Topics in Macroeconomics

Volume 3, *Issue* 1 | 2003 | *Article* 2

The Human Capital Constraint: Of Increasing Returns, Education Choice and Coordination Failure

Shekhar Aiyar*

*International Monetary Fund, saiyar@imf.org

The Human Capital Constraint: Of Increasing Returns, Education Choice and Coordination Failure

Shekhar Aiyar

Abstract

If technological innovations in the North can be costlessly imitated by educated workers in the South, and if education decisions are endogenous, why aren't all countries well-educated and rich? This paper explores a possible answer: if technologically advanced sectors, operating under increasing returns to scale, need a minimum pool of educated workers to commence production, then coordination failure can arise in the choice of education. A simple two-sector model is shown to yield multiple equilibria: countries that perform well educationally and adopt technology successfully can co-exist with countries that fail in both endeavors.

KEYWORDS: Increasing Returns, Education Choice, Coordination Failure

1. Introduction

1.1 Three Hypotheses and a Puzzle

It striking how varied the development experience of different LDCs has been over the past several decades. Some have succeeded in growing at a rate hitherto unparalleled in human history, others have made progress slowly and haltingly, and a substantial group of countries has remained mired in the most abysmal poverty, contracting rather moving forward for long periods of time. The central thrust of growth theory or development economics should surely be to find ways to explain this bewildering diversity.

The diversity that we observe in levels and growth of incomes may be posed as a puzzle if three hypotheses are granted. First, let us assume, in accordance with the empirical record, that the overwhelming bulk ofscientific advances and technological innovations are carried out in the rich world. Second, assume that these innovations may then be copied by poorer countries provided that they have the human capital necessary for such imitation. Third, assume that the choice of whether or not to acquire education depends, at the individual's level, on a comparison between the costs of acquiring an education and the benefits that flow from it.

It is indisputable that several countries have very poor stocks of human capital and fairly uncontroversial to infer that they are therefore unable to benefit from technologies developed in the North. But why is this the case if educational decisions are endogenous? Presumably, if a worker knew that an education would enable her to work in a sector that paid sufficiently higher wages than the traditional sector, she would choose to acquire schooling. The endogeneity of educational decisions should automatically lead to a stock of human capital that is able to succesfully imitate technologies developed elsewhere. So why is it that some countries have had such success both in educating their people and in setting up industries that depend on foreign technologies, while others have had such a poor record in both spheres? Accepting the three hypotheses outlined previously would seem to rule out such divergence.

This paper discusses a possible resolution of the puzzle in terms of coordination failure. If an individual's choice about whether or not to acquire education depends on the choices that all other people in the economy are making, then it is possible to get multiple equilibria. In such a model, a good equilibrium would correspond to a situation in which sufficient people acquired education and an advanced sector "took-off", whereas a bad equilibrium would correspond to a situation where neither happened.

1.2. Outline and Literature Review

The macroeconomic coordination literature was pioneered by Rosenstein-Rodan, who argued that industrialization may require coordinated investment acrossseveral sectors in order to be successful. His ideas have received a new lease of life with the work of Murphy, Shleifer and Vishny (1989), who make several of the older ideas mathematically precise. They focus on the constraint that LDCs face in terms of a small domestic market, in which industrialization by a single firm is unprofitable, but coordinated industrialization by several firms, which has the effect of creating a bigger market through income-generation, *is* profitable. More general forms of strategic complementarity and multiple equilibria in macroeconomics are explored in Cooper (1999).

