

**A Review of Brian Arthur's *Increasing Returns and Path
Dependence in the Economy*. Applications in Economic
Development Theory**

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Abstract

This paper reviews W. Brian Arthur's 1994 book *Increasing Returns and Path Dependence in the Economy* and links the book's key findings to economic development theory, more specifically to the literature on poverty traps. We treat both critical threshold and dysfunctional institution models of poverty traps and show that they embody many of the concepts advanced by Arthur and his co-authors: unpredictability, non-ergodicity, path inefficiency and inflexibility. A poverty trap view on economic development, if empirically validated by further studies, will have serious policy implications.

1 Introduction

'The increasing-returns world in economics is a world where dynamics, not statics, are natural; a world of evolution rather than equilibrium; a world of probability and chance events. Above all, it is a world of process and pattern change.' (Arthur, 1994:xx)

It is not hard to see how the world sketched in the quote above applies *a fortiori* to 'developing' countries (low-income and middle-income). As their perhaps over-generalising prefix suggests, most of these countries find themselves, arguably more so than their high-income counterparts, in a state of flux. Shocks of different kinds, such as political upheaval, commodity price fluctuations or sudden financial market disruptions, are constantly reshaping these countries' economic growth and development paths. Some of them appear to be launched (albeit not always comfortably) on a highway to economic prosperity, while others, most notably those labelled as 'failed states', seem to be stuck in a self-reinforcing cycle of low economic growth and poverty.

The aim of the present paper is twofold. First, we want to provide a brief summary of and critically review W. Brian Arthur's seminal 1994 book *Increasing Returns and Path Dependence in the Economy*, distilling its main findings and value added for the economics profession. We do so by focusing on certain parts of the book that, we think, are most representative of Arthur's work. Another criterion we use when putting in the spotlight particular chapters is their relevance for economic development theory. This brings us to the second purpose of the paper: to link the concepts and analysis initiated and/or elaborated by Arthur and his co-authors to the growing body of literature on conditions and mechanisms that may keep developing countries in a self-sustaining state of underdevelopment, so-called 'poverty traps'.

The structure of our paper is as follows. Section 2 introduces the work of Brian Arthur before studying chapters III and II of his 1994 book in greater detail. Section 3 shifts the focal point to economic development theory in laying out the concept and basic model of poverty traps (thereby thankfully making use of Matsuyama's (2008) graphical representations). A selection of both older and more recent studies on poverty trap mechanisms, embodying many of Arthur's findings, is examined in Section 4. We choose to distinguish here between *critical threshold* and *dysfunctional institutions* models. Section 5 concludes and raises some (preliminary) policy lessons implied by the poverty trap hypotheses presented.

2 Increasing returns and path dependence in the economy

2.1 Introducing Brian Arthur's work

The concept of increasing returns, lucidly defined as ‘the tendency for that which is ahead to get further ahead [and] for that which loses advantage to lose further advantage’ (Arthur, 1996:100) has been present in economic theory well before Brian Arthur's first major publications. The idea itself goes back at least to Alfred Marshall (or even to Adam Smith, according to some), who did, however, not study it in detail. Marshall is quoted by Arthur (1994:2) as having noted in his 1890 classic *Principles of Economics* that ‘whatever firm gets a good start’ would conquer the market to the detriment of others. One early example of increasing returns in growth theory is Allyn Young (1928:539) who stated that ‘...the division of labour depends upon the extent of the market, but the extent of the market also depends upon the division of labour’, arguing that this two-way relation is what lies at the center of economic progress. Gunnar Myrdal's cumulative causation theory of economic geography in the late 50s is another.

Despite these early-hour impulses, standard economic theory, taking a more solid shape in the 1970s and early 1980s, long regarded increasing returns with great scepticism, as the concept did not sit well with conventional assumptions of perfect competition. There was a dominant, narrow focus on models with a single, predictable equilibrium outcome, representing moreover ‘the best of all possible worlds’. Diminishing returns generating negative feedback loops in the economy were seen as the mechanism leading to such an equilibrium, as they would offset any deviations (from that equilibrium).

By the late 1980s, however, increasing-returns economics had largely emerged from obscurity. Part of this ‘return to increasing returns’ (Buchanan and Yoon, 1994) can be explained by the growing recognition that increasing returns (and other non-convexities) *are* a fact of life and can be naturally observed when studying the economy (especially its knowledge-based parts). Advances in mathematical formulation and modelling of such phenomena were another driver, dimming voices that put off increasing-returns research as ‘unscientific’.

This second issue is one area where Brian Arthur's work has certainly been of instrumental importance. As will be shown, the papers and articles collected in the book *Increasing Returns and Path Dependence in the Economy* are testimony to Arthur's rigorous

and detailed modelling of increasing returns and their consequences. In the foreword to that book, Kenneth Arrow, Nobel Prize laureate and to some extent Arthur's 'mentor' (see further), discerns at least three other distinct features of Arthur's work that have given it the standing it now has today. First of all, he points to the vigorously dynamic character of that work, making 'history' the central object of study. Second, mentioning is made of Arthur's explicit attention to stochastic processes (most visibly in his analysis of non-linear Polya processes; see section 2.2). Third, and most importantly, Arrow welcomes Arthur's audacity of going against the current of standard economic analysis in studying increasing returns (under different forms) and how they may possibly lock in non-optimal (inefficient) forms of economic behaviour (see Durlauf, 1995 for a similar appreciation).

To this encomium we can add Brian Arthur's sense for 'generalisability' or 'deep, strong laws' which gives his work a multi-disciplinary edge (with applications in several economic sub-disciplines and far beyond that). In the preface to *Increasing Returns and Path Dependence*, Arthur himself gives us a clue on where such wide applicability may come from: his (undergraduate) background in electrical engineering and wide interest in and study of exact sciences as different as molecular biology, thermodynamics and condensed-matter physics.¹ Also particularly novel in Arthur's work is that he moves beyond merely showing the existence of multiple equilibria towards exploring *how* one out of such multiple steady states comes to be selected over time. As he himself outlines, using up to then ill-known (dynamic) probabilistic methods have greatly helped him doing so (Arthur, 1994:xv-xvi).

