First world theories in third-world realities: How useful is an evolutionary approach for understanding technological change in developing countries?

ABSTRACT

The body of literature on innovation systems in the developed North is constantly on the increase. Since the 1980s there has been a renaissance in the application of evolutionary theory in this field, often with ideas and concepts from evolutionary biology being used as metaphors and theoretic building blocks. However, the theoretic as well as empirical underpinning for the evolutionary approach of innovation and development processes in social sciences and technology studies are typically taken from Western industrial economies. But how useful is the evolutionary theory in non-typical settings, such as in developing countries in the South? This paper aims at exploring the applicability of evolutionary theory for innovation, technical and social change in a context far from the traditional textbook setting. It looks at technological change in systems for urban water supply in Kenya in colonial as well as post-colonial times. Furthermore, the paper discusses in what way the peculiar conditions of this case affects the applicability of evolutionary theory. In summary, this paper suggests that evolutionary theory may be useful but needs to take the contextual factors into a careful consideration.

1. Introduction

How does wealth come about in society? The founding father of classical economics, Adam Smith, alluded to this puzzle in the title of his seminal work 'On the Wealth of Nations' already in 1776. The centrality of the issues of economic growth in social sciences needs no further explanation. However, when discussing the issue of economic growth, the topic soon enough spreads to include various issues such as politics, ethics, science, and technology. Karl Marx, in his landmark volume "Das Kapital" from 1867, brought in issues of social order and wealth distribution into the discussion on wealth creation[1]. In addition, he

[1] Marx (1867)

pointed to the importance of technology as well as how industrial production enables new forms of organisation of the productive factors, and how these forms of organisation could act as destabilising factors vis-a-vis the established social order.

Hence, the question of economic growth soon expands into questions of standards of living, of equality, of power, knowledge and; technological progress. These are questions that have puzzled and intrigued scholars all over the world for centuries. But with Marx, the progressive nature of economic production systems comes into focus. By establishing the dialectic view on social development borrowed from Hegel, Marx introduces a dynamic view on economies, instead of a static one. Starting with Marx, economists will also have to deal with economic change, not only economic growth.

This notwithstanding, for most of the 1800s leading economists would remain focussed on a static model of economic production, what we generally know as the 'equilibrium' model. Towards the end of the 1800s, iconic economists such as Alfred Marshall and Thorstein Veblen tried to introduce more dynamic and change-oriented theories into the equilibrium models[2]. However, it was not until Joseph Schumpeter wrote his milestone dissertation in 1911 that there was a more comprehensive theory on economic change, and particularly one that co-opts technological change and innovation as an integral part of economic life[3]. The popularity in academic circles of the Schumpeterian model of economic development has waxed and waned over the years, but from the 1980s it gave important impetus for a revival of evolutionary theory in economics and studies of innovation. Inspired by Darwin, evolutionary theorists moved far from the static models of the early 1800s and focuses on the mechanisms of economic and technological change. This school of thought now boasts quite an impressive body of literature[4]. Evolutionary theory holds many exciting opportunities for explaining the dynamics of social or technical change in contemporary contexts as well as in the past. Seen in a global context however, evolutionary theory appears to be mainly focused on how economies work in the more developed North.

The purpose of this paper is to discuss theories of technological change, and particularly evolutionary theory, within a context of developing countries. More specifically, I wish to

[2] Laestadius (1992); Veblen (1919)
[3] Schumpeter (1911/1934)
[4] See e.g. Ziman (2000), for an introduction

explore whether the ideas and assumptions about evolutionary technological change - as presented in the dominant Western discourse - are valid and useful in a third world context, using the case of Kenya in East Africa. Indeed, there is already an entire field of scholarly inquiry called 'development economics'. Over the years, it has included many different theories on the roots of under-development in the poor countries of the world. Concepts and theories such as the take-off theory, import substitution, dependency theory, the statist perspective and trade liberalisation have surfaced[5]. Most of the theories or concepts presented have a short time axis; to the extent that they include dynamic models they are often limited to processes that can be executed within a generation or two. Although some scholars, such as historian David Landes, have tried to bridge the gap of evolutionary theory and development economics, these two schools of thought still seem to live separate lives[6]. This paper does neither wish to compare and evaluate evolutionary theory and development economics, nor does it aspire to make an exhaustive account of dynamic theories of economic and technological change. Instead, this paper builds on the conviction that it would be of great use if evolutionary theory could be applied also in a developing economy context, but that there may be a number of limitations and obstacles for its application that first must be explored.