This paper aims to combine some of these ideas with the links between a country's accumulation of human capital and its growth experience. Several theories of endogenous growth point to the accumulation of human capital as the primary engine of economic development (Lucas (1988), Arrow (1962)). Models describing a world of ever increasing product variety or continual quality improvements to existing ones typically rely on the notion of an R&D sector employing educated workers (Grossman and Helpman (1991), Aghion and Howitt (1992)). Models that describe LDCs as imitators of technological innovations carried out in the rich world implicitly assume they contain people sufficiently educated to undertake the relevant imitations; there are also explicit models of this nature that date back to Nelson and Phelps (1966). Arguably the rapid advancement of technology over the past few decades has led to a situation in which the most productive new industries are precisely those which are the most dependent on highly educated workers as inputs. Acemoglu (1998) develops a model in which the choice of which new technologies to produce depends on the factor abundance of human capital in an economy; a greater ratio of human capital to other factors leads to skill-biased technological progress. Acemoglu andZillibotti (1999) extend this notion to a multi-country setting in order to explore international productivity differences.

The link between coordinated industrialization and the accumulation of human capital is a simple one. It is indubitable that technologically advanced industries require inputs of educated workers. Furthermore, it seems plausible that such industries require a certain minimum *pool* of educated workers in order to take off; a country boasting a single engineer will not be able to set up an electronics industry. In such a situation the size of the domestic market is not the only factor inhibiting industrialization; an equally if not more important constraint may be the lack of a stock of human capital sufficiently large to enable production in the advanced sector.

To make the idea of a human capital constraint precise, and thereby to examine issues of coordination, two more crucial observations, neither of which are novel, are in order. First is the fact that industries that use skilled workers as an input rather than unskilled labour are likely to face different production possibilities in terms of returns to scale. While it may be reasonable to assume that agriculture, relying on variable inputs of unskilled labour and a fixed endowment of land faces diminishing returns, it seems that technologically advanced industries which mainly depend on highly educated workers should face constant or increasing returns instead. The second observation is that rather than viewing a country as having a certain fixed endowment of human capital it should be recognized that choices of whether or not to acquire education are endogenous, and depend on a comparison of the rewards to be had from education with the costs of acquiring it. These rewards are, of course, intimately connected with the prevailing levels of technology in sectors that differ in the educational qualifications that they require their workers to have.

Combining these observations yields several insights which are explored in the body of this paper. The next section of the paper describes a simple two-sector model. The first sector uses unskilled labour and faces diminishing returns to scale. The second produces a technologically complex good using a continuum of intermediate products. These intermediate products are produced monopolistically using educated workers as their inputs. It is shown how the requirement of a certain minimum pool of educated workers in order for production in the second sector to commence can be modelled quite naturally. Given this minimum requirement of educated persons it can be shown that the system has multiple equilibria: while it is individually rational for certain workers to acquire education if others make the same decision, it is individually rational for them not to acquire education if others do not (and the second industry, in consequence, fails to commence production). The problem of co-ordination failure therefore indicates a role for a "big push" government initiative in the style of Murphy, Shleifer and Vishny. It may be, then, that clues to the different track records of different LDCs in educating their people and establishing new, technologically advanced industries are to be found in their differing degrees of success in addressing these coordination issues.

The possibility of multiple equilibria implies the existence of development traps in the case of coordination failure. There is already a literature in this tradition, but our analysis departs from it in certain crucial aspects. Azariadis and Drazen (1990), for example, examine development traps which may arise due to insufficient investment in human capital by previous generations; in their model this reduces the incentives of the current generation to invest in human capital and hence propogates underdevelopment. Our approach shows, however, that coordination failure in education can occur not just across generations, but within a single generation comprising heterogenous agents. Redding (1996) develops a model in which there are strategic complementarities between R&D investments made by entrepreneurs and education investments made by individual workers; here equilibria with high R&D and education investments can coexist with equilibria involving low levels of both. Our approach differs in showing that coordination failure might arise even in an environment in which no R&D is undertaken, and poor countries can simply imitate production technologies developed in the North; an environment that seems more in line with the realities of the developing world. With heterogenous agents, coordination *within* the set of workers making educational choices, rather than between this and some other group in the economy, may also be important.