To be sure, Brian Arthur's research extends beyond the analysis of increasing returns. In 1988, on invitation of Kenneth Arrow, Arthur became the first director of the Santa Fe Institute's economics research programme, one of the pioneering institutes to initiate what is now known as 'complexity research' (in economics and a wide range of other sciences). In a recent article Arthur (2010), eschewing a formal definition, explains complexity research in economics (or at least the 'Santa Fe approach' thereto) as the study of *unfolding* patterns in the economy, with various agents adapting to the very patterns they themselves help to create. This form of economics is said '...not [to be] in competition with equilibrium theory, nor ...a minor adjunct to the standard economic theory; [i]t is economics done in a more general, non-equilibrium way' (Arthur, 2010:164). To the extent that increasing returns analysis deals with pattern formation through feedback effects it arguably falls under the broad tent of complexity economics.

¹ Besides holding a PhD in Operations Research, Arthur has obtained MA degrees in Economics and Mathematics (see http://tuvalu.santafe.edu/~wbarthur/Bio_Info/Resume_Web.pdf).

Although the ‘complexity’ label surely risks to be misused to denote every research that is unconventional and the framework proposed by its adepts is still far from becoming a full-fledged paradigm in economics, studying pattern formation and out-of-equilibrium economics seems an interesting research programme that may well attract more attention from economists and other researchers in the years to come.² Indeed, also in development studies complexity theory is being considered, albeit still in a rather rudimentary way (see e.g. Rihani and Geyer, 2001).

While this paper chooses to limit its scope to the theme of increasing returns and path dependence, it is nonetheless important to keep in mind the broader ‘complex’, out-of-equilibrium economic context in which it is to be understood. In what follows, we look further into some of the seminal contributions by Brian Arthur, brought together in *Increasing Returns and Path Dependence in the Economy*, focusing, as said, on those chapters we see as having particular relevance for economic development theory.

2.2 Path dependent processes and the emergence of macrostructure

A natural starting point for a review and discussion of Brian Arthur’s work is his chapter III on *Path dependent processes and the emergence of macrostructure* (originally published as Arthur, Ermoliev and Kaniovski, 1987). In this chapter Arthur and his co-authors, two ex-USSR probability theorists, develop a general mathematic model for so-called ‘nonlinear Polya processes’ displaying multiple possible (asymptotic) outcomes. These mathematics (in greater detail laid out in chapter X of the book) have provided the foundations for much of (Arthur’s) subsequent work on path dependence.

Processes like simple reiterated coin-tossing, where repeated random variables (taking a value ‘head’ or ‘tail’) are independent from previous ones, are marked by a unique and predictable structure or long-run pattern; the proportion of heads (and tails) to all outcomes will settle at 50 percent. This is said to be a direct consequence of Emile Borel’s famous ‘strong law of large numbers’ which states, first, that the average outcome of a large number of trials should approach its expected outcome and, second, that once convergence to this value has taken place, it persists over time with probability 1.

² Such a reorientation may be reinforced by the dire state in which the economic profession (and its dominant general equilibrium approach) finds itself now because of the recent financial crisis (see e.g. Colander *et al.*, 2009)

Arthur rightly claims that such simple textbook processes have only limited applicability in economic life and therefore searches for similar ‘strong laws’ for *path-dependent* systems where the probability of drawing a variable of type j from a pool of N variables depends on/ is a function of earlier drawings.

Already in 1931, George Polya, a Hungarian mathematician, proved that in case of path dependence again there is strong, persistent convergence, but that the exact structure that emerges is not uniquely determined. He did so by formulating a process whereby balls of two possible colours, e.g. red and white, are added to an urn of infinite capacity and with initially one ball of each colour inside. Randomly selected balls are placed back in the urn together with an extra ball of the same colour *ad infinitum* (i.e. if the ball chosen is red, another red ball is added, if not, one adds a white ball). For such a process one can prove the outcome, the proportion of red balls, to approach a limit X , but with X , unlike in the case of simple (path-independent) coin-tossing, now being a random variable uniformly distributed between 0 and 1. Where the process settles in the long run depends entirely on its early random movements and cannot be predicted in advance.

Polya (1931), however, only considered this specific case where at any time the probability of adding a red-coloured ball is exactly equal to the proportion of reds in the urn. His results are therefore not necessarily valid for other stochastic processes.

This has urged Arthur and his ex-USSR colleagues to go much further than Polya; they theorise a more general, multi-dimensional version of an urn process, with probabilities of new additions of type j variables (balls) being an *arbitrary function* of current proportions of all N types. The dynamic equation governing such a process is found to have a deterministic, non-linear ‘driving’ part as well as a ‘perturbational’ part. Most importantly, Arthur, Ermoliev and Kaniovski prove the existence, subject to certain technical provisos, of a strong law for these non-linear Polya processes; they converge to one of multiple possible fixed (and stable) points with probability 1. It turns out that the deterministic ‘driving’ part of dynamics fully *determines* the different structures that may possibly emerge, whereas the stochastic Polya perturbations involved *select* (out of these candidate structures) the eventual outcome.

At first sight, the processes and ‘laws’ analysed here, although certainly more nuanced than coin-tossing, could easily be dismissed as excessively abstract and too distant from any real-life phenomenon. On closer inspection, however, it appears that Arthur and his co-authors offer important insights into issues that are at the very core of economic life: multiple equilibria surrounded by great uncertainty of which the actual outcome is dynamically

selected through a process combining what one could call ‘fundamentals’ (or ‘deterministic drivers’) and stochastic ‘perturbations’. Their logically sound (albeit technically complex) mathematic formulations could well prove useful (and indeed *have* done so) as an overarching framework for further work on path dependence in the field of economics (and beyond). In the next section we move on to one of such extensions by Arthur himself which, we believe, holds important lessons for economic development theory and policy: the case of competing technologies exhibiting increasing returns.

2.3 Competing technologies, increasing returns, and lock-in by historical small events

In chapter II of his 1994 book (originally published as Arthur, 1989) Brian Arthur studies the earlier-mentioned ‘selection problem’, meaning the process governing how an allocation outcome gets selected over time, in a situation where there are increasing returns. Interestingly, he compares these dynamics with those that become apparent under regimes of constant and diminishing returns.

For exposition purposes Arthur uses the example of two ‘unsponsored’ (generic, openly available) technologies *A* and *B* that compete with each other to replace an older, outdated technology, say, *C*.³ In order to bring in the notion of increasing returns to adoption, Arthur relies on the well-known concept of ‘learning-by-using’ whereby increased adoption of a technology leads to cumulated experience that translates into new and better variants of that technology (see e.g. Arrow, 1962). Consequently, here, returns to technology *A* (*B*) are assumed to rise with the number of people adopting technology *A* (*B*).