However, evolutionary theory does not have a single manual or a canonical document, one whose applicability can be easily evaluated. In the following section, I will therefore spend considerable effort on synthesising an account of what I argue to be a set of key sub-theories or themes within the literature on evolutionary economic and technological change. Thereafter, I will describe some of the peculiar characteristics of a developing economy, as exemplified by Kenya in East Africa. I will discuss the implications of the contextual factors described, in relation to the key themes in evolutionary theory, as presented in section two. Finally, I shall present my conclusion on the applicability of evolutionary theory in these contexts, and offer some pointers to what special considerations or modifications the analyst must allow.

[5] See e.g. Gunnarson and Rojas (1995), So and Chiu (1995), Easterly (2006)

[6] David Landes (1998) offers a comprehensive analysis of long-term changes of institutional, social and technological factors as a way of explaining global inequality, with an evolutionary perspective

2. Five key themes in evolutionary theory

In this section, I will outline five key themes that I believe have emerged as central theoretic foundations in evolutionary theory: variation; recombination; selection; inheritance, and; behaviour. I argue that these key themes will be of critical interest for my subsequent application of evolutionary theory to a developing country context. These themes all have connotations to biology and to Darwin's theory of the evolution of species. It is obvious that evolutionary theory in social and technological change have borrowed a leaf from biology in terms of analogies and metaphors. Although such metaphors can be useful, I will not try to make any further comparisons with biological evolution. I will here instead discuss how a number of thinkers and analysts of evolutionary economics and technological change all relate to these key themes.

The primacy of variation

Although Joseph Schumpeter did not call himself an evolutionist, he was one of the first major economists to propose a comprehensive theory for economic change, especially in terms of how economic change relates to technology and 'innovation'. As will be argued in this text, Schumpeter's ideas include several of the key themes of evolutionary theory. First, I will discuss how he assumed a certain degree of variation within the cultural sphere concerning human wants and skills.

According to Schumpeter, economic life is a "stream of goods" flowing in one way, matched by a corresponding opposite flow of money. Prices are determined in this exchange as expressions of values, with its base in the totality of all individuals' value systems. The main driving forces of this exchange are the 'Wants and Satisfaction' of individuals, and among any group of individuals, there will be variation of these wants and satisfaction. Production and consumption are staged in consecutive 'periods' such that production is based on the consumption pattern in preceding, historically experienced period. There will therefore always be a certain amount of unsatisfied wants in a population, and the producer of goods will strive to change production in order to satisfy the aggregation of wants and thus strive

for a new point of equilibrium[7]. However, Schumpeter acknowledged that there is also a more revolutionary kind of change. With reference to Marx, Schumpeter stresses that new technologies and new forms of organisation of the productive forces is a type of change that constitute economic 'development' at a more fundamental level. How does this change come about? In Schumpeter's own words: "It is, however, the producer who as a rule initiate economic change..."[8]. The process of economic change is thus centred on the producer, or more specifically, the 'entrepreneur' in Schumpeter's theory. The 'entrepreneur' is the actor who initiates change through recombination of productive factors. I shall discuss 'recombination' later on. But here one would ask: from where does the entrepreneur come?

A basic assumption in Schumpeter's theory is that there is great variation among any population of humans. Each individual has different characteristics in terms of wants but also ability and skills. In line with early 1900 jargon, Schumpeter argues that there are humans of many different 'types' in society. However, not all types can fulfil the requirements of being the entrepreneur. 'Type' refers both to a certain conduct and to a person. Schumpeter also distinguishes between the 'manager' and the 'entrepreneur' where the former can run a business along traditional routines, in a static economy. But only the entrepreneur will manage economic change and be able to operate in an uncertain and new economic environment because it defies learned behaviour and practices. The entrepreneurial type must be able – and desire – to walk off the trodden path, because: "[...] every step outside the boundary of routine has difficulties [...]"[9]. Schumpeter therefore argues that technological change and innovation assumes existence of a certain variation among the population, where at least some – albeit few – among the population belong to the entrepreneurial 'type'. And the entrepreneurial skills are needed to "bring inventions into practice", that is; necessary for innovation.

The primacy of variation has also been stressed by David S. Landes, although on a more aggregated level than that of the entrepreneurial psyche. In Landes' study of the Industrial Revolution in Western Europe, he concluded that it was a successful and varied mix of

[7] Schumpeter (1911/1934)
[8] ibid, page 65
[9] ibid page 84

geography and culture that led to a self-re-generating technological progress and long-term industrial growth. In explaining why Britain was the country to spearhead industrialisation in the 18th century, Landes holds out flexible attitudes, relatively tolerant and liberal governance and a high social mobility as features that made Britain different from other European societies. In short, it was not only a relatively wealthy country to start with, but also a relatively free society, which favoured variation and individualism over coherence and uniformity. Once industrialisation had begun, innovation snowballed through a 'see-saw pattern'. An innovation in one productive sphere spilled over into another, and back again; from mining to steel industry, from steel industry to mechanical industries, from mechanical to mining and so on. Thus, a multitude of factors and actors could come to further influence and speed up innovation, technological and economic change. This multitude of productive factors and criss-crossing of technologies is simply spelt: 'variation'[10].

That there is a multitude of factors that can influence technological development trajectories has been underscored by Joel Mokyr[11]. According to Mokyr, the trajectory of an economy will be depending on a long list of factors such as life expectancy; nutrition levels; geography and natural resources; labor costs; science; religion, attitudes and values; institutions and property rights; politics and the state; demography, etc. What Mokyr concludes is that no single factor can be said to be dominant or superior to the other factors. Societies are complex mixtures of culture and geo-physical conditions and artefacts, and variation is omnipresent. Mokyr's position also aligns with what Landes says about the industrialisation of the rest of Western Europe; although the other countries tried to copy the successes and methods of Britain, they all ended up on slightly different paths of development, due to the context-specific variation existing in each country[12].

George Basalla is perhaps the scholar who took the evolutionary model of technological development and innovation to its extreme end in his book "The Evolution of Technology"[13]. For Basalla, there is no such thing as the 'entrepreneurial type', or if there is, it is not of any significance for technological innovation. In his model of innovation and development, selective pressure from the social and physical environment is the main genius at work in

[10] Landes (1969)
[11] Mokyr (1990)
[12] Landes (1969)
[13] Basalla (1988)

the innovative process. The great innovators and entrepreneurs are, according to Basalla, social constructs, stories of iconic figures and great minds that we create around those technologies and inventions that precipitate as successful in a competitive selection process. And it is the existence of variation that makes such a selection process possible and thus enables evolution. Basalla's model of an evolutionary innovation process presupposes an almost infinite amount of invention activity; it assumes a very large degree of variation in technological development in society.

In sum; the existence of variation is key to any evolutionary approach, whether studying a human population's wants and abilities, cultural factors, diversity of economy, geography or invention activities. Next, I shall discuss the process of creating and expanding variation through recombination.

The source of novelty: recombination

I shall again start with Joseph Schumpeter, as he saw recombination or "new combinations" as the main raw material of innovation. Economic change comes out of recombination of previous means of production, raw material, and goods. Opening a new market, a different combination/quality of a good, a new source of raw material, a new organisation of industry are examples of innovation through recombination. Schumpeter also noted that recombination is often carried out by new actors on the market, not by the already established actors. In carrying out new combinations in the production, the new mode utilises and gradually replaces the old means of production. Schumpeter also underscores the role of capitalists for this process of recombination. The new actors will need capital to start production of the new combination; the problem of acquiring the means of production. This could be done either through using existing ones or replacing old with new, an alternative only available for the already established actors. The new actors must establish a completely new set of means of production (basically: setting up an industry). The latter will require capital, which can be achieved as credit from the 'capitalists' in society. According to Schumpeter, this is what is fundamental about the capitalist system; that economic change through recombination depend on credit. In an economy without economic change; a "circular economy", there is no need for credit and therefore no need

for interest. There can still be economic growth in a circular economy but no economic development. To obtain economic change, credit and therefore capitalists are necessary.

But in addition to recombination of goods, raw material and means of production, Joel Mokyr stresses that also the underlying ideas and design principles can be recombined through exchange and borrowing ideas. Through scientific and professional journals, conferences, espionage, and other forms of spill-over between the actors, ideas of how to structure and address technical or managerial problems can circulate and recombine. Sometimes this circulation and recombination take place through a planned and conscious process, but often it happens through chance and serendipity. However, Mokyr distinguishes between 'macro-inventions' and 'micro-inventions'. The macro-inventions change technology drastically and break away from the trodden path. These new combinations are then gradually refined by micro-inventions until a new macro-invention comes about. It is mainly the macro-inventions come about through recombination. [14]

The theme of recombination of ideas and principles is picked up by Brian W. Arthur. He even goes as far as to state that "all technology is combination". In its essence, technology is therefore 'modular '; built up in hierarchical layers of systems, sub-systems, sub-sub-systems etc. Therefore, innovation comes about when old technology is pieced together in a new way. Technology is grouped into what Arthur calls 'domains', such as 'telephony', 'cars' or 'railway systems', often the development in one domain has a spill-over effect on another technology. Thus, innovation in one area often generates development in other areas. There are two main ways of innovation:

a) internal replacement: parts and sub-systems are shifted

b) structural deepening: new parts and sub-systems are added

Internal replacement means shifting one component or sub-system in the modular structure of technology. Structural deepening means expanding and adding new modules, which increases complexity. But, argues Arthur, both cases build almost entirely on recombination[15]. Thus, the opportunity of recombination offers almost endless variation.

[14] Mokyr (1990)
[15] Arthur (2009)

Survival of the fittest: selection

If there is a possibility of endless variation, brought about by recombination, then what makes the new combinations survive? What – and who - determines success? According to Landes, it is a matter of satisfying the needs and preferences on the market, but doing it as efficient as possible[16]. For a new combination to lead to innovation and technological change, it must be able to outperform the old technology. However, he acknowledges that there is more to it than optimising only economic efficiency. How else could one explain the resistance of certain industrial practices in France, that demonstrably had yielded a higher economic return in Britain? The short answer is: because France is not Britain. I shall return to issues of path dependency and inheritance later, here it will suffice to state that economic efficiency is important, but is not the complete answer.

But to understand how selection actually takes place, we also need to look at the more detailed level and not just at the aggregated national levels. Why does a particular invention become successful or not? What makes up the selective pressure, to which Basalla assigned so much importance? According to Walter Vicenti, there are both man-made selective pressure and those given by nature. On one hand, the designers or entrepreneurs have some objectives about the function and performance of new technology, and on the other, there are physical constraints exerted by nature, such as gravity forces, wind forces, stress and shear forces. Those new combinations that can meet selective pressure from both sides (man and nature) will be successful[17]. In addition, Paul A. David shows that for a large number of iterations, the role of knowledge is not very important for the outcome. Instead he – just as Edward Constant – argues that it is the 'recursive practice' of technology that contributes development[18]. Simply put: 'trial and error' is a very powerful selection mechanism for innovation and technological change.

Richard Nelson and Sidney Winter, in their path-breaking neo-Schumpeterian and evolutionary book from 1982, ask: how does knowledge increase in firms and how does

[16] Landes (1969, 1998)
[17] Vicenti (2000)
[18] David (2000); Constant (2000)

innovation take place within an organisation? How do firms and individuals make the selection? According to orthodox economic theory, selection in firms is done against a search for profit maximisation. But Nelson and Winter argue this is too simplified an approach. The objectives of firms (and actors therein) do not necessarily have to be only profit-maximising. Furthermore, no-one has access to perfect information and therefore, decisions are made under what is called 'bounded rationality'. We choose based on what we know and believe in, not based on perfect information. And more important; the ability of the actors to collect and process information is linked to the issue of skills[19].

Skills in the firm are acquired routines for carrying out a task or solving a problem. Some of these skills can be 'tacit', ie "observance of a set of rules which are not known as such to the person following them"[20]. Tacit knowledge is more difficult to diffuse and also to measure. Performing a skills-based routine involves many choices; but often these choices are made automatically or unconsciously as a part of the skill. Thus; skills generate a preferred choice and give rise to a certain selective behaviour. Nelson and Winter agrees that active and deliberate choice take place as well, but they stress that much selection in economic life is done in a programmed behavioural way. Thus, we have now gradually moved into the fourth and fifth themes: inheritance and behaviour.

Inter-generational linkage: inheritance

What do I mean with 'inheritance'? First, we must remember that the concept of 'inheritance' is again a metaphor. As already indicated, technological development and innovation processes tend to resemble hereditary processes, but these processes are not governed by some genetic code.

As discussed in the foregoing, Nelson and Winter argue that selection and therefore innovation in firms depend on the 'organisational capabilities'; the skills and routines in the firm. Routines define how to work and how to optimise; the common sense of the operations. These routines resemble genetic material; they programme the firm in selection and in search. Organisations are therefore not presented with an unlimited set of options to

[19] Nelson and Winter (1982)
[20] ibid, page 77, quoting Michael Polyani.

choose between. These routines act like organisational memory as well; they can be acquired, but they are slow to change. Nelson and Winter express it that: "firms may be expected to behave in the future according to the routines they have employed in the past" (p 134). Hence, Nelson and Winter strongly suggest that there is an inter-generational linkage in routines and firm behaviour; the organisational capabilities are hereditary.[21]

Another useful concept is that of 'paradigms', today widely used in many different contexts. Thomas Kuhn showed in his classic "The Structure of Scientific Revolutions" how knowledge and science is embedded in society in a way that old 'truths' are only replaced once too many inconsistencies and challenges have piled up against them. The scientific community tends therefore to cling on to knowledge until it becomes untenable, and therefore science is perceived to develop in leaps in a revolutionary way[22]. Knowledge, principles and ideas are products of the social system within which they are produced, but they are handed down over generations like genetic material[23]. Out of Kuhn's ideas, Giovanni Dosi has derived the concept of 'technological paradigms', which will be important for this discussion. In a similar vein to Kuhn, Dosi states that a technological paradigm "defines contextually the needs that are meant to be fulfilled, the scientific principles utilised for the task, the material technology to be used". The idea of the technological paradigm embraces both "a set of exemplars" as well as "a set of heuristics". Moreover, innovation in the paradigm tends to be conservative as most practitioners within a technological paradigm are typically confined to thinking 'within the box'[24]. The technological paradigm therefore is a normative model of how to conceptualise and frame the problem and articulate the need, it proposes a restricted set of solutions from within the toolbox of the paradigm, and it defines the technology to be used and the norms for how to use it. In short, the technological paradigm defines the problem as well as the solution from a restricted set of options. Components within the technological paradigm can be shifted and gradually replaced. There is thus scope for conservative innovations and even radical innovations within the paradigm. The cellular phone can serve as an example of an innovation leading to a shift of technological paradigm. This would be synonymous with the 'macro-inventions' of

[21] Nelson and Winter (1982)
[22] Kuhn (1962)
[23] Joel Mokyr (1990), has proposed that ideas and principles embedded in technology could be regarded as the genetic material of technological evolution, in line with the concept of 'memes' coined by Richard Dawkins
[24] Dosi (1988)

Mokyr. A technological paradigm is not a monolith unable of change, but typically the paradigm revolves around a characteristic component or technological design concept inscribed in the paradigm which will not be shed until a paradigm shift takes place. Therefore, as long as a certain technology develops within a paradigm, it will typically be confined to the smaller, micro-inventions, and radical change will happen very seldom. The new generations of technology therefore typically has great resemblance of previous generations; a type of inheritance.

The tendency of technology to develop in a conservative way along a continuous trajectory has been described by Paul A. David using the term 'path dependence'. According to this view, technology develops gradually, building on choices made in the past. Such processes are said to be non-ergodic; they are "unable to shake free of their history" and therefore yield path-dependent outcomes[25]. Some of these choices could be seen as irreversible, at least in practice. The difficulties of reversing decisions made and enter a new development path has been described by Brian Arthur as 'lock-in'.

When technology develops through what was described in the foregoing section as 'structural deepening', at some point new additions will not significantly add to the performance. The technology has become 'mature'. To improve the efficiency or performance, a new principle is needed. Such a recombination corresponds to what Dosi would call a shift of technological paradigm. But, according to Arthur, the present technology often experiences 'lock-in' in the old principle, making it difficult to undergo such a more radical change.

There are three ways that lock-in can occur: through economic inertia, biased competition, and through mental resistance[26]. First, if physical structures (frameworks, buildings, infrastructure) around the technology are affected by a shift in principle (radical innovation or revolutionary change), then economic inertia delays innovation or radical shift. The system experiences is said to experience economic lock-in. As an example, the weaving industry in UK could not fully benefit from mechanisation in the 1800s because of difficulties in rearranging the manufacture buildings to accommodate steam engines and mechanised

[25] David (1997)
[26] Arthur (2009)

production. Second, new technologies have to compete against old ones on a market that has been set up for the old system. Therefore there will be an uphill struggle for new technology and market arrangements including patent rights etc favour the old technology. This second form of lock-in resembles the conservatism of selection rules as part of the firm's organisational capabilities, described by Nelson and Winter. Finally, lock-in can arise from interest of self-preservation by the expertise involved in the industry. New technology and new knowledge can be threatening to the old cadre of expertise, who would prefer the traditional ways of doing things in which they excel. Also Douglass C North has discussed this kind of mental lock-in, or 'scaffolding' as he calls it; actors involved in the (re)production of a certain technology would not favour change that they do not perceive being beneficial for them[27].

Therefore, old technology is often pushed to solve new problems that arise, although from a rational point of view a new technology would be more efficient in solving it. The old system will be pushed and pushed to its limit. Arthur calls the ability of an existing technology to adapt to new problems its 'adaptive stretch'. Only once the old technology has been strained to or beyond the limits of its adaptive stretch will it give way to a new technology. Arthur here makes explicit reference to the similarity with scientific paradigm shifts as described by Kuhn.[28]

Hence, the idea of technological change being strongly influenced by inheritance in one form or the other seem to be a key theme supported by many evolutionary theorists, although this hereditary mechanism has many names; lock-in, path dependence, paradigms etc.

Behaviour as a cross-cutting theme