvious enough: the more is consumed now, the less is saved and thus the less growth and consumption there is tomorrow. Consuming less now, means consuming more tomorrow, and time preference says that this means lower utility. Thus, a balance must be somehow struck between all the periods such that the total stream of utility is maximized, which means sacrificing some consumption every period, but (because of time preference), not sacrificing all of it. The constraint is merely the Solow growth model. We know that $sf(k) = nk$ at steady-state. If $sf(k) > nk$, then capital-labor ratio grows and if $sf(k)\ dk/dt = sf(k) - nk$ or, because $sf(k) = f(k) - c$, then $dk/dt = f(k) - c – nk$.

Thus, maximization of the intertemporal utility stream is subject to this equation as a constraint. To solve the problem, we need to set up the present-value Hamiltonian:

$$H = U(c_t) + z(f(k) - c - nk) \qquad (2)$$

where z is the current-value costate variable. The first order conditions for a maximum, yield the following:

$$dH/dc = U_c - z = 0 \qquad (3)$$

$$-dH/dk = dz/dt - pz = -z(f_k - n) \qquad (4)$$

$$dH/dz = dk/dt = f(k) - c - nk \qquad (5)$$

$$\lim ze^{-zt} = 0 \qquad (6)$$

From the first result, we see that $U_c = z$ (where $U_c = dU/dc$, the marginal utility of consumption in this period). Thus, differentiating this condition with respect to time, we obtain $dz/dt = U_{cc}(dc/dt)$ (where $U_{cc} = d^2U/dc^2$ - the second derivative). Thus, we can plug in this dz/dt and our z into our second condition so that:

$$U_{cc}(dc/dt) - pU_c = -U_c(f_k - n) \qquad (7)$$

or, rearranging:

$$dc/dt = -[U_c/U_{cc}][f_k - n - p] \qquad (8)$$

if we had used a utility function (i.e. $U(c) = c^{1-e}/(1-e)c$ where 0 c/U_{cc}] would have been merely 1/e, and our equation reduced to:

$$dc/dt = (1/e)[f_k - n - p] \qquad (9)$$

The solution to the optimization program will be a pair of differential equations - dc/dt just derived, and dk/dt derived from our third condition:

$$dk/dt = f(k) - c - nk \qquad (10)$$

There is steady-state or "balanced growth" where dk/dt = 0 and dc/dt = 0, or:

$$f_k - n - p = 0 \qquad (11)$$

$$f(k) - c - nk = 0 \qquad (12)$$

From dk/dt = 0, we see that:

$$c^* = f(k^*) - nk^* \qquad (13)$$

k* is taken from the dc/dt = 0 condition, i.e. k* is the k that yields:

$$f_k = n + p \qquad (14)$$

where, note, this is not the Golden Rule because of the presence of p, the discount term for time preference. This type of growth is the golden utility growth. What about stability? In fact, our steady-state point, (k*, c*) are not stable in a dynamic sense, but only saddle point stable. The fourth condition of the optimization problem, lim $ze^{-zt} = 0$, guarantees that given some initial k, we choose consumption such that we jump on the saddle path and make our way to the balanced growth point at (k*, c*). Thus, in this optimal growth model, we always go to steady state. If we accidentally veer off this path, the consumption decision will make us jump back onto the saddle path and back to steady state. In short, optimal growth in the Cass-Koopmans model is steady-state growth at (c*, k*) where we have the Golden Utility, i.e. f_k = n+p. If we had added exogenous technological change, i.e. q, this would change our model slightly. Namely, the golden utility condition would now be f_k = n+p+q, which implies that our dc/dt = 0 would shift to the left and we would have a lower k* as our steady-state capital-labor ratio. There are two important features of this model which recent growth theories have challenged: if markets are competitive, the contributions of each factor input to output are equal to their respective shares in total income (output). For all firms in an economy taken together this could be approximated by the National Accounts breakdown into wage and non-wage income. If people save a constant proportion of their incomes, capital per effective worker must be constant in the long run, so that k' = 0 and therefore per capita income growth is entirely determined by the growth of knowledge, a. Increasing the savings investment ratio can raise an economy's income level permanently by raising the growth rate of capital and income in the short-run, but since the ratio of savings to income cannot go on increasing indefinitely, investment cannot cause income to grow permanently. Regions that invest more will be wealthier but will not grow faster. And, since the only source of long-run growth is technical progress or knowledge accumulation, which by assumption is occurring at an exogenous rate, income growth rates are beyond the control of the government or the private sector.

