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Convergence and divergence in the global economy from a technological perspective

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Abstract: It is precisely because of the importance now ascribed (by many scholars) to technical change as a source of economic growth, that our view of the way in which innovations are actually generated, appropriated and diffused among different countries bears so heavily on what we think will be the dispersion over time of growth rates between rich and poor countries. On the other hand there are economists whose view of technological relationships leads them to anticipate a convergence of per capita incomes between countries at different stages of development. In yet another category are those who take a different view of how technologies are generated, appropriated and diffused internationally. This group tends to conceive of a process of economic divergence, whereby the gap between rich and poor countries becomes larger rather than smaller over time.

The purpose of this paper is to compare the assumptions about technical change that give rise to these contrasting perspectives, to confront them with the available evidence and to suggest an analytical framework which is more suitable for analysing the influence that is currently being exerted on the inter-country patterns of globalisation by the introduction of information technology. We find among other things, that although the notion of international technological dualism was conceived as early as 1970, it is only recently that an accurate view of technical change based on this concept has been formalised in growth theory.

Keywords: technical change; technological dualism; catch-up; globalisation; innovations; growth.

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1 The technological assumptions of convergence theories

1.1 International trade theory

Perhaps the best known of the mechanisms through which a convergence of per capita income between countries is supposed to occur, has to do with international trade and in particular the conclusions drawn from the standard Hekscher-Ohlin model, which, in its most pure form assumes that all countries have access to and operate on the same production functions. According to this version of the model, that is to say,

> "we expect that as trade barriers are reduced so production will relocate according to comparative advantage (for example, with relatively unskilled-labour-intensive activities moving to relatively unskilled-labour-abundant locations). And the changes in demands for factors of production that follow from this will tend to equalise factor prices across countries. ... The theory provides strong and – in part at least – intuitive predictions about the effects of globalisation" [1, p.2].

That is to say, the reason why convergence may not yet have occurred is because the assumptions of the model are only now beginning to approximate reality (i.e. perfect markets on a global scale).

1.2 Empirical convergence literature

In a critique of what they refer to as 'empirical convergence literature', Bernard and Jones [2] refer to several studies which

> "aim to explain both cross-country differences in output levels and growth rates with a Solow-style growth model in which *countries have identical exogenous rates of technological change*. The exercise is one of pushing the simple model of capital accumulation to its logical limit, adding only a second capital type when the estimated factor share for physical capital seems too large.
>
> *Almost completely forgotten by the empirical literature is the role of technology*. Technology, at best, is allowed to index differences in an initial multiplicative factor, and *all economies are assumed to accumulate technology at the same rate*. In such a capital-based world, differences in growth rates stem from differences in capital accumulation. Technological choices, through adoption and accumulation, are completely assumed away in explaining ... convergence" [2, p.1037].

Such views, we should note are tantamount to neglecting the role of technical change in economic growth.

1.3 Catch-up theory

In contrast to the two previous strands of literature, in which countries were assumed either to have equal access to technology or experience the same rate of technical change, it is *differences* in technology between rich and poor countries that form the starting point of so-called 'catch up' theory. And according to this theory of how convergence takes place, it is precisely the difference between 'early' and 'late' industrialising countries that allows the latter – via absorbing technologies that already exist - to 'catch-up' to the former. More specifically,

> "When a leader discards old stock and replaces it, the accompanying productivity increase is governed and limited by the advance of knowledge between the time when the old capital was installed and the time it is replaced. Those who are behind, however, have the potential to make a larger leap. New capital can embody the frontier of knowledge, but the capital it replaces was technologically superannuated. So – the larger the technological and, therefore, the productivity gap between leader and follower, the stronger the follower's potential for growth in productivity; and, other things being equal, the faster one expects the follower's growth rate to be. Followers tend to catch up faster if they are initially more backward." [3, p.221]

In the following Section, we try to show that the processes of technical change and technological diffusion depicted by these three approaches are simply not supported by the empirical evidence and we argue, further, that this is due in large measure to the unrealistic assumptions that each of them embodies.