2.The Model

2.1 Production

There are two sectors producing two different goods. The first sector, producing good Y, uses uneducated workers as its input and faces diminishing returns; its production function is described by:

$$Y = L_y^{\beta} \qquad 0 < \beta < 1 \tag{1}$$

where L_y denotes the labour hired in sector Y. We are, of course, implicitly positing a fixed factor in this sector. Workers are paid their marginal products, so that $w_y = \beta L_y^{\beta-1}$.

The second sector produces good X competitively, using a continuum of intermediate inputs of measure n.

$$X = \left(\int_0^n x_i^{\gamma} di\right)^{\frac{1}{\gamma}} \qquad 0 < \gamma < 1 \tag{2}$$

Each of the intermediate goods x_i is produced monopolistically by a single producer. These producers use educated workers as their input, in the following way; they must incur a fixed cost of f units of educated workers, subsequent to which every additional worker hired is able to produce a quantity of output $D > 1$. Since the final good X is produced competitively, the inverse demand curve faced by each of the intermediate producers is:

$$x_i = p_i^{\frac{-1}{1-\gamma}} X P_x^{\frac{1}{1-\gamma}} \tag{3}$$

where p_i is the price of intermediate good x_i and P_x is the price of the composite good X. It is easily shown that $P_x = \left(\int_0^n p_i^{\frac{-1}{1-\gamma}} di\right)^{\frac{-(1-\gamma)}{\gamma}}$.

The intermediate producers, as monopolistic competitors, take the wage rate as given. The price they charge is a markup over the wage they pay per unit of output, so that:

$$p_i = \frac{w_x}{\gamma D} \qquad \text{for all goods } x_i \tag{4}$$

Each firm makes zero profits in equilibrium, due to free entry. Therefore we have:

$$p_i x_i - \left(\frac{x_i}{D} + f\right) w_x = 0 \tag{5}$$

where $\left(\frac{x_i}{D} + f\right)$ is the amount of labour needed to produce an amount x_i and w_x represents the wage of educated workers. Combining (5) with (3) and (4) yields:

$$x_i = \frac{\gamma f D}{1-\gamma} \qquad \text{for all } i \tag{6}$$

Thus the output of each intermediate producer i is completely determined by the parameters γ, f and D. The number of intermediate goods produced is determined by the following market-clearing condition for educated workers:

$$L_x = n(\frac{x_i}{D} + f) \tag{7}$$

from which, using (6), it follows that:

$$n = L_x \frac{(1-\gamma)}{f} \tag{8}$$

Finally, it follows from our expressions for n and x_i and the definition of the composite good X that:

$$X = (\frac{1-\gamma}{f})^{\frac{1-\gamma}{\gamma}} \gamma D L_x^{\frac{1}{\gamma}} \tag{9}$$

This completes the description of the production side of the economy. Note that the advanced sector X is primarily distinguished from sector Y in that it uses a range of intermediate goods (which, in turn, require human capital to produce). This aspect of the model is consistent with the stylized fact that industrial technologies are much more intermediate input-intensive than the technologies they replace. For example, Chenery, Robinson and Syrquin (1986) find, in their comprehensive study of industrialization, that the share of intermediate inputs in manufacturing product rises over the industrialization process, very markedly for some countries.[1]

2.2 Individuals and Education Choice

In each period a measure of individuals normalized to one is born. All individuals live for two periods. In the first period they must choose whether to acquire education or not. If they choose not to acquire education they work in Sector Y in the second period and consume all their wages at the end of the period. If they decide to acquire education in the first period then they work in sector X in the second period.[2]

Individuals differ from one another in terms of ability, which is reflected in their differing costs of acquiring education. Specifically individuals are uniformly distributed over the unit

[1] According to their analysis, this share rose particularly rapidly in South Korea, Israel and Japan as those countries industrialized. In Taiwan it tripled between 1956 and 1971. The authors identify technological change as the main cause of the rise in intermediate input-intensity.