Keynesians and neo keynesian models

John Maynard Keynes (1936) attempted to provide a consistent, closed, interdependent theoretical structure for the determination of aggregate output and economic phenomena such as unemployment in a simple economic model. Positive saving, which plays such a great role in the

General Theory is essentially a dynamic concept in the model. A steady allocation of one-tenth of income to saving is essentially dynamic, since it involves a continuing growth in one of the fundamental determinants of the system, namely the quantity of capital available. This must entail, even if none of the other determinants are subject to change, continued changes in the values of many of the dependent variables.

The multiplier accelerator relationship was introduced by Harrod (1936) in his theory of cycles, and then re-adapted by Harrod (1948) for a theory of growth. This was followed up by Hicks (1949, 1950, 1973 y 1985), who formalized the Harrodian trade cycle in accordance to the mathematical methods introduced by Samuelson (1939a;b). Subsequent work by Duesenberry (1949) and Pasinetti (1960) helped merge the growth and cycle story. The other strand of the Keynesian school was the endogenous cycle tradition initiated by Kalecki (1937) and followed up by Kaldor (1940). Harrod, Hicks, Kaldor and Kalecki perceived the market to be the creator of growth and cycles and developed models, which generated these dynamic phenomena largely out of a real interdependent system.

New classicals criticized the old Keynesian IS-LM models for the allegedly ad hoc nature of its assumptions regarding expectations as in Lucas (1972). They developed models with continuous Walrasian market clearing with rational expectations as a micro foundation that implied the impossibility of involuntary unemployment, arguably the core Keynesian idea. The theoretical triumph of such models in the seventies led to declarations of the death of Keynesian economics. Such declarations triggered a response. The initial response came in what Rosser (1990) calls weak new Keynesian models. They assume a weakened version of rational expectations and then derive the possibility of involuntary unemployment as a result. Usually they involve deriving some stickiness of wages or prices or investment from the near rational expectations assumption. The core concept is that of information asymmetry as the foundation of the deviation from perfectly rational expectations, ultimately derived from the work of Akerlof (1971).

Two main assumptions define the New Keynesian approach to macroeconomics. Similar to the new classical approach, New Keynesian macroeconomic analysis usually assumes that households and firms have rational expectations. But the two schools differ in that New Keynesian analysis usually assumes a variety of market failures. In particular, New Keynesians assume prices and wages are sticky, which means they do not adjust instantaneously to changes in economic conditions.

The best-known empirically satisfying new keynesian models are those of menu costs by Mankiw (1985) and Akerlof and Yellen (1985a;b). Asymmetric information and a variety of costs are invoked as explanations for an unwillingness of firms to change prices frequently. This becomes the small deviation from perfect rationality that triggers large output swings. Any nominal price stickiness can trigger declines in real output in response to declines in aggregate demand, at least temporarily. Closely related to the menu cost approach are models emphasizing rule-of-thumb pricing behaviors arising from search costs similar to Okun (1981) and models of staggered price contracts like Blanchard (1983). The more recent development has been the efficiency wage theory in the style of Shapiro and Stiglitz (1984) that sees the quality of the labor force in a firm as endogenous to the wage rate. This can lead to high and sticky wages. Post Keynesian critics of these models, such as Davidson (1994), emphasize that although Keynes allowed for wage and price stickiness through much of The General Theory, he ultimately sought an explanation for involuntary unemployment that did not depend on that assumption and relaxed it.

At the border of Keynesian modeling is the array of models calling themselves evolutionary. We are interested in those with a nonlinear dynamics foundation and some connection to a Keynesian approach. Finally we have a set of models that have been identified as both New Keynesian and

Post Keynesian by various observers. One of these is the hysteresis approach, clearly drawing on nonlinear underpinnings. Sharing elements in common with the path dependence approach, the fundamental idea is that the economy is influenced by its history of past shocks, to the extent that there is a natural rate of unemployment, which is endogenous to past rates of unemployment. Cross (1993) argues that hysteresis models are nonergodic and therefore consistent with Post Keynesian economics. Davidson (1993) questions this, labeling hysteresis a new Keynesian model and arguing that it is not truly Keynesian or Post Keynesian because it depends on exogenous real shocks, although those could be demand shocks endogenously generated, at least in some models. In any case it would appear that there is good reason to view these models as lying in the intersection between New and Post Keynesian economics.