Arthur further assumes a large (infinite) pool of agents or ‘technology adopters’, either of type *R* or type *S*, with equal numbers of each category. *R*-type agents only differ from *S*-type agents in their natural preference (reflected in receiving a higher fixed pay-off) for technology *A*. Logically then, *S*-type adopters incline more towards technology *B*. Besides reflecting natural preferences, pay-offs for each agent choosing technology *A* (*B*) are constructed in such a way as to depend (or not) on the number of previous adopters of technology *A* (*B*). Table 1 summarises the pay-off scheme just described.

³ These ‘technologies’ are to be interpreted in a very broad sense, thus allowing for generalisability (see further).

Table 1: pay-offs of choosing technology A or B for R- and S-type adopters

	Technology A	Technology B
R-type agent	$a_R + rn_A$	$b_R + rn_B$
S-type agent	$a_S + sn_A$	$b_S + sn_B$

Source: Arthur (1994:17)

Here $a_R > b_R$ and $a_S < b_S$ (revealing the natural preferences of both types of agents), and n_A and n_B represent the number of previous adopters (or the corresponding variant) of technology A and B, respectively. Coefficients r and s can be chosen to represent a regime of constant ($r = s = 0$), diminishing (r and s simultaneously < 0) or increasing returns (r and s both > 0) to adoption.

Only one element of the selection process is left open in this model, i.e. the sequence in which agents, one at the time, make their choice between A and B, or more accurately, the ‘historical small events’ that determine this sequence. This assumption gives the model a stochastic twist. Faced with this uncertainty, an outside spectator thus only observes a binary string of R- and S-type technology adopters, with chances of the next agent in line being of the R-type (or S-type) 50 percent.

Arthur elegantly proves that under these conditions the eventual allocation outcome, being the respective market shares held by technology A and B in the long run, differs according to whether technology adoption exhibits constant, diminishing or increasing returns.

He finds that, in the case of constant returns, long-run market shares can be accurately predicted (at 50-50, a direct consequence of the equal proportions of agent types) as in the case of coin-tossing. The selection process is simply a free-ranging random walk showing ‘ergodicity’, meaning that different sequences of events (and here, consequently, a changed order of agents) in all likelihood lead to the same allocation outcome. Under constant returns the selection process is also said to be (at least partially) ‘flexible’. Adjustment to the pay-off functions of agents (e.g. via tax or subsidy interventions), if large enough to surmount natural preferences, can alter technology adoption choices at all times. The process is also necessarily ‘path-efficient’ since each agent in line simply adopts his naturally preferred technology, with the non-adoption of the alternative implying no gain foregone.

A scenario with diminishing returns is shown to be very similar to the constant-returns case. Again the outcome of the selection process tends to a perfectly predictable 50-50 market split since, over time, the difference in adoption $n_A - n_B$ freely fluctuate between finite

constants (Arthur refers to such a process as a random walk with reflecting barriers). There is ergodicity and full, automatic path efficiency. Flexibility is complete since adoption choice is easily altered (even more so than under constant returns).

Importantly, as Arthur points out, all this changes when considering a situation marked by increasing returns. First, since technology *A*'s market share will, with probability 1, converge to *either 0 or 100 percent* in the long run, the actual outcome of the selection process becomes unpredictable per definition. This is a direct consequence of the self-reinforcing nature of technology adoption under increasing returns (and can be graphically represented as a random walk process with absorbing barriers). A leading start of, say, *R*-type agents in the line-up, caused by some small events that are below the radar of the outside observer, may push adoption of their preferred technology *A* far enough ahead of *B* so as to make *S*-type agents switch to choosing technology *A* as well (if their natural preference for *B* is countered by the sheer number of agents adopting *A*). A lock-in of technology *A* then occurs.

Second, this importance of small-event history makes the selection process under increasing returns non-ergodic; different sequences of events may alter the eventual outcome of the process.

Third, the process is not necessarily path-efficient anymore. A lock-in of technology *A* means that *R*-type agents obtain their maximum pay-off. *S*-type agents, on the other hand, would have had a higher pay-off if their initially preferred technology *B* would have been equally often adopted. It may well be that technology *B* is the one with the greatest long-term potential, but that, by mere chance, an early run of *R*-type agents locks in the inferior alternative. As Arthur (1994:10) notes in chapter I, 'early superiority is no guarantee of long-term fitness'.

And, fourth, flexibility is lost as the size of intervention needed to tilt the balance becomes ever larger once a lock-in into technology *A* or *B* has occurred.

In checking the robustness of his theoretical model, Arthur further finds that under *non-linear* increasing returns, where learning-by-using diminishes over time (or better, over subsequent adoptions), lock-in may be not complete. There is a possibility of (sub-optimal) market sharing outcomes, besides the monopoly solution implied by the standard *linear* increasing-returns model.

Adding rational expectations about the future adoption process to the standard model, on the other hand, does not alter earlier findings. Indeed, Arthur shows that this addition may even exacerbate instability and speed up lock-in as expectations become self-fulfilling.

One can think of numerous examples in the economy (and elsewhere) of the selection process and lock-in by historical small events described by Arthur. He himself refers to Paul David's renowned study on how QWERTY keyboards came to dominate the market.⁴ David (1985) eloquently argues that the lock-in of the QWERTY layout from the 1890s onwards, in spite of the existence of better alternatives, was mainly due to this layout's initial lead (in itself an 'historical accident') and later aided by the technical interrelatedness, scale economies and the quasi-irreversibility of investments that marked the touch typing industry (which ensured that a dominant market position would arise out of competing keyboard arrangements). Another illustration (further elaborated in chapter IV of Arthur's book) is that of industry clustering, driven by increasing 'agglomeration' returns, in places that are initially attractive to entrepreneurs, Silicon Valley being the most famous example here.

Importantly, in his chapter on *Competing technologies* Arthur goes beyond the theoretical exercise of modelling increasing returns (and giving illuminating real-life examples thereof). He provides an interesting, albeit only short, introduction to the interpretation of economic history and policy implications brought to the fore by his work. Arthur concludes that, when increasing returns are present, history, or what one could call the chain of small events, becomes a central object of study. This stands in sharp contrast to a regime with diminishing- (or constant-) returns dynamics, where because of ergodicity, history could be seen as no more than 'the deliverer of the inevitable'.