[2] In this model nobody works in the first period of their lives. It is possible to alternatively specify that uneducated individuals work in both periods while educated individuals work only in the latter period, but since such a specification adds nothing of intuitive interest to the model it is discarded in the interests of simplicity.

interval according to the ability parameter σ, i.e. $\sigma \sim U[0,1]$. Lower levels of σ denote higher levels of ability. The cost of acquiring an education is $\tilde{K}g(\sigma)$, where $\tilde{K}$ is a constant and $g(.)$ is an increasing function of σ.[3]

Since individuals are born without endowment, they must borrow an amount $\tilde{K}g(\sigma)$ in the first period if they choose to pay for and acquire an education. The country is assumed to be open to capital flows, so that they can borrow this amount without hinderance at an internationally fixed rate of interest r. Educated individuals work in sector X in the second period of their lives, and repay their debt before consuming. The amount they must repay is $Kg(\sigma)$, where $K = \tilde{K}(1+r)$.

Individuals will therefore choose education if:

$$w_x - Kg(\sigma) \geq w_y \tag{10}$$

The above expression satisfied with equality determines σ^* such that all persons with $\sigma < \sigma^*$ choose education and the remainder do not. This fixes the supply of uneducated and educated labour at $L_y = (1-\sigma^*)$ and $L_x = \sigma^*$ respectively, since $L_x + L_y = 1$ by definition.

2.3 Equilibrium

To close the model it is necessary to specify how demand is distributed among goods Y and X. We assume that all individuals have identical CES preferences described by the utility function:

$$U = [Y^\gamma + \eta X^\gamma]^{\frac{1}{\gamma}} \qquad (11)^4$$

[3] "Ability", of course, may be interpreted as broadly as desired. For example, it could be argued that those at a large geographical remove from urban centres with large and diverse educational facilities are naturally disadvantaged, and must incur higher "costs" to achieve a standard level of education.

[4] It may appear rather contrived that the elasticity of substitution in consumption is exactly the same as the elasticity of substitution of inputs in the production of X. In fact, all the qualitative results of the model are unchanged if we denote the production parameter as γ and the preference parameter as ρ, so long as $\gamma \geq \rho$. This amounts to requiring that the elasticity of substitution of inputs in the production of X be greater than or equal to the elasticity of substitution in consumption. However it proves analytically very convenient to set $\rho = \gamma$; this enables us to avoid much tedious algebra that contributes nothing to the intuitive power of the model.

These preferences dictate that aggregate demand for X and Y is described by the following relationship, in which commodity Y is taken to be the numeraire:

$$P_x = \gamma(\frac{Y}{X})^{1-\gamma} \tag{12}$$

In examining the production side of the economy we have already established that all producers of intermediate products charge $p_i = \frac{w_x}{\gamma D}$. This implies, taking into account our expression for n, that $P_x = (L_x \frac{(1-\gamma)}{f})^{-\frac{(1-\gamma)}{\gamma}} \frac{w_x}{\gamma D}$. In combination with (12), our expressions for Y and X, and the fact that $L_x = (1-L_y) = \sigma^*$, it follows that :

$$w_x = \tau D^\gamma (1-\sigma^*)^{\beta(1-\gamma)} \tag{13}$$

where $\tau = \eta(\frac{1-\gamma}{f})^{1-\gamma} \gamma^\gamma$

This completes the model, for σ^* is determined by equation (10) with equality, which becomes:

$$\tau D^\gamma (1-\sigma^*)^{\beta(1-\gamma)} - Kg(\sigma^*) = \beta(1-\sigma^*)^{\beta-1} \tag{14}$$