Chaos theory, drawing on work of Lorenz (1963) and Li and Yorke (1975) among others, depends on the idea of sensitive dependence on initial conditions, which a small change in the value of a parameter or a starting value and a system will behave dramatically differently. This is known as the butterfly effect for Lorenz's idea that a butterfly flapping its wings in China could cause a hurricane in the US. This dependence on initial conditions is seen as fundamentally destructive of the possibility of forming rational expectations in a noisy environment, especially because chaotic dynamics can arise even in models with rational expectations. They thus can be seen as a source of fundamental Keynesian uncertainty. Chaotic dynamics also exhibit endogenously generated aperiodicity. Interacting particle systems models draw on statistical mechanics theory in which there are critical thresholds in the interaction of entities, which can lead to discontinuous changes in the outcomes of their activities. These models can represent coordination failure in multiple equilibria situations very well. An attractor is the set toward which a dynamical system asymptotically tends if it is inside the basin boundary of the attractor. It has often been thought that chaotic dynamics and strange attractors coincide, but this is not true in general, although there are many models in which both do occur. Lorenz (1992) also developed a model based on the Kaldor (1940) model with a strange attractor but without chaotic dynamics.

Recent growth models

Neo-classical model presumes a simple competitive economy, where households own the inputs of the economy (capital and labor) and rent them to firms. Firms will pay them income, which they then choose to save or consume. Government, human capital and an open economy can be added. The people also make choices as to how many children to have. Firms hire labor, capital and other factors of production to determine the output levels. The choices of households are different in different countries, resulting in different availability of inputs and thus outputs. Firms will use technology to create outputs from inputs. In particular, previous researchers found it useful to presume a specific production function (Cobb-Douglas) and technology function that is labor augmenting.

The production function at time t can be then written as:

$$Y(t) = K(t)^{\alpha}\,(A(t)L(t))^{1-\alpha} \qquad 0 < \alpha < 1 \tag{15}$$

The notation is standard: Y is output, K is capital, L is labor and A technology. It is assumed that there are only two inputs and they are paid their marginal product (competitive economy). Also α is a constant, and neo-classical theory predicts that empirically it will be equivalent to the factor's share of GDP income. By restricting the factor shares to be equal to 1, we assume constant returns to scale. This is a testable assumption. However, when the test fails, a problem is present in the neoclassical model, as increasing returns would violate the competitive economy assumptions.

Furthermore, neo-classical convergence results require diminishing marginal products (a<1). If this is not the case, we obtain the endogenous growth model.

The production function in this form satisfies the Inada conditions. This also can be tested. In particular, this implies convergence of per capita income as the marginal products of capital and labor tend to 0. L and A grows exogenously at rates n and g:

$$L(t) = L(0)e^{nt} \qquad (16)$$

$$A(t) = A(0)e^{gt} \qquad (17)$$

Thus, the number of effective units of labor A(t)L(t) grows at rate (n+g). The model assumes that constant fraction of output is invested (s). Also there is a constant rate of depreciation δ. Thus the capital stock evolves as:

$$K(t+1) - K(t) = sY(t) - \delta K(t) \qquad (18)$$

It is helpful to express all quantities per effective unit of labor. Thus I define k=K/AL, y=Y/AL. Furthermore, I will denote changes in a variable with a dot, as is $\dot{k} = k(t+1) - k(t)$. Thus

$$y(t) = k(t)^{\alpha} \qquad (19)$$

$$\dot{k}(t) = sy(t) - \delta k(t) = sk(t)^{\alpha} - (\delta + n + g)k(t) \quad (because\, \dot{k} \equiv \frac{\dot{K}}{AL} - nk - gk) \qquad (20)$$

The equation implies that k(t) converges to a steady value k*

$$\begin{aligned} 0 &= sk^{*\alpha} - (\delta + n + g)k^{*} \\ k^{*} &= \left[\frac{s}{(\delta + n + g)}\right]^{\frac{1}{1-\alpha}} \end{aligned} \qquad (21)$$

Substituting and taking logs yields the following equation:

$$\ln\left[\frac{Y(t)}{L(t)}\right] = \ln A(0) + gt + \frac{\alpha}{1-\alpha}\ln(s) - \frac{\alpha}{1-\alpha}\ln(n + g + \delta) \qquad (22)$$

The basic model to test is shown by the following equation:

$$\ln\left[\frac{Y(t)}{L(t)}\right] = a + \frac{\alpha}{1-\alpha}\ln(s) - \frac{\alpha}{1-\alpha}\ln(n + g + \delta) + \varepsilon \qquad (23)$$

Where a is the region specific initial technology level that will be proxied by numerous variables. The variables that determine income simultaneously determine changes in technology. Thus, the assumption that the residual technology is similar in all regions is not that restrictive.