2 Empirical evidence

To begin with let us consider the evidence that bears on the validity of the Heckscher-Ohlin model, the first and perhaps best known of the three approaches to convergence described above. As reviewed by Krugman [4] that evidence tends not to confirm the predicted view that actual patterns of international trade are wholly ascribable to differences in resource endowments between countries. On the contrary, "empirical evidence ...." has, over time, tended to reinforce the view that patterns of comparative advantage are largely driven by international differences in production functions. That is, technological differences are a major engine of trade [4, pp.345-346].

If differences in factor endowments are thus not the sole (or perhaps even the major explanation) of actual trade patterns, it is also true that factor prices have not exhibited the predicted tendency to equality (the so-called factor-price equalisation theorem). Indeed, the evidence seems to suggest a divergence rather than convergence of real wages between rich and poor countries, as predicted by that theorem, e.g. [1].

Nor, one should emphasise, is the apparent lack of factor-price equalisation the only problem with the application of the standard trade model. For, quite apart from the consequent absence of convergence between rich and poor countries, there is some evidence that certain countries may experience *absolute* (as distinct from *relative*) losses from international trade (such losses, of course, are precluded by definition in traditional theory, which argues that free trade always, albeit to different degrees benefits *each* participant). Historically, for example, benefits of the enlargement of markets brought about by the Industrial Revolution and the sharp reduction in transport costs during the nineteenth century clearly accrued to certain branches of British manufacturing but "at the same time the arrival of cheap factory made goods eliminated local producers (of hand-woven textiles and so on) who became incompetitive in consequence, and it made these countries 'specialize' in the production of raw materials and minerals" [5, pp.596-597, 6,7].

If convergence cannot thus rest on Hecksher-Ohlin trade theory with its implication of factor-price equalisation across countries, could it be reflected instead in the operation of one of the other two mechanisms described above? In these cases as well, however, the cross-country evidence is scarcely suggestive of any very powerful convergent or equilibrating forces at work to reduce differences between rich and poor countries.

Indeed, if anything, the opposite tendency, towards a growing divergence of incomes between developed and developing countries is the more easily discernible. According to one recent survey of the evidence, for example,

> "On a global level, the evidence on dispersion is remarkably consistent and clear. The international dispersion of per capita incomes has been increasing rapidly for more than a century. ..... There is little evidence to suggest that this trend has been reversed in the past decade or so.
>
> Indeed, if anything, the evidence points to a strengthening of the polarisation forces.
>
> Nor is more detailed examination of the historical evidence linking globalization and convergence very convincing. ..... Growing dispension over the past four decades has been most noticeable in the developing world, accompanied by a significant increase in the absolute income gap between the richest and poorest developing countries and a near doubling of the ratio of maximum to minimum per capita. ..... These forces of polarization appear to have intensified in the early 1980s." [8, pp.10, 11]

According to a more recent empirical test of the convergence hypothesis, moreover, the "results indicate that disparities among rich and poor countries have not shown a tendency to diminish during the last three decades, not even among the eight high-performing countries" [9, p.54]. The conclusion of this later study is that "The late entry of most less-developed countries into the economic race may prevent them from ever competing with the developed nations; instead they will just fade further and further behind" [9, p.65].

In the next Section we seek to replace the technological assumptions underlying theories of convergence with alternative hypotheses, which, we feel, are more consistent with the actual patterns of inequality between rich and poor countries. In so doing, we rely on the literature in the area of technology and development, a literature that is hardly ever referred to in growth theory.