The comparative statics yielded by this equation are just as we would expect; technological progress in sector X, in the form of an increase in D, raises w_x and consequently raises the number of people choosing education. The same results flow from a reduction in the cost of acquiring education in the form of a decrease in K. The implicit function theorem may be applied to equation (14) to confirm that:

$$\frac{d\sigma^*}{dD} > 0 \qquad \text{and} \qquad \frac{d\sigma^*}{dK} < 0$$

Note that these results follow no matter what form for $g(.)$ is chosen, so long as it is an increasing function of σ. In order to obtain a closed form solution, however, it is convenient to choose $g(\sigma) = (1-\sigma)^{\beta-1}$; this functional form is maintained for the remainder of the paper and allows us to obtain:

$$1-\sigma^* = L_y = \left(\frac{K+\beta}{\tau D^\gamma}\right)^{\frac{1}{1-\gamma\beta}} \quad \text{and}$$

$$\sigma^* = L_x = 1-\left(\frac{K+\beta}{\tau D^\gamma}\right)^{\frac{1}{1-\gamma\beta}} \tag{15}$$

Clearly the equation above imposes restrictions on the parameters of the model: we can only have an equilibrium with both sectors in operation if $\tau D^\gamma > K+\beta$. The intuition behind this is straightforward - unless technology, and, therefore, the wage-rate in sector X are high enough relative to the costs of acquiring education and to the rewards offered by sector Y, nobody will choose education.

Although not the focus of the paper, it is interesting to note how this model sheds light on an issue in the development literature concerning the adoption of "appropriate technology", that is, technology that complements the abundant factor in a country. Assuming that an LDC is typically scarce in human capital and abundant in unskilled labour, many conventional arguments would hold that it is preferable to adopt technologies that increase the productivity of the abundant resource. However, in the model under consideration it can be seen that adopting technological innovations complementary to the scarce factor (in the form of an increase in D have not only the static effect of increasing productivity in the period of adoption, but also a dynamic effect that induces more people to choose education in the succeeding period. Of course, this raises productivity in the unskilled sector as well, and increases National Product.

Another point worth making relates to the typical growth accounting methodology of separating increases in National Product into those attributable to factor accumulation and those attributable to increases in (total factor) productivity. The simple model presented here shows that this is likely to be a false dichotomy, for any technological adoption in Sector X leads not only to a rise in productivity, but also to the accumulation of human capital. The increase in productivity is what *causes* the factor accumulation via an increase in factor rewards, so that it is misleading to regard them as two separate influences on prosperity. This point has been made before, for example in Klenow and Rodriguez-Clare (1997) with regard to investment in physical capital responding positively to increases in productivity.

3. Minimum Scale and Co-ordination Failure

We now introduce a consideration that is likely to be important for the production of any technologically complex good, namely, that there exists a lower bound to the number of different intermediate inputs required for its production. For example, consider the intermediate input needs of a computer-systems industry. A cursory and incomplete list would include several varieties of integrated circuits and semiconductors; precison tools including lasers and magnifying equipment for assembly; precision parts for the interior; specialized glass, cathode ray tubes and color filters for monitors; advanced plastics materials for the body;

connecting cables and adaptors; packaging equipment for the final product; and, for the manufacturing unit itself, interior climate control and hazard-detection systems. Clearly these intermediate goods would each require considerable amounts of human capital in their manufacture. Moreover, the absence of any of these inputs would pose serious difficulties for the production of the final product, and the absence of a sufficient number would render production impossible.

In our model, in which good X is produced using a continuum of intermediate inputs of measure *n*, this is succinctly represented by requiring that $n \geq m$ in order for good X to be produced at all. If the equilibrium value of *n* turns out to be less than *m*, given the values of the model parameters, then sector X produces nothing. Of course, this implies that nobody in the economy has an incentive to choose education, and the entire labour force devotes itself to the production of good Y.