However, it could also be that the initial level of technology is different in different regions and that affects the results. Several variables can be used, such as education, life expectancy and political measures in order to account for technology. Including human capital is relatively straightforward. When including the stock of human capital, then the relevant equation becomes:

$$\ln\left[\frac{Y(t)}{L(t)}\right] = a + \frac{\alpha}{1-\alpha}\ln(s) - \frac{\alpha}{1-\alpha}\ln(n+g+\delta) + \frac{\beta}{1-\alpha}\ln(h^*) + \varepsilon \qquad (24)$$

Many of the endogenous models predict some convergence and are similar to the neo-classical model. However, in allowing the technological process to be internally generated, they might have a better explanatory and predictive capacity. Furthermore, they might be helpful in determining the direction of causation between components of the growth model, like answering whether investment causes growth or vice versa, and might provide better policy recommendations. It is not clear whether endogenous models are better or worse than neoclassical models. Neoclassical ones definitely manage to describe the data reasonably well, and the convergence hypothesis is supported by the data. However, they fail mostly in a dynamic setting that is not picked up by my cross-sectional model very well.

In the neoclassical model there is no explicit role for education and no externalities. Capital owners and workers are independent inputs and each is fully rewarded for their contributions to output. An important motivation for the new growth theories is the apparent inconsistency between estimates of the marginal productivity of capital and capital's share in income. For example, when applying the Solow model to international data, Mankiw, Romer and Weil (1992) predict the capital share (from estimates of its marginal product) at about 60%, yet observed capital shares are around 25-35%. Capital (labor) appears to be much more (less) important for growth than the Solow model would suggest. Perhaps then the data will be better explained by a model, which gives a greater role to human capital.

Recent growth theories have attempted to model these processes both by introducing human capital explicitly into production functions and by allowing for the possibility of externalities. Although higher education is not typically the specific focus of attention, there is a role for human capital externalities because of its twin outputs of research, which generates new knowledge, and graduates embodying potentially labor-augmenting training. In particular, for major industrialized countries we might reasonably think of labor as workers embodying minimum education (acquired during years 5-16) and human capital as the skill acquired in post-16 education. This is less true for developing countries where minimum education (common to all workers) can be at the primary level.

Human capital is introduced in new growth theories both with and without externalities. The two main approaches are the incorporation of human capital as a factor input, for example by adapting the Solow model like Mankiw, Romer and Weil (1992), and Romer (1990b) by explaining the process of knowledge accumulation by relating it directly to human capital accumulation, or indirectly via research and development (R&D) activity such as Lucas (1988) and Romer (1986, 1990a;b).

Mankiw, Romer and Weil (1992) have recently demonstrated that if an augmented production function that includes human capital such that:

$$Y = K^a H^b (A_t L)^{1-a-b} \qquad (25)$$

and solved for the equilibrium growth rate in the manner of the Solow model, this yields a (per capita) income growth equation with physical capital and human capital investment rates as ratios of GDP entering separately among the arguments. Alternatively the initial level of human capital can replace the human capital investment rate.

Three types of models that use human capital can be distinguished. The sources of growth equation models; the augmented Solow model; and endogenous growth models in which an education sector produces human capital for use in the production sector.

Sources-of-growth equations are typically based on an aggregate Cobb-Douglas production function. When differentiated gives a relationship between the growth of output and the growth of factor inputs. The production function can be adapted to include human capital, H, which would give the following function:

$$Y = AK^{a}L^{b}H^{g} \quad \text{where } a+b+g=1 \qquad (26)$$

The approach is more for empirical use than a theory and has been used as the basis for the Barro (1991) regressions in which the parameters a, b and g are estimated to identify the relative contribution of each input and can be extended to other inputs and determinants of the term. The equation is the basis for growth accounting exercises in which values for the parameters a, b and g are imposed and applied to factor input and TFP growth rates. In both these cases therefore aggregate output (or output per capita) growth is a function, inter alia, of the rate of growth of human capital. Sala-i-Martin (1996) has proposed a more disaggregated form of the production function, which decomposes the externality effect.

$$Y_j = AK_j^{b}(H_j)^{1-b}(H_j/N_j)^{e}{}_{j}(H/N)^{e} \qquad (27)$$

where N is the level of employment. The term ej captures an intra-firm externality (the effect of educated workers on their colleagues within the firm) and e captures an inter-firm externality, with (H/N) representing the average human capital to employment ratio in the economy as a whole, as in Lucas (1988). Note that the intra-firm externality is not an externality in the usual sense of the term since it is not external to the firm's profit-maximizing calculation. It has an effect external to the worker and there may still be a reason for subsidizing education to persuade them to undertake the optimal level, including spillovers to other workers within the same firm. The inter-firm externality on the other hand could be internalized by subsidizing firms who employ more graduates, rather than subsidizing the graduates themselves. The previous two models treat human capital as a private good; since education is embodied in the individual worker the skills which education creates are best thought of as rival and excludable.