3 Technological realities and divergent patterns of globalisation between rich and poor countries

As noted earlier, technology has become widely recognised as a major determinant of international trade patterns and hence also patterns of economic growth. Indeed,

> "It is now generally accepted that advantages in technological competence will lead to a better performance in foreign trade. There are at least three links between innovation and international competitiveness. First, process innovations reduce production costs and hence output prices, increasing competitiveness. Second, minor product innovations improve the quality of commodities and make them more appealing in both domestic and foreign markets. Third, major product innovations create, for a limited period of time, a monopolistic position which helps to impose those products in the market, while at the same time bringing in monopoly profits." [10, p.11]

These advantages however do not accrue uniformly across different countries. Rather, as emphasised by Griffin [11] more than 25 years ago, they occur overwhelmingly in the developed countries where more than 95% of global R&D – and hence new knowledge - is still concentrated. In his view, therefore, comparative advantage cannot be

thought of as a phenomenon that 'changes slowly and essentially randomly', but is rather a determinant of international trade that "can and does change swiftly, particularly as a result of technological developments and that it tends to change systematically in favour of rich countries" [11, p.8]. And if developing countries tend to be excluded in this way from the benefits of international trade thus generated by technical change, they may, in the process even suffer in an absolute sense. This possibility, too, was recognised in the same paper by Griffin, when he observed that

> "All poor countries ..... face a permanent threat to their trading position because of the capacity of the developed countries (given time and effort) to produce commodities that are competitive to the exports of underdeveloped countries." [11, p.9]

Both variants of technologically generated trade bias mentioned by Griffin - which work systematically in favour of the rich countries - can readily be observed in the present context of rapid change in information and communications technologies. On the one hand, for example, the form of technologically induced trade bias that has given rise to absolute losses in developing countries is well illustrated in the clothing industry, where, according to Chesnais,

> "a new phase of technological advances, new marketing strategies focussed on very short life cycles, ... have permitted a new generation of clothing manufacturers (including a new variety of true network firms like Benetton) to bring the manufacture of clothing, in particular knitting, back to the heart of each of the three poles of the Triad. This has had consequent impacts on the exports of many developing countries, where the modern version of transnational putting-out had been practised for over a decade." [12, p.19]

Partly because scientific knowledge is currently playing a particularly important role in the information technology revolution [13–15] moreover, the comparative advantages conferred differentially by the new technologies thus generated are especially unlikely to accrue to developing countries (or indeed the smaller, less-advanced of the developed countries). Such countries indeed may be prone to suffer from a competitive advantage 'reversal' over time. Furthermore, the need for scientific knowledge induces firms to engage in strategic technology alliances of one kind of another in many branches of the information technology sector [16-18] which, however, are almost entirely concluded by firms from Europe, Japan and the USA (otherwise known as the Triad region). Indeed,

> "Technology cooperation between firms seems practically to exclude firms that do not already have an established reputation within the developed economies. There is some role left for companies from the most advanced NICs, but for most high-tech sectors we see a 'closed shop' which only underscores the process of divergence of technological capabilities on a world scale." [17, p.55].

The general tendency towards technological divergence in information technology does not, of course, preclude exceptional cases where indigenous research and innovation in a developing country give rise to a comparative advantage in a certain branch of the sector, with the accompanying possibility of export growth. A case in point is the design and manufacture in India of small-scale digital exchanges for use in rural areas [19,20]. The idea was that such exchanges would not only be more appropriate to climatic and other conditions in India but would also give that country "one piece of digital equipment that no other country manufactured but that many nations could use: a small rural exchange"

[20, p.70]. In the late 1980s after much political opposition by vested interests, just such a product emerged in the form of a 128-line rural exchange, which, subsequently, was exported to some 12 relatively poor developing countries, mainly but not exclusively in Sub-Saharan Africa. For further example see James [21].