The restriction that $n \geq m$ means that there is a certain minimum size to the educated workforce $L_x = \sigma^*$ that is necessary for Sector X to commence production. Using (8) we see that for Sector X to exist it is necessary that:

$$\sigma^* = 1 - \left(\frac{K+\beta}{\tau D^{\gamma}}\right)^{\frac{1}{1-\gamma\beta}} \geq \frac{mf}{1-\gamma} \tag{16}$$

If the equilibrium value σ^* fails to satisfy inequality (16) then the economy must operate with only one sector. This must continue until the point that technological progress in sector X or subsidies to education (increases in D and decreases in K respectively) raise σ^* to a level where production in the monopolistic sector is at least feasible.

Suppose, however, that we are in an LDC that satisfies (16). There remains the important issue of coordination to be considered. If a fraction σ^* of the population chooses education, then that is exactly sufficient for Sector X to commence production, and all those who chose education are better off than they would have been without education. On the other hand, suppose that a fraction of people slightly less than σ^* choose education. In this case Sector X is unable to commence production, and all those who chose education are worse off than they would have been without education. Another way of putting it is that for every individual with $\sigma < \sigma^*$, the optimal choice of whether or not to acquire education depends on the choices that all others with $\sigma < \sigma^*$ are making. It is readily seen that there are two possible equilibria; one in which all individuals with $\sigma < \sigma^*$ choose education, and another in which nobody chooses education. Clearly the first equilibrium leaves everybody better off (including those who do *not* choose education), but it can only be achieved if it is possible to coordinate the education decisions of all people. [5]

---

[5] Note that coordination failure in this model is driven entirely by the assumption that a certain minimum number of intermediate inputs is required for production of the final product, *not* by the requirement that production of each intermediate input requires a fixed cost *f*. The latter requirement simply fixes the equilibrium number of firms in the monopolistically competitive

Why could the firm producing the final product not internalise the coordination problem by simply manufacturing the necessary intermediate inputs itself? One could imagine amending the model here so that the final goods sector hires human capital in its own right to produce a number of crucial inputs, and then buys the remainder from intermediate producers. In our example of the computer-systems industry, why doesn't this industry also produce connecting cables and cathode ray tubes? Two answers immediately suggest themselves. First, a certain minimum amount of human capital would be necessary to produce these items as well, since each of these items would in turn require several different types of inputs for their manufacture. Therefore the coordination problem would not be solved. Second, the sheer diversity and quantity of the inputs required - from air-conditioning units to soldering irons - would create diseconomies of scale if one firm were to manufacture them all. This analysis implies that there exists an important coordination role for government to play. Individuals will choose education only if they can see that the government ensures that all similarly situated people are also acquiring education.

Must the government solve the coordination problem in every period in order for Sector X to produce in every period? In the simple model presented here that is formally the case. However it is easy to see how small modifications to the model would lead to a result that the coordination problem must be solved only once. For example, assume that agents live for three periods, working for two and (possibly) acquiring education for one. [6] From a situation in which $\sigma^* = 1 - (\frac{K+\beta}{\tau D^{\gamma}})^{\frac{1}{1-\gamma\beta}} \leq \frac{mf}{1-\gamma}$, suppose the government subsidises education so as to reduce K to the point where the inequality is reversed and (16) holds. Further assume that the government is able to solve the coordination problem for the current generation of education-choosers. This ensures that there will be enough educated workers for the next *two* periods for Sector X to produce. And this ensures that no coordination problem can occur in the next period, since those choosing education know that even if even if nobody else in their generation chooses education, Sector X will still exist to offer them employment. This

---

sector, which would otherwise be indeterminate. To see this assume that there is no floor on the number of intermediate inputs required, i.e. the condition $n \geq m$ need not be satisfied for Sector X to produce. In this situation, the only stable equilibrium is for everybody with $\sigma < \sigma^*$ to choose education. A stable equilibrium with nobody choosing education is impossible. For if ε people with $\sigma < \sigma^*$ "defect" and choose education, they will benefit: from (8) we get that $n = \varepsilon(\frac{1-\gamma}{f})$, and we will have production of X using $\varepsilon(\frac{1-\gamma}{f})$ intermediate inputs. In other words, without the condition $n \geq m$, an agent's education decision is independent of the education decisions of other agents, and coordination issues do not arise.