The various theoretical approaches discussed have raised the possibility of a number of externality effects arising from education in general and higher education in particular. To identify intertemporal externalities, ideally we would like to observe different regions and/or time-periods when these externalities were thought to be present and absent so that the growth performances of the two may be compared. Spillovers between countries or regions (perhaps associated with education) may explain tendencies for country/region income levels to converge but so might a number of other theories, which exclude the possibility of such externalities. Identifying the existence and extent of education externalities from macro evidence has many difficulties in practice and, until the methodologies and data used in empirical studies are developed further, all results should be treated with caution.

In terms of other forms of capital, De Long and Summers (1993) find that investment in equipment is strongly associated with growth; each additional one per cent of GDP invested in equipment is associated with an increase in GDP growth of one-third of one percent, much higher than the association between growth and any other investment component.

Looking at initial GDP per capita, population growth, education and the investment to GDP ratio in isolation show only limited support for the neoclassical model of growth. Taking all of these variables into consideration offers stronger support for the theory. The evidence does support the convergence hypothesis when we control for differences in population growth and investment, implying that countries and regions, which were relatively poorer initially, were beginning to catch up to the richer countries by the end of the 1980's. Much of the growth literature has been concerned with understanding why different regions grow at different rates, at least for decades at a time.

Although the number of studies is quite large, the empirical literature, which seeks to test between alternative growth theories, is very much in its infancy with considerable debate regarding appropriate testing methodologies. Barro and Sala-i-Martin (1995), following extensive testing on international cross-section data, conclude that the evidence is consistent with the neoclassical model but could also be consistent with models of technological diffusion across countries or regions. While Romer (1990a;b) has also argued that international data are consistent with an endogenous growth model, which includes human capital as the source of research ideas.

New growth theory

The new growth theory, which is also called endogenous growth theory, attempts to deal with the major shortcomings of the traditional growth theory. Namely, it explicitly attempts to endogenize the role of technical change into the model. It has been hypothesized that there are knowledge externalities in research and development. In other words, one good idea begets another, which begets a third and so on. In addition, the market structure that firms operate in is also important. A non-competitive market or effective protection of intellectual property rights may allow the firm to capture economic rents from the development of its products, thus increasing the potential rewards of R&D. These are the variables that endogenous growth theory attempts to include. In a nutshell, endogenous growth theory is based on the assumption that long-run growth is based on economic incentives provided by the economic environment within which economic actors work.

Romer (1986) presented a theoretical argument that, even with a constant state of technology and population, growth in per capita incomes can increase, and may even increase without an upper bound. The model accomplishes this by dropping the diminishing returns assumption in the neoclassical growth model. Thus, the rate of technological change becomes endogenized in his model, and not exogenous as in the traditional growth theory model. This is owing to the hypothesis that investment in knowledge will have increasing returns to scale. In addition, increasing the stock of knowledge creates a public good whereby positive externalities are derived. For example, investment in R&D will result in firm-specific knowledge that is used to develop a certain product, but it also increases the stock of such knowledge, thus increasing the possibilities for development of new products. Opening an economy to international trade may also have positive growth implications, increasing the transfer of knowledge and the positive externalities that it produces.

Lucas (1988) models human capital in a firm's production function in a manner analogous to the augmented Solow model and also allows for an external effect' whereby the average level of human capital in the economy affects individual firms' outputs but is not taken account of in the profit-maximizing decisions. Individual workers decide on their time allocation between acquiring education and working in the production sector on the basis of standard (intertemporal) utility maximization. The Lucas production function for firm j can be represented as:

$$Y_j = AK_j^b(H_j)^{1-b}H_ag \qquad (28)$$

where H_a is the average level of human capital across all firms and g captures the externality effect on output. Unlike the Mankiw, Romer and Weil (1992) approach there are constant returns to the firm's two reproducible factors (Kj and Hj) but increasing returns to all factors so long as g > 0. An important feature of the Lucas representation is that, unlike the Solow model and even if there is no external effect (g = 0), long run growth is now a function of investment in both physical and human capital. There is therefore an important role for education in the long run, as well as the short-run. This arises from the assumption of constant returns to the aggregate of the two types of capital. It follows that in principle this model could be tested by testing for constant returns to K_j and H_j in a firm or industry level production function and/or for increasing returns at the aggregate or economy-wide level, which would allow a value for the externality effect on output. The recent interest in endogenous theories of economic growth has focused attention on the nature and role of knowledge in the growth process as in Romer (1986, 1990b) and Grossman and Helpman (1994). Unlike earlier models of growth like Solow (1956) in which technological change appeared as an exogenous parameter, new growth theory has sought to endogenize technical change. Knowledge is now produced as the result of the rational optimizing behavior of economic agents. Much technological knowledge cannot in fact be transmitted easily to others; much technological knowledge is inarticulate and tacit, and can be transmitted only at a cost through imitation and apprenticeship. This observation creates a difficulty for knowledge-based theories of growth. To the extent that knowledge is tacit in this way, it behaves like an ordinary private good, and its role in generating increasing returns is lost.

The new growth theory has shown very little interest in who gains and who loses from convergence. The theory tends to be highly aggregative, and its empirical applications deal with coarse aggregates like gross domestic product per worker. Understanding the sources of convergence is fundamental to understanding who gains and who loses from convergence, and thus to understanding policy responses.

Barro and Sala-i-Martin (1995) argue strongly that for regions within the US, Japan and Europe there is clear evidence of convergence in income levels though this does not imply unambiguous support for the neoclassical model. They also find, with the possible exception of Europe, that labor migration between regions has facilitated regional income convergence. Overall, the appropriate conclusion from this evidence seems to be that of Jones (1995), that mentions that the macro evidence cannot distinguish between a neoclassical growth model and an R&D-based growth model. Additional evidence must be brought to bear to make this distinction. There is some empirical support at the aggregate level for several types of growth model but equally each typically fails with respect to one or more of its predictions. There does however seem to be very little empirical support for the endogenous growth prediction of constant returns to a broad measure of capital (increasing returns to capital and labor), from which we may infer that, at the level of the economy as a whole, any externality effects would have to be very small at best.

Most empirical and cross-country studies which investigate the role of higher education include Barro and Lee (1993) and Barro and Sala-i-Martin (1995). The most comprehensive evidence from cross-section regressions comes from Barro and Sala-i-Martin (1995). They find, for male educational attainment, that higher initial secondary and tertiary education have significant, positive growth effects, and these are more strongly evident than when years of education are aggregated. Across a wide ranging sample of countries they find that higher education has especially large effects, increasing average male secondary schooling by 0.68 years raises annual growth by 1.1 percentage points per year while a 0.09 year increase in average tertiary education raises annual growth by as much as 0.5 percentage points. A strange finding is that female education (both secondary and tertiary) appears to be inversely related to growth, though this may be a result of deficiencies in the construction of the educational dataset. Barro and Sala-i-Martin also test whether the tendency for countries with relatively low initial GDP to grow faster is enhanced when they have higher levels of human capital in the form of educational attainment by adding a multiplicative education-initial income term to their regressions. This might occur for example if adequate education was important for the adoption or imitation of foreign technologies. Their results confirm a significant role for education in this catch-up convergence process. They also investigate whether public educational expenditures significantly improve growth performance and again confirm a positive role. Data constraints prohibit examination of higher education expenditures separately.

Using an educational attainment index, Benhabib and Spiegel (1994) investigate a simple growth accounting or sources of growth equation, for samples of developed and developing countries, and fail to find a significant role for the growth of human capital in explaining the growth of output. However when they use the level of human capital to explain the growth of total factor productivity they find a highly significant, positive impact. Their evidence also supports that of Barro, that initially lower productivity countries tend to catch up faster where they have better educational provision (in terms of overall years of education).

Countries with faster GDP growth rates, most of which are in East Asia, appear to have based their performance more on the speed of factor accumulation than on the pace of TFP growth. TFP growth between 1960 and 1987 is strongly associated with the initial level of human capital. Young (1992, 1995) suggests that the rapid growth performances of the East Asian economies (often held up as examples for OECD countries to emulate) are substantially due to the educational (and other) investments they have made to raise their human capital stocks, rather than due to acquiring new technologies to make existing factors more productive. Finally, Barro and Sala-i-Martin (1995) consider the possibility of educational externality effects on fertility and health. They do find significant effects of education on fertility but it seems that while primary education has the expected effects (positive for males, negative for females) the reverse holds for secondary and higher education.