On possible policy repercussions, it is suggested that a situation of increasing returns nullifies the (often dogmatic) laissez-faire conclusions that neoclassical economists draw from their perfect-competition, complete-market, diminishing-returns models. Under increasing returns, letting the 'market' decide allocation does not guarantee survival of the technology that is (socially) optimal in the long run, as early adopters do not adequately integrate the consequences for later adopters into their decisions. This argument is akin to, but perhaps a more dynamic version of, long-standing claims made in the literature on economic externalities and incomplete markets (see e.g. Greenwald and Stiglitz, 1986).

By no means, however, does the foregoing reasoning seem to induce Arthur to put more thrust in government. He argues that, while in theory a 'super-agent' in the form of a central authority could incentivise early adopters to explore promising alternatives to their

⁴ This *AEA Papers and Proceedings* article by Paul David was instrumental in getting the concept of path dependence on the research agenda of economists and turning David into its 'godfather' (see Arthur, 1994:xvii). David (1985) nonetheless acknowledges his indebtedness to Arthur (whose papers were at that time not yet published in leading journals).

preferred technologies, outperforming the market requires the government to have a clear idea about the economy's future path, which the model showed is impossible to predict. Having only limited foresight, a central planner may well bet on the 'wrong' technology (i.e. one not yielding the best possible long-term result) and thereby lock in 'a regrettable course of development'.

Arthur has taken up this point in later work where he argues for government policy to prudently steer between a strict 'hands off' and 'desired outcome coercion', guiding the economic system gently towards favoured configurations that can emerge naturally over time. 'Not a heavy hand, not an invisible hand, but a *nudging* hand' (Arthur, 1999:108, emphasis added).

In the same trend, David (2000) denounces critics and sceptics of his and Arthur's work that have come to see ideas of path dependence merely as an attack on the normative free-market message brought by neoclassical economists. He retorts that bringing more 'historicity' into economic analysis has been the chief purpose of his endeavours. According to David, the first-best government policy in a situation where 'history matters' (i.e. in cases with positive feedback effects) would be to temper impatient market agents by improving the informational state in which both private and public parties make their choices. Clearly, this is a long way from promoting active state intervention.

We will return to policy issues in our concluding section 5. Now we proceed to linking Arthur's work on increasing returns and path dependence to economic development theory. More specifically, we search for parallels between the mechanisms we have just described and those touted in the growing literature on poverty traps.

3 Poverty traps: concept and basic model

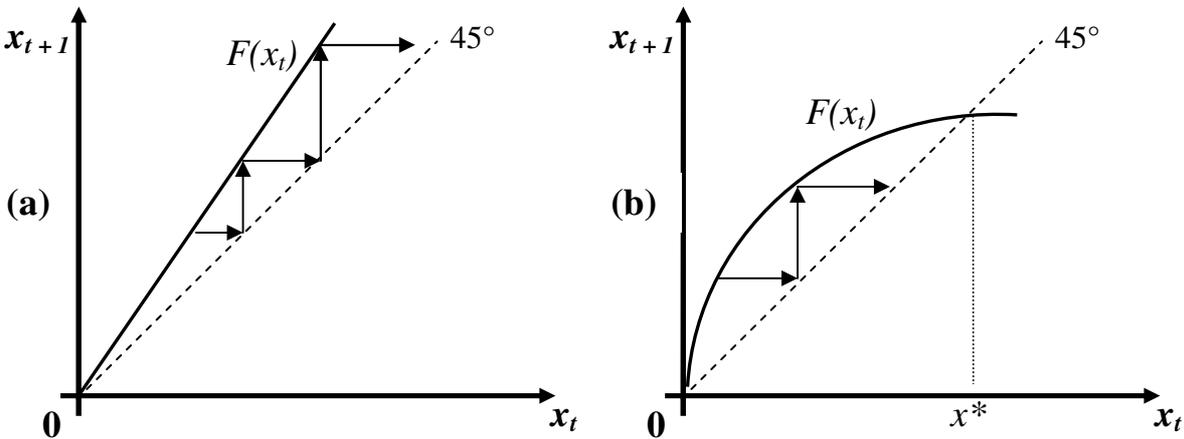
To put it very bluntly, traditional economic theory supports what has been termed the 'achievement model of income determination' (Bowles, Durlauf and Hoff, 2006a:1): acting in a perfectly competitive environment, individuals (and by extension countries) can without hindrances enjoy economic opportunities that reward productive undertakings and savings; poverty will only fall on those that choose not to make the effort. Neoclassical growth models such as that of Solow (1956) moreover imply conditional convergence; provisional on determinants of the long-term steady states of output per person, countries that start off with lower levels of per capita output will grow faster than those that have already reached higher levels.

Such beliefs seem to have lost much of their relevance now that income inequality between (and within) countries is rising. Developing countries, with the notable exception of some emerging economies, are not noticeably catching up with high-income forerunners. The convergence pressures suggested seem to be countered by some sort of ‘counter-pressures’ that keep countries underdeveloped (Bowles, Durlauf and Hoff, 2006a). This is where theories of poverty traps comes in.

We follow Kiminori Matsuyama (2008) in defining a poverty trap as ‘a self-perpetuating condition whereby an economy, caught in a vicious circle, suffers from persistent underdevelopment’. Here we explicitly frame the concept in a dynamic setting (as does Matsuyama) so as to make a clear distinction between what we call poverty *traps* and *static* low-level equilibrium outcomes (discussed in standard market failure literature). Considering dynamics also bring us much closer to Brian Arthur’s focus on *processes* of equilibrium selection (see section 2).

In simple wordings, the idea of poverty traps can be understood as follows.⁵ Suppose we represent the state of an economy in period t by a single variable x_t (e.g. income (GDP), capital accumulated or any other wealth indicator) whose increase signifies greater economic development, and that the (deterministic) law of motion $x_{t+1} = F(x_t)$ describes the equilibrium path followed by this economy. Starting from the initial state of the economy x_0 , one can then set out the entire course of the economy, the actual trajectory followed depending of course on functional form F .