[6] This seems a reasonable assumption, given that the average career tends to be at least twice as long as the average education.

argument applies to each successive generation, ensuring that once the coordination problem has been resolved, it will not arise again.[7]

Finally, it should be emphasised that our model is one of a closed economy. A natural area of further research would be various extensions of the approach developed here to an economy that trades. If the advanced sector could import some of its required inputs, that would resolve the coordination failure problem. If, for example, there were significant transport costs, then the advanced sector would use all of the intermediate inputs available domestically, and then import the rest. This would imply that people's education decisions were no longer interdependent, and those people for whom the skill-premium was greater than the cost of schooling would always choose education. This points to a gains-from-trade argument that is novel: trade could lead to the resolution of coordination failure in education and hence enegender a larger stock of human capital in developing countries.

4. Conclusion

This paper sets forth a framework in which a single and partial explanation of the diversity of the development experience is explored. Theorists and empirical practitioners alike find it uncontroversial that the accumulation of human capital is an important part of the growth story. Although there are interesting counterexamples - Sri Lanka, Cuba and Kerala are probably the best known - it is indisputable that there is in general a positive link between a country's track record in educating its people and its record in moving from traditional subsistence farming to more technologically complex manufacturing and service industries. But the question remains - why have some countries had such tremendous success in *both* areas and some such scant success in either? If scientific breakthroughs and technological innovations occur mainly in the developed world (the evidence suggests that they do) and are then available to imitators in all poor countries, why is it that some countries have taken advantage of this state of affairs while others have not? Of course the immediate answer is that the countries which were able to take advantage of it were the ones that had educated people in requisite numbers to exploit the new opportunities. But this is an insufficient answer. If the rewards to acquiring education are linked to the productivity of the potential sectors which hire educated people, then why did so many people in some countries acquire education and so few in others? The answer suggested by this paper is that coordination issues may have been satisfactorily resolved in some countries with competent and credible governments, while they remained insurmountable in others. The central coordination issue explored in this paper relates to convincing people who are about to choose education that sufficient numbers of other people are choosing education to enable advanced industries with minimum scales of production to take off.

A valid criticism of the approach followed in this paper is that it appears to predict that countries in which the coordination problem has not been solved, and which therefore face a human capital constraint, should have zero returns to education. In fact extensive empirical

[7] Strictly speaking this holds provided that population is not decreasing over time.

work (Psacharopolous (1994), among others) suggests that the returns to higher education are always positive, and in fact are greater in less developed countries. This suggests an extension of the model to incorporate the fact that in LDCs there typically exists a small rent-seeking sector of bureaucrats, petty officials, revenue officers and the like, which hires educated people. However, if this group is mainly predatory rather than productive, then there is a natural upper limit to the number of people it can support. Then, in a country which fails to resolve coordination issues high returns to education could coexist with a very small group of people who acquire it. A country which solves the coordination problem and attracts large numbers of people to education could then be characterised by falling returns to the same, if, for instance, the predatory power of the rent-seeking group diminishes with the process of development.

Specific evidence for the co-ordination failure story is hard to gather, since empirical work has not typically focussed on the kinds of mechanisms described here. However some recent studies are suggestive. Borensztein et al (1998) find that there are threshold effects in education. Bils and Klenow (2000) find that if returns to schooling are to be consistent with microeconomic evidence then they can only explain about one-third of the coefficient that is found on human capital in cross-country growth regressions such as Barro (1991). They suggest two other channels for the relationship: (a) there may be some reverse causation from growth to schooling, and (b) there may be third factors which influence both growth and schooling positively. The first channel, in which schooling responds to an increase in productivity in the sector requiring educated people, is a crucial feature of the framework presented here. Moreover, in our analysis a solution to the coordination problem would enable rapid increases in both schooling and National Product; this would seem to be a plausible candidate for the third factors posited by Bils and Klenow.