An increasing number of studies are investigating the effects of R&D and innovation on growth, including the roles of both domestic and foreign R&D. Recent innovation literature such as Romer (1994) suggests an endogenous dynamic of innovation that is highly dependent on the specificities of a regions' technological capability, firm characteristics and the incremental nature of much of the innovation process.

Economic geography, economies of agglomeration and growth

Recent work in regional economic growth is related to economic geography and economies of agglomeration. The basic question in the study of economies of agglomeration is to ask as to why economic activities get concentrated in a small number of places. We know for a fact that there has been an increase in the number of people living in cities worldwide. Why do they congregate in relatively small areas? Two possible causes of agglomerations are externalities under perfect competition and increasing returns to scale in imperfect markets. The debate in the literature can be broadly categorized into the market clearing approach and the history approach, which are derived from the two opposing views on the possible causes of agglomeration. The first school is the traditional urban school and in the work of Henderson and Eaton and Eckstein. The second school of thought is a view pioneered by Krugman and the followers of the New Trade Theory.

The market clearing approach is able to handle aspects of agglomerations related to why and how cities specialize, and how cities of various sizes coexist. The new economic geography attempts to explain the locational aspects of cities. Both views of agglomeration economies are based on ideas from growth theory.

Henderson's approach to modeling the systems of cities explains other aspects of agglomerations that Krugman's model is not able to answer. It is an example of the neo-classical approach, where there exists a market for cities, with a demand for agglomerations by the product market and a supply of agglomerations determined by populations. The Henderson models assume a representative city in a system of cities. The functional form of the representative city has to be specified without a spatial dimension because it would hinder the development of the properties of the cities.

Eaton and Eckstein (1994) use a market clearing approach to cities, and the theoretical underpinnings come from the Henderson type results about the stability of the system of cities, the specialization by cities in production and the coexistence of cities of different sizes. They validate the rank size rule by looking at the population data on city sizes for France and Japan during this century and construct Lorenz curves to show that the growth rates of the cities in the sample have been largely stable and similar. Where the rank-size rule looks at the size distribution of cities at one point in time and finds them convergent to the population of the largest city. The study looks at the changes in size distributions of cities over time and finds similar growth rates across cities of different sizes. Eaton and Eckstein (1994) put forth a view that population growth rates are independent of initial city sizes with growth rates converging to a common value. The theory they construct, is a model of urbanization and growth consistent with the stylized fact, which is driven by acquisition of human capital.

The best way to think about the sizes of urban areas is to think of them as a frequency distribution; ranking the cities according to their size in descending order. With reference to city size, from raw census data, the frequency (number of cities of similar sizes) decreases as the urban size (population) increases. Hence the size distribution of cities is skewed to the right or is a Pareto Distribution with a function:

$$G(x) = Ax^{-a} \qquad (29)$$

where G(x) is an order function that ranks the cities by size by descending order and x is the population; A and a are some constants to be estimated from data. If a = 1, the product of the urban areas rank and population is equal to the constant A; which is also the population of the largest urban area. This relationship is called the rank-size rule. The preliminary empirical work by Mills laid the foundation for looking at cities and urbanization within the market-clearing framework.

Krugman (1991) examined the extent of localization in production for manufacturing industries in the US and Europe. Krugman finds that industries are typically highly localised but that high-tech industries are not particularly localized. Historical and even accidental factors often determine where an industry begins but the agglomeration process that follows reflects the advantages of local externalities, particularly the gains from local labor pooling. Interestingly Krugman also finds that the three localities where innovative industries developed recently in the United States (Silicon Valley, Route 128 and North Carolina's Research Triangle). The innovative industries began from initiatives by university presidents (Silicon Valley, Route 128) and state research park support (North Carolina). Higher education and the state may therefore have a role to play but not as conventionally thought. Finally Krugman finds tentative evidence that industry is more localized in major U.S. regions compared with European countries and argues that this reflects the fact that trade within the U.S. is easier than trade between European countries. Trade allows increased geographical concentration of production by reducing the need to be close to consumers. By similar reasoning this evidence would suggest that, within the UK production could be more localized for goods supplying the domestic market since goods are likely to be more mobile within the country, than the labor force.

Krugman mentions that increasing returns to scale plays a large role in explaining sustained growth and location of production in regions. Transport costs drive a cumulative process of regional divergence. Outside the core area, cities exist to serve farms and within the manufacturing belt or core farms exist to serve cities. The strong economies of scale in manufacturing as opposed to agriculture implies that there is imperfect competition in the product market, since an economy can only accommodate a finite number of firms.