Figure 1: no poverty traps

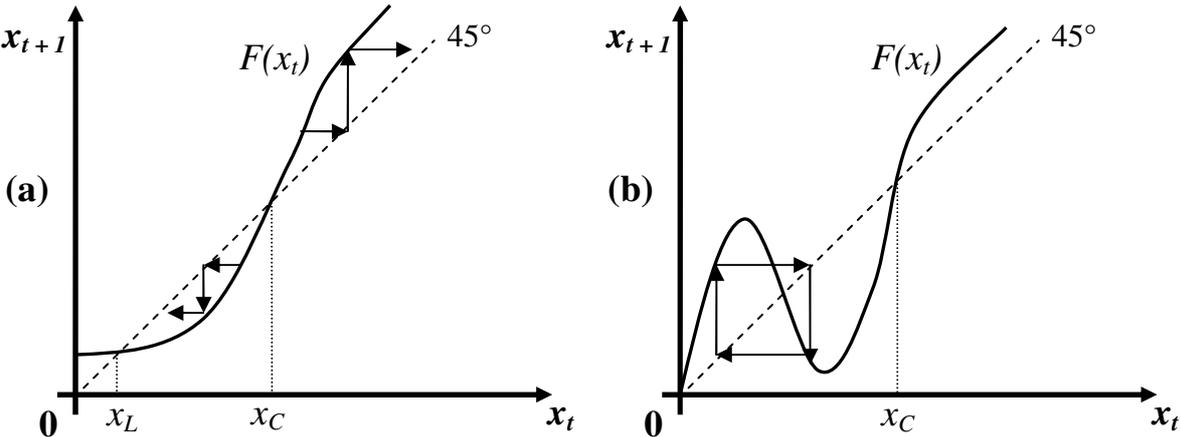


Source: Matsuyama (2008)

⁵ For a more elaborated overview, see recent contributions by Matsuyama (2008) and Azariadis and Stachurski (2005).

Figure 1a depicts the situation where the economy in question grows (develops) continuously and forever. This is a model largely consistent with endogenous growth theory as exemplified by the standard Harrod-Domar and Frankel-Romer models where constant returns generate sustained accumulation (for an overview of these two ‘AK’ approaches to endogenous growth, see e.g. Aghion and Howitt, 1998). In Figure 1b, on the other hand, the economy is sure to converge to a state x^* , much like in the benchmark neoclassical Solow-Swan growth model with diminishing returns that cause growth to eventually cease (see e.g. Solow, 1956). Notice that in neither of the two representations one can observe a poverty trap. Where the economy starts out (or, in other words, its initial state x_0) does not determine its long-run performance; there are no self-perpetuating conditions of any kind. Even in Figure 1b, the limit to growth x^* cannot be explained by the initial ‘underdevelopment’ of the economy.

Figure 2: strong poverty traps



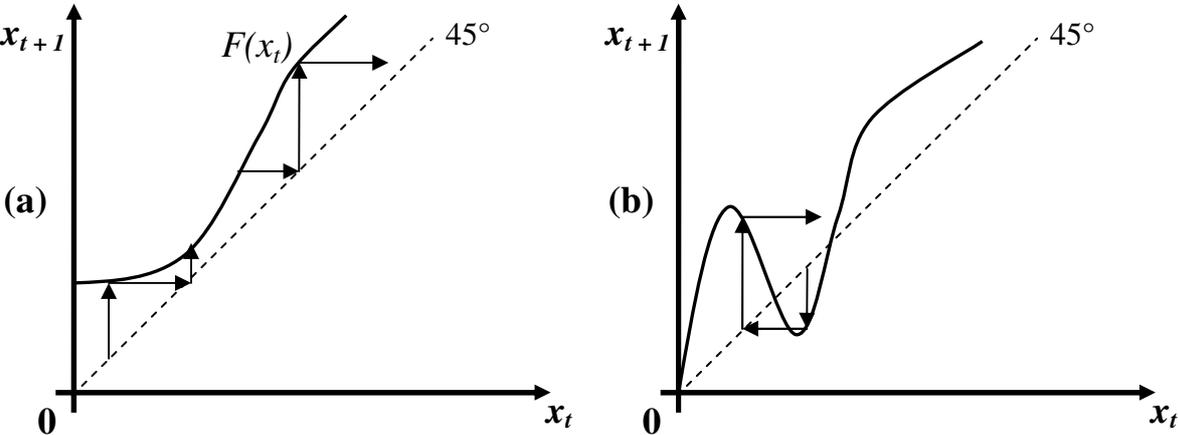
Source: Matsuyama (2008)

A total different picture emerges from Figures 2a and 2b. Here initial conditions *do* make a difference in the long run. In Figure 2a the economy will only reach higher levels of x_t if its starting point x_0 lies to the right of threshold x_C ; if not, it will be trapped forever below x_C and converge towards x_L , a low-level stable equilibrium.⁶ Threshold point x_C is in itself unstable; it merely demarcates the two different ‘basins of attraction’. Figure 2b is analogous to 2a, but here the economy may continue to fluctuate below x_C rather than reaching some low-level steady state. Both figures appear to represent a strong or ‘absolute’ version of poverty traps

⁶ Note that Figure 2a can also be drawn so as to include the possibility of convergence towards a high-level stable equilibrium, say x_H (similar to x^* in Figure 1b).

where escape is impossible (at least without any outside intervention). Weaker versions of poverty traps are illustrated in Figures 3a and 3b.

Figure 3: weak poverty traps



Source: Matsuyama (2008)

An economy as represented in Figure 3a will eventually manage to advance rapidly, no matter what its starting position is, but before that it may experience long-time stagnation as it sluggishly crawls through the narrow ‘corridor’ between F and the 45° line. Similarly, in Figure 3b, the economy seems destined for growth but may have to deal with some period of volatility first. What makes Figures 2 and 3 different from Figure 1 is that in the former figures initial underdevelopment or poverty of the economy makes it harder (Figure 3) or even impossible (Figure 2) to develop further over time; poverty is self-perpetuating.

This is not the whole story, however. For one thing, the analysis above could be greatly enriched by introducing stochastic shocks, in the spirit of Brian Arthur’s ‘historical small events’, transforming the law of motion into $x_{t+1} = F(x_t ; \varepsilon_{t+1})$. If shocks are simply additive (i.e. $x_{t+1} = F(x_t) + \varepsilon_{t+1}$), this implies a leap in the state variable of the economy (up or down), with the possibility of launching the economy on a path of steady growth (in case of a positive shock tilting it over threshold x_C) or condemning it to lower (equilibrium) levels of development (in case of a negative shock). More generally, the effect of perturbations can be perceived graphically as switching back and forth between, for example, Figure 2a (2b) and Figure 3a (3b). As a consequence, the economy may from time to time escape or fall back into poverty traps. Both initial conditions and random (unpredictable) events have a role to play in shaping the long-run ‘end-state’ of an economy (see Arthur, 1994:119-120). Costas Azariadis and John Stachurski (2005) study this class of dynamic stochastic poverty trap models into

detail. They show that once stochastic shocks are brought in into the analysis, one has to rely on stochastic kernels to describe the probability density functions of the possible outcomes of an economy.