5. Colophon

I gratefully acknowledge useful discussions with David Weil, Oded Galor, Peter Howitt, Franziska Ohnsorge and John Driscoll. Charles Jones and two anonymous referees provided valuable advice. Thanks also to seminar participants at Brown University and the NEUDC conference at Cornell University. All remaining errors and omissions are my own. The views expressed are those of the author and do not necessarily represent those of the International Monetary Fund. Please direct all correspondence to: The International Monetary Fund, HQ 5-403, 700 19th. Street, NW, Washington, DC 20431. E-mail: saiyar@imf.org.

6. References

Acemoglu, Daron (1998), "Why do New Technologies Complement Skills? Directed Technological Change and Wage Inequality", *Quarterly Journal of Economics*, 113, 4, pp. 1055-1089.

Acemoglu, Daron and Fabrizio Zilibotti (1999), "Productivity Differences", *NBER Working Paper 6879*.

Arrow, Kenneth J. (1962), "The Economic Implications of Learning by Doing", *Review of Economic Studies*, 29, pp. 155-173.

Aghion, Phillippe and Peter Howitt (1992), "A Model of Growth Through Creative Destruction", *Econometrica*, 60, pp. 232-251.

Azariadis, Costas and Allan Drazen (1990), "Threshold Externalities in Economic Development", *Quarterly Journal of Economics,* 55, 2, pp. 501-526.

Barro, Robert J. (1991), "Economic Growth in a Cross Section of Countries", *Quarterly Journal of Economics*, 106, pp. 407-43.

Benhabib, Jess and Speigel, Mark M.(1994), "The Role of Human Capital in Economic Development: Evidence From Aggrgate Cross Country Data", *Journal of Monetary Economics,* 34, pp. 143-73.

Bils, Mark and Peter J. Klenow (2000), "Does Schooling Cause Growth or the Other Way Around?", *NBER Working Paper 6393*.

Borensztein, Eduardo, Jose De Gregorio and Jong-Wha Lee (1998), "How Does Foreign Direct Investment Affect Economic Growth?", *Journal of International Economics*, 45, pp. 115-35.

Chenery, Hollis, Sherman Robinson and Moshe Syrquin (1986), *Industrialization and Growth: A Comparative Study*, New York, Oxford University Press.

Cooper, Russell J. (1999), *Co-ordination Games: Complementarities and Macroeconomics*, Cambridge University Press.

Grossman, Gene M. and Elhanan Helpman (1991), *Innovation and Growth in the Global Economy*, Cambridge, MA, MIT Press.

Klenow, Peter J. and Andres Rodriguez-Clare (1997), "The Neoclassical Revival in Growth Economics: Has it Gone Too Far?", *NBER Macroeconomics Annual,* pp. 73-103.

Lucas, Robert E. (1988), "On the Mechanics of Economic Development Planning", *Journal of Monetary Economics*, 22, 1, pp. 3-22.

Murphy, Kevin M., Andrei Shleifer and Robert W. Vishny (1989), "Industrialization and the Big Push", *Journal of Political Economy*, 97, 5, pp. 1003-26.

Nelson, Richard and Edmund Phelps (1966), "Investment in Humans, Technological Diffusion and Economic Growth", *American Economic Review*, 56, 2, pp. 69-75.

Psacharapoulos, George (1994), "Returns to Investment in Education: A Global Update", *World Development,* 22, 1325-43.

Redding, Stephen (1996), "The Low Skill, Low Quality Trap: Strategic Complementarities Between Human Capital and R&D", *Economic Journal*, 106, 435, pp. 458-70.

Rosenstein-Rodan, Paul N. (1943), "Problems of Industrialization of Eastern and Souteastern Europe", *Economic Journal*, 53, pp. 202-211.