4 International technological dualism revisited

Although we have so far used examples drawn from the electronics industry, it is important to emphasise that the so-called digital divide between rich and poor countries is simply another manifestation of the same forces identified as far back as 1970, in an important contribution by Singer to the study of global patterns of technological development [22]. What he then referred to as international technological dualism was meant to convey the notion that the *direction* of technical change is dictated by the factor scarcities prevailing in the rich rather than the poor countries. The latter, in turn, would find such change difficult to adopt and would consequently lag behind the former. As Singer further pointed out, moreover, "This international imbalance, or dualism, in the field of science and technology explains to a large extent why the growth of the under-developed countries has not been as fast as one theoretically would expect" [22, p.63]. As he saw it, there was a clear need for a different type of technical change that was better suited to the needs of poor people in poor countries. Such people, he argued are "much more interested in simple products, simple designs, saving of capital and particularly land, reduction in skill requirements, and production for smaller markets" as opposed to the interests of the rich countries in "sophisticated products, large markets, sophisticated production methods requiring large inputs of capital and high levels of skill and management while saving labour and raw materials" [22, p.64]. Indeed, it was only three years later, in 1973, that Schumacher published his highly influential book entitled *Small is Beautiful* [23] and in 1977, another highly influential volume, of a more academic nature, written by Frances Stewart, appeared [24].

What we have sought to show so far, then, is that technical change in general and in informatics in particular, does not in fact bestow its benefits at all evenly on the comparative advantage of different countries. Nor, as naively assumed in the empirical convergence literature referred to above, do changes in technology occur at the same exogenous rates for all countries. What occurs rather is that such changes occur overwhelmingly in the developed rather than the developing countries. Consequently divergence over time between the two groups is, from this important point of view, by far the more likely outcome than convergence. Let us next turn our attention to the technological assumptions underlying the catch-up model of convergence, the main features of which were outlined above.

5 Catch-up theory and its limitations

In contrast to the two other mechanisms of convergence described above, the high degree of concentration of innovations in the developed countries does not in itself constitute a problem for catch-up theory, at least in its simplest form. For it is precisely the fact that innovations are already available in developed countries that affords developing countries

(and especially the most backward among them) with the potential for catch-up by means of technological borrowing. "Insofar" that is to say,

> "as the potential for productivity growth depends on technological opportunity it is governed by latent knowledge and by the gaps between existing and newly emerging best practice. Taken by themselves, their larger gaps give follower countries a relatively strong potential.
>
> They tend to enjoy relatively rapid productivity growth rates in a catch-up process that is self-limiting as nations' productivity levels converge." [3, p.47]

Yet, as Abramovitz [3] has rightly emphasised, it is one thing to recognise the *potential* thus afforded to developing countries, but quite another to assume that such potential will actually be *realised* in practice. Indeed, when one examines all the conditions that are needed for actual (as opposed merely to potential) catch-up, it seems to be precisely the most technologically backward of the developing countries that face the severest difficulties and to this extent a process of technological divergence (instead of convergence) will tend to occur. Framed thus in terms of realised as opposed to potential behaviour, the simple catch-up hypothesis may need to be inverted, as we shall now seek to argue using the concept of a technological system [25,26].

6 Inverting the simple catch-up hypothesis

As emphasised with particular clarity by Stewart [24], the characteristics of innovations in products and processes tend to be heavily shaped by and to be reflective of the entire socio-economic system in which the changes first occur. As Stewart put it,

> "Any single technical innovation has to fit in with the rest of the system both in terms of the requirements it imposes for inputs, and in terms of the demand for the good. ..... A new technique must use inputs that are available, and must provide output which will fit into further production if it is an intermediate good, or into consumption patterns if it is a consumer good. .... There are technological linkages between different parts of the system which mean that much of technology comes as a package, which cannot be separated and introduced bit-by-bit, but which goes together. The requirements of a technique extend beyond the material inputs directly involved in the productive process to managerial inputs and infrastructural services. Thus the efficient use of a particular technique may only be consistent with sophisticated managerial methods involving advanced methods of accounting and computerised stock control; it may impose particular demands for energy, water and transport. Technical requirements extend to methods of administration in the system as a whole; the type of law and order required for successful operation, the tax system, etc. are all related to the technology in use." [24, pp.6-7]