Having illustrated the basic workings of poverty traps that can keep an economy underdeveloped, the question that arises now is what kind of deeper mechanisms underlie such traps. In other terms, what are the ‘(micro)foundations’ that could possibly account for function F to take a form as portrayed in Figures 2 and 3 rather than the one given by Figure 1?

The next section (selectively) presents some of the mechanisms that have been suggested in the economic development literature.⁷ Our discussion is divided into two parts. First, we describe a number of models that one could place under the lowest denominator of *critical threshold* models. A second subsection deals with models of *dysfunctional institutions* (see Bowles, Durlauf and Hoff, 2006b for a similar classification).⁸

4 Poverty trap mechanisms

4.1 Critical threshold models

Richard Nelson (1956) was one of the first to offer a formal explanation of why underdeveloped economies may be caught in a ‘low-level equilibrium trap’. His model is built on the assumption that, at subsistence levels of income, the rate of capital accumulation is lower than or equal to population growth (as death rates fall with rising income), so that per capita capital stock, and therefore income, will not increase. Nelson further argues that an economy is more likely to be trapped when per capita income and population growth are highly (positively) correlated (because of a diminishing death rate), when marginal propensity to invest is low, when uncultivated arable land is scarce, and when production methods are inefficient.

Another landmark study on traps and multiple equilibria in an economic development context is the formalisation by Kevin Murphy, Andrei Shleifer and Robert Vishny (1989) of Austrian School economist Paul Rosenstein-Rodan’s (1943) ‘Big Push’ story. Writing specifically on Eastern and South-Eastern Europe, Rosenstein-Rodan made a plea for a large-

⁷ A wider range of poverty trap mechanisms, not all of them formulated in a ‘developing’ country setting, can be found in Azariadis and Stachurski (2005) and Bowles, Durlauf and Hoff (2006b).

⁸ As will become clear from the text, this distinction is somewhat artificial as some models would arguably fit in both categories.

scale, multi-sector, planned industrialisation of these countries, to be funded by a trust endowed by both post-war creditor and debtor governments. The underlying idea was that, because of (among other things) complementarities in the demand for industrial products, individual industries would not consider it profitable to invest in expanding their production (which would benefit other industries), thus leading to an inferior lock-in situation; only a grand, coordinated effort would succeed in breaking the trap. In the same spirit, Murphy, Shleifer and Vishny (1989) present different models, all of which invoke externalities generated by imperfect competition with large fixed costs as a source of multiple equilibria (low- and high-level). They show, however, that this multiplicity of equilibria is only guaranteed if industrialising firms boost the size of markets of other firms through channels other than the industrialising firms' profits. Possible channels are wage increases in the industrial sector and an inter-temporal shift in aggregate demand.

Steven Durlauf's (1993) non-ergodic economic growth model extends the analysis by explicitly incorporating *stochastic* dynamics. Durlauf⁹ demonstrates that, under assumptions of incomplete markets and technological spill-overs between different industries, the long-run behaviour of an economy is jointly determined by initial production conditions and transition-to-higher-productivity probabilities (the latter depending on the magnitude of technological complementarities and industry-specific productivity shocks). *Ceteris paribus*, the possibility of multiple long-run equilibria increases with the degree of complementarity across industries.

Costas Azariadis and Allan Drazen (1990), on their part, focus on *human* capital accumulation as possibly generating multiple growth paths. Augmenting an endogenous growth model with threshold externalities, they find that when private rates of return on human capital investment ('training') hinge on the average quality of the existing pool of labour, an initial critical mass of high-quality labour could trigger countries in 'taking off' (in a Rostowian 'stages of growth' sense; see Rostow, 1960). Yet, Azariadis and Drazen acknowledge that historical events or shocks such as bad economic policy or political upheaval could well delay progress, making a highly qualified labour force a necessary but *not sufficient* precondition for economic development.

Also of particular relevance is Matsuyama's work on credit market imperfections. In contrast to the models cited above, Matsuyama (2004) formulates a world economy model existing of *multiple* countries whose levels of (physical capital) development are intimately

⁹ Interestingly, Steven Durlauf is a serving external faculty member (and former co-director) of the economics programme at the Santa Fe Institute where Arthur has resided (see section 2.1).

interrelated.¹⁰ For each country, representative agents (in an overlapping generations model) are assumed to either invest their wages in a project or to lend out their wealth in a competitive capital market, in order to finance old-age consumption. Wages are furthermore taken not to cover full project starting-up costs, thus requiring agents to borrow. Credit market imperfections however limit the amount borrowers can take out; agents can credibly commit to repay only a fraction of project revenue. Under such circumstances, Matsuyama shows that financial autarky (meaning the absence of *international* lending and borrowing) leads to the world economy having a unique and globally stable state, identical for all countries (as represented in Figure 1b, section 3). In the small open economy case, there is the possibility of ‘symmetry-breaking’, with the symmetric steady state losing its stability and new, asymmetric but stable states coming into existence (like in e.g. Figure 2a, but with convergence towards a higher-level state). Again, a regime of increasing returns is at work; higher domestic investment increases collateral (i.e. reduces the borrowing limit) which, in turn, stimulates domestic investment. This virtuous circle may become a vicious one, of course; also low domestic investment replicates itself. Where a country ends up in a financially integrated world economy depends on the kind of shocks it faces (as well as its initial capital stock). Countries hit by bad shocks are put at a disadvantage compared to those facing good shocks in the competition for the world’s savings, giving rise to a world economy that is, Matsuyama says, ‘endogenously polarised’ into rich and poor countries.

While clearly focusing on different aspects of economic activity, there is one thing that the models just described seem to have in common, i.e. the existence of some sort of *critical threshold* (be it in human or physical capital) that countries need to overcome in order to escape underdevelopment. To be sure, the literature on poverty traps is not exclusively concerned with the *level* of economic activities (e.g. more or less investment); another strand studies the *kinds* of interactions and arrangements between economic agents that may cause poverty to persist (Hoff, 2000). This (nascent) field of study is introduced in the following subsection.