In the late 1980's, a new group of neoclassical economists rediscovered geography and attempted to include space in their economic models. These path dependency theorists contrast the preordained spatial ordering envisioned by the old location school with their model of a historically dependent trajectory with multiple possible outcomes. While recognizing that the cumulative causation school did address the effects of history on regional development, theorists such as Krugman (1995), argue that until recently economists did not have the proper techniques to rigorously model the effects of increasing returns to scale. Krugman (1991) provide models of regional development in which outcomes are not preordained but dependent on the historical chance sitting of the first firm in an industry. The lock-in effect and unbalanced sectorial rates of technological progress are the basis for Williamson (1980) account of US regional inequality.

Real business cycle theory

Real business cycle (RBC) models are macroeconomic models in which business cycle fluctuations to a large extent can be accounted for by real, in contrast to nominal shocks. Unlike other leading theories, RBC theory sees recessions and periods of economic growth as the efficient response to exogenous changes in the real economic environment. That is, the level of national output necessarily maximizes expected utility, and government should therefore concentrate on the long-run structural policy changes and not intervene through discretionary fiscal or monetary policy designed to actively smooth out economic short-term fluctuations. Real business cycle theory was introduced by Kydland and Prescott in their seminal 1982 work. According to Rebelo (2005), three revolutionary ideas were associated with that paper. They are that business cycle can be studied using dynamic general equilibrium models. These models feature atomistic agents who operate in competitive markets and form rational expectations about the future. The second idea is that it is possible to unify business cycle and growth theory by insisting that business cycle models must be consistent with the empirical regularities of long-run growth. The third idea is that we can go way beyond the qualitative comparison of model properties with stylized facts that dominated theoretical works in macro economics before 1982.

Another major contribution of Kydland and Prescott (1991) is that supply-side shock due to technological advances are the driving force behind business cycles rather than variations in demand. RBCs also constitute a point of departure for economic growth theories in which technology shocks do not play a central role. They have also become laboratories for policy analysis and for the study of optimal fiscal and monetary policy. Interest in business cycles and RBC research, in particular, is gaining ground in the Latin America and South Asian countries during the last decade.

CONCLUSIONS

For the last sixty years, the neoclassical growth model remained the most important model of regional economic growth. Solow (1956) shows how growth in the capital stock, labor force and exogenous advances in technology interact and how they affect the growth of output. The Solow growth model shows that in the long run, an economy's rate of saving determines the size of its capital stock and thus its level of production. Starting in the 1980's, more sophisticated growth models have been developed. Unlike the neoclassical model, technological change is not assumed to be exogenous. The new endogenous growth models explain the sources of technologically driven productivity growth. In particular, the accumulation of knowledge plays a key role in driving productivity growth in these models.

The new research also includes models of the diffusion of technology like the work of Grossman and Helpman (1994). In many of the newer growth models, an effort is made to analyze directly how technological progress is transferred across countries. One important implication of the new studies is that the location of research and development (R&D) activity may matter. If there are significant agglomeration effects associated with R&D activity, then the benefits of R&D are largely captured by the region in which R&D activity takes place. Romer (1993) argues that economics needs a greater appreciation for the role of ideas, both revolutionary ideas and incremental ideas, in a region's or nation's development. Romer also highlights the role of collective action and institutions in facilitating the use of ideas.

Finally, another key element of the endogenous growth models is that the long-run growth rate can depend on government actions. In the basic neoclassical growth model, government does not have an impact on the long run growth rate. In an endogenous growth framework, government policy can affect the long run rate of growth, since government policy actions such as taxation, provision of infrastructure, protection of intellectual property, regulations, maintenance of law and order, and a lower bureaucracy can affect the underlying rate of inventive activity. The government plays an important role in the promotion of regional economic growth.

The introduction of new theories of regional development has strengthened our analytical ability and provided new insights to the changing nature of regional economics. It is not necessary to believe in a deterministic structure like long waves to recognize that the past fifty years has profoundly reshaped the theory of regional economics and the role of individuals, regions and national governments. It is clear that regional growth theory has increased it complexity of analysis. The growth literature to date has proposed several economic models, including neoclassical models, exogenous technological progress and endogenous models that emphasize capital accumulation through externalities, learning by doing, or in conjunction with human capital; and endogenous technological progress.

The recent theoretical and empirical evidence on regional economic growth has mixed results in explaining regional growth with any single theory. Finally, further work on regional growth is needed in order to better understand all the determinants of economic growth.

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