I have quoted at length from this source because the notion that it advances – of technology as a package or system – strongly suggests how numerous may be the difficulties involved in transposing a technological innovation from its original source and associated technological system to a country with a quite different type of system. The essential point is that in the absence of the entire package of initial characteristics, innovations may be either entirely inaccessible to, or difficult to operate efficiently in, follower countries lacking the non-technological component of the package. (One has only to think, for example, of the difficulty of operating much electronic equipment in countries with weak telecommunications and lack of the necessary skills). Much then

depends, of course, on the extent to which technological systems in the leader and follower countries differ from one another. And disregarding the possibility of importing elements of the package, it is tempting to go so far as to suggest that the greater is the extent of this difference, the more difficult will tend to be the process of catch-up via technological borrowing. Consider first the two extreme situations envisaged by this hypothesis, namely, where the differences between technological systems are either very small or very large, corresponding, respectively, to circumstances where technological catch-up may well be at its easiest and most difficult respectively. As an example of the former, one can do no better than the post-war growth experience of Europe and Japan vis-a-vis the USA. In particular,

> "The end of World War II produced a hiatus in European and Japanese growth relative to that of the United States. It left these countries at the end of World War II with greatly enlarged technological gaps. Because their social capabilities were strong and had continued to rise, however, their potential for productivity growth was especially powerful when the postwar period began.
>
> And that, together with the great improvement in conditions supporting the realisation of potential, were the bases for the postwar growth boom, for the strong convergence of the productivity levels of these countries, and for their rise relative to the United States." [3, p.53]

At the other polar extreme are cases where although there is a large potential for catch-up, it is difficult or impossible in practice to realise because the technological system (as defined above) of the follower country diverges so markedly from that of the leader [27,28]. This case is most clearly represented by most countries in Sub-Saharan Africa which, on the one hand, have actively pursued the advantages of backwardness afforded to 'latecomers', but which, on the other hand, have signally failed in this endeavour [29-31]. That failure, one should emphasise, is certainly not about a lack of modern technologies transferred to African countries in the period following their independence. Indeed under the auspices of vast numbers of foreign aid projects financed mainly by the West and international organisations, much of African industry (owned as it mostly was by the state) came in fact to be dominated by just such technologies. The problem lay instead with the outmoded technological systems then prevailing in the follower African countries and in particular with the acute inability of those systems to assimilate the large-scale, capital- and skill-intensive techniques that inevitably were typically associated with foreign aid projects.

Lall [32], for example, cites the infamous case of a totally failed World Bank financed shoe project in Tanzania that was based on highly sophisticated technology, to illustrate his point that deficiencies in technological capabilities and institutions "lie at the roots of Africa's long-term industrialisation problems". And he further asserts that

> "many such projects, with minor variations on the basic theme, lie littered across the continent. The lack of local investment capabilities, the virtual absence of requisite design, production, maintenance or adaptive skills, the inability to absorb skills rapidly into a poorly educated workforce, and the lack of experience of how to ensure adequate technology transfer - all conspired to wreck a project ostensibly in the right industry using the right materials and well stocked with foreign exchange." [32, p.123]

Thus it was that African industry tended to diverge ever further from the performance of leader countries, in spite of the considerable potential for catch-up that is afforded to the

least developed of the developing countries and in spite of the ready availability of the foreign technologies with which that potential could have been exploited.

By thus focusing on two seemingly diametrically opposite cases, we have sought to show that actual, as opposed to potential catch-up possibilities, depend on the presence of a wide range of technological and other circumstances prevailing in the follower countries, circumstances which, jointly, can be described as a 'technological system'. What one would also like to know of course is whether this explanatory framework can be applied not just to extreme cases but more generally across developing countries as a whole. Extending the analysis in this way, however, would require some overall index of the sophistication or complexity of technological systems prevailing in different countries, a daunting task which to the best of our knowledge, has not yet been systematically undertaken, though measures of technological capabilities across countries do exist.