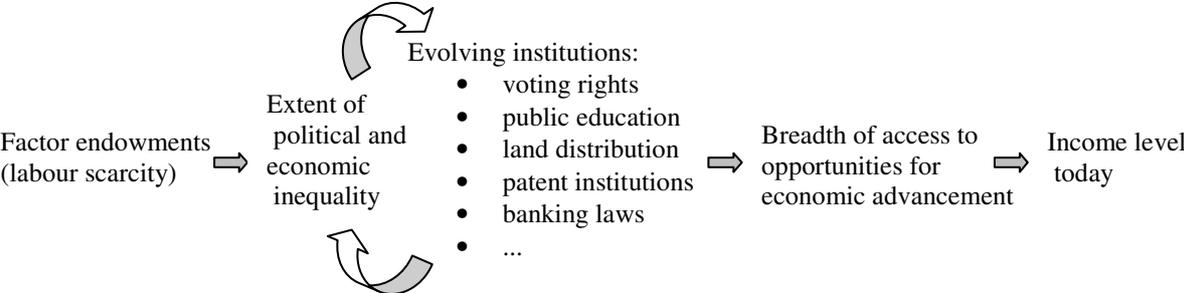
¹⁰ This is exactly why Matsuyama (2004) distinguished his ‘symmetry-breaking’ approach from that of poverty trap models that study countries in isolation. We deem the self-perpetuating conditions present in Matsuyama’s approach, however, sufficient to treat it here as an example (albeit a very particular one) of a poverty trap model (see also section 6 of Azariadis and Stachurski, 2005).

4.2 Dysfunctional institution models

Institutions, or what Douglass North (1994) defines as the whole of humanly devised formal and informal constraints that shape human interaction, now occupy a central place in economic development theory. These ‘rules of the game’, constituting the incentive structure of societies (and more particularly, economies), have often been said to provide a *fundamental* explanation for economic growth and cross-country differences therein, whereas factor accumulation and innovation, the channels analysed in ‘traditional’ growth theory, are only *proximate* causes (see among many others, Acemoglu, Johnson and Robinson, 2005; Rodrik, 2003 and World Bank, 2002). Much less is known about what *specific* institutions matter most, how they are formed and how they may change (or not) over time. Nonetheless, as pointed out by Azariadis and Stachurski (2005), recent research suggests that institutions may well be path-dependent and path-inefficient; ‘historical accidents’ may lead to the lock-in of institutions that are non-conducive to growth and cause poverty to persist.

One dynamic theory of *dysfunctional institutions* is that developed by authors such as Stanley Engerman, Kenneth Sokoloff, Daron Acemoglu, Simon Johnson, James Robinson and Karla Hoff. Economic historians Engerman and Sokoloff (2002; 2006) put forward the now increasingly popular but highly provocative hypothesis that per capita income differences between the United States and Canada on the one hand and the rest of the ‘New World’ (being Latin America) on the other hand today can be largely brought back to factor endowments (especially labour scarcity¹¹) back in the 16th-17th century and their influence on the nature of European colonisation subsequently taking place in these areas.

Figure 4: Institutional origins and persistence in the New World



Source: Hoff (2003)

¹¹ Alternatively, in a much-cited (and much-criticised) study, Acemoglu, Johnson and Robinson (2001) focus on the disease environment of different colonies (proxied by European settler mortality rates) as the most important aspect of factor endowments.

The reasoning is as follows (see Figure 4). Around the time European colonisers arrived in the Americas (roughly between 1500 and 1650) they were faced with three broad ‘types’ of societies. First, mainly in the Caribbean, one could find a climate and soils well-suited for crops (such as sugar) with large scale economies. This induced early colonisers to import slaves and start plantations, creating a highly unequal political and economic environment. Second, large parts of Latin America, including Mexico and Peru, had rich concentrations of minerals. Colonisers carved up the land and distributed it, together with claims on the labour of the ubiquitous native population, among their own small elite. Third, the sparsely-populated mainland of North America appeared only profitable for grain production and livestock. Here labour shortages allowed early settlers of European descent to set themselves free from feudal lords and start their own family-sized farms. As a result, the degree of inequality was very modest compared to the previous two types of colonies (see Engerman and Sokoloff, 2006).

How is it then that these disparities in labour scarcity and resulting inequality differences some 400 years ago matter for income levels today? Engerman and Sokoloff (2002:63-64) assert that initial factor endowments and degrees of inequality steered institutions in certain directions in the New World. Evolving institutions in turn affected endowments and distributional patterns of human capital, wealth and political control. In freshly colonised societies marked by high inequality, such as those in the Caribbean and Latin America, institutions have tended to develop in ways that were favourable to the aspirations of the narrow elite, leading to further consolidation of economic and political power.¹²

The real ‘Reversal of Fortune’ for New World colonies came only in the late 18th-early 19th century, at the onset of the Industrial Revolution (see Acemoglu, Johnson and Robinson, 2002 for evidence on a broader class of colonies). By that time, initially ill-endowed colonies, i.e. the United States and Canada, possessed institutions that made participation in investment and entrepreneurship possible for most of their populations. The Industrial Revolution put a high premium on such participation and hence enabled the US and Canada to surge ahead. Other colonies that had a better starting position but suffered from

¹² These assertions are based on an in-depth analysis of a selected number of institutions deemed of particular importance for economic development: a.o. voting rights, public education, land distribution, patent institutions and banking laws (see Engerman and Sokoloff, 2002; 2006 and Hoff, 2003).

dysfunctional ‘extractive’ institutions, aimed at concentrating everything in the hands of a few, stayed behind (Hoff, 2003).

While perhaps less apparent than in the case of critical threshold models, there are again strong parallels with Brian Arthur’s work on path dependence and historical lock-in here. Initial conditions (read: factor endowments) and the course of history (read: European colonialism) both seem crucial in explaining paths of economic development. To put it in very crude terms: if Latin America and the Caribbean would have had less interesting features for European colonisers to begin with, or if colonisation commenced in a later stadium (or not at all), when indigenous institutions could have already established themselves more firmly, paths of development of these regions would certainly have looked very differently.¹³ A full assessment of such counterfactual ‘if-scenarios’ is however an arduous, if not impossible task, as acknowledged by Engerman and Sokoloff (2006) themselves.

Other, often more stylised models have also contributed to the idea of institutional poverty traps. Many of these studies examine corruption or other government failures as instances of dysfunctional institutions. A case in point is Murphy, Shleifer and Vishny’s (1993) work on rent-seeking and its impact on growth. These authors point to several reasons why rent-seeking, defined as ‘any redistributive activity that takes up resources’, may display increasing returns. First, setting up rent-seeking schemes, such as laws biased towards certain segments of the population, may require large fixed costs. Once in place, these schemes can be cheaply exploited by new rent-seekers. Second, rent-seeking may be self-reinforcing by the simple fact that certain offenses create a demand for defense, arms races being one example. Third, rent-seekers may benefit from copycats. The more people steal or loot, the lower chances of any one of them getting busted become. Fourth, more generally, as rent-seeking uses up scarce resources, returns to productive activity, as well as to rent-seeking, fall. There may then be a range of rent-seeking levels for which returns to production decline faster than those to rent-seeking; over this range, rent-seeking is *relatively* more attractive than production and could therefore be self-perpetuating.

Murphy, Shleifer and Vishny model this last situation in a simple farm economy setting where each person has the choice of engaging in one of the three following activities: producing a subsistence crop (free from rent-seeking), cash cropping (vulnerable to rent-

¹³ This is not to say that these indigenous institutions would have been definitely less ‘extractive’ or more conducive to growth. The main argument here is that their further establishment would have *altered* the path of institutional development, for the better or the worse (see e.g. Acemoglu, Johnson and Robinson, 2005:414-416).

seeking), and rent-seeking itself (more specifically, through expropriation). It is shown that, depending on the strength of property right enforcement, a system with multiple equilibria emerges.

More recently, but in a similar fashion, Havlor Mehlum, Karl Moene and Ragnar Torvik (2006) have considered parasitic enterprises, to be interpreted as Mafia-like organisations that defy the ‘state’s [Weberian] monopoly of taxation, protection and legitimate violence’. They imagine a situation where entrepreneurs can run either productive firms or parasitic enterprises. The latter protect the former against extortion by other predators in exchange for protection money. As in Rosenstein-Rodan’s Big Push model, there is the assumption of joint economies between producers through demand spill-overs. Although slightly more sophisticated than Murphy, Shleifer and Vishny (1993), the main findings of Mehlum, Moene and Torvik (2006) are the same; because of increasing *relative* returns to ‘parasiting’, a high initial fraction of parasitic enterprises may lock in the economy into a poverty trap. Only external shocks, such as a sufficient overall increase in the number of entrepreneurs or large resource flows (in the form of foreign aid or export revenues) earmarked to productive parts of the economy, can make the trap disappear.

5 Concluding remarks and policy implications

This paper has shown how some of the key concepts developed in Brian Arthur’s seminal 1994 book *Increasing Returns and Path Dependence in the Economy* have found their way, perhaps increasingly so, into economic development (and more specifically poverty trap) theorising. The existence and selection (through deterministic drivers and stochastic perturbations) of multiple long-term outcomes that Arthur and his ex-USSR colleagues have revealed for general non-linear Polya processes (see section 2.2) very much resemble the basic workings of poverty traps.

As shown in Arthur’s study of competing technologies, increasing returns may lead to the lock in by historical small events of inferior long-run steady states that are difficult, if not impossible, to escape from (see section 2.3). Such notions of *unpredictability*, *non-ergodicity*, *path inefficiency* and *inflexibility* can also be found in various studies that attempt to explain the deeper mechanisms that may keep countries underdeveloped. This should not come as a surprise since poverty trap models, whether dealing with processes of physical or human

capital accumulation, technological advancements or institutional change, typically invoke increasing returns or other, similar forms of self-perpetuation.

Besides a growing theoretical literature, empirical testing of different poverty trap hypotheses is also beginning to receive some attention from researchers. While a review of these empirical studies falls outside the scope of this paper, one could cautiously conclude that the overall evidence so far looks mixed; most authors do seem to find some empirical support for the existence of various kinds of poverty or underdevelopment traps (see e.g. Durlauf and Johnson, 1995; Bloom, Canning and Sevilla, 2003; Graham and Temple, 2006; Cassimon and Van Campenhout, 2008), but others clearly have their doubts (most notably, Kraay and Raddatz, 2007). Of course, much hinges on the specific poverty trap mechanisms considered and the methodology used (e.g. econometric estimation *versus* model calibration). Attribution may furthermore be complicated by the possibility that different trap mechanisms, operating at macro, meso and micro levels, interact and reinforce each other (i.e. the so-called ‘fractal poverty trap’ hypothesis, proposed by Barrett and Swallow, 2006).¹⁴ More detailed empirical analysis is surely needed to advance on these issues.

If poverty traps are a reality, policy implications will obviously be dramatic. Critical threshold models like the ones presented above (section 4.1) seem to suggest the need for a centrally-planned, short-lived ‘Big Push’ approach, rather than a long series of small interventions, to lift countries out of poverty and launch them on a self-sustaining path of growth and development. Indeed, such arguments now underlie much of the rhetoric surrounding the Millennium Development Goals and debates about the scaling-up of development aid (Jeffrey Sachs (2005) arguably being one of the fiercest supporters¹⁵). The relevance of country insurance or other safety nets, preventing a backslide of more successful countries below the threshold because of external shocks, could be another policy lesson to draw.

However, as pointed out by Matsuyama (2008), one should keep in mind that when many sorts of poverty traps coexist, large policy interventions that aim to pull an economy out of one trap may yet push it into another ‘regrettable course of development’. Especially if one takes the poverty trap theories on dysfunctional (government) institutions at face value, strong external interference will not be without problems.

¹⁴ Such a multi-dimensional system would yield a much richer set of dynamics that we would no longer be able to plot in simple (two-dimensional) graphs as we did in section 3.

¹⁵ See a.o. Easterly (2006) for an equally fierce critique on Sachs’s propositions.

As Brian Arthur's work and the theoretical poverty trap literature suggest: both initial conditions and 'luck' (random fluctuations or shocks) matter for where one ends up over time. Hence it follows that '...economies starting with low wealth need better luck than richer societies' (Azariadis, 2006:32). Well-meaning, capable developing country governments and ditto donors could perhaps only try to *nudge* that luck a bit.

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