What can be found in the literature, though, is an innovative attempt to measure the related concept of 'social capabilities' for a large number of developing countries [33]. Based heavily on early attempts to construct an index of socio-economic development by Adelman and Morris [34], this measure turns out, with the help of a detailed econometric analysis, to confirm the importance of social capabilities (or, in our terms, technology system) for economic growth, as hypothesised earlier by Abramovitz (to whose work on catch-up we have already referred [3]). Rapid growth, that is to say, appears to be partly due to a conducive set of social arrangements. And although it is not entirely clear what underlies this relationship, it may in part be due to the fact that "higher levels of socio-economic development are associated with greater investment in physical and human capital, with more productive investments, or with a greater ability to assimilate technology from abroad" [33, p.974].

From a theoretical, as opposed to an empirical point of view, one also needs to take into account that the growth literature has begun to incorporate a more realistic concept of technical change that is closely in line with the views espoused many years ago by Singer, Griffin and Stewart. In particular, a model developed by Zeira [35] assumes that innovations generated in countries with high productivity (and thus high average incomes) will tend to be adopted primarily in similar countries (with a similar factor endowment). In effect, labour-saving innovations are consistent with and adopted primarily by rich rather than poor countries. With biased technical change of this kind, the model is able to explain the large and growing international differences in per capita income described above. In this way, growth theory and the literature on technology and development have at last found some common ground (having been kept so strictly isolated from one another for so many years).

7 Conclusions

Because technical change is so widely recognised as a major source of economic growth, the manner in which innovations are generated, diffused and assimilated, bears heavily on whether we think that growth rates between rich and poor countries will converge or diverge over time. Our goal in this paper has been to compare the assumptions about technology that underlie these contrasting viewpoints, to confront them with the available evidence and ultimately to reach a conclusion as to whether in reality technology gives

rise to convergence or divergence between rich and poor countries in the global economy.

We began by examining the technological assumptions underlying three different views of how convergence is assumed to occur (via international trade, aggregate capital accumulation and technological borrowing, respectively). In each case, subsequent analysis suggested that these assumptions tend to be very poor descriptions of how technical change is actually generated, how it is diffused and the degree to which it is actually used in developing countries. By drawing heavily on the substantial literature that deals with technology and development, we then argued that an alternative (and more realistic) set of assumptions about technical change is generally likely to yield divergence rather than convergence in the global economy. The former, we further suggest, is much more consistent with the observed patterns of global inequality over time. Indeed,

> "Bearing in mind that technical progress in most of the industrialised countries continues to move ahead of the industrialising countries ..... Many firms in most industries in [developing] countries have been generating increases in process and product performance at rates that ..... [are] not even high enough to allow any significant 'catching up'. Indeed, the achieved rates of change have often been below those in the industrialised countries, *implying a widening, not narrowing, gap.*
>
> Often for substantial periods of time, many firms in many industries in a large number of countries have not generated any significant improvement in production efficiency or product quality/performance, and consequently have been rapidly 'falling behind' as advances have been made elsewhere. In Africa in particular, performance has frequently declined over time - implying that *industry has been falling behind even more rapidly.*" [36, p.120] (emphasis added)

We found, finally, that with the exception of one recent contribution, growth theory has little or no contact with the literature on technology and development. This separation, we feel, is unhelpful if growth theory is to become more consistent with the way that technology is actually generated and diffused across rich and poor countries.

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> "The scarcity of such successful examples, however, illustrates how non-automatic and exceptional such processes of effective technological catching up are. As straightforward as might appear the use of foreign, imported technology as a short cut to industrialisation, as difficult and complex is the effective assimilation of foreign technology. ... the country's, and the domestic firms', absorptive capacity is crucial" [28, p.108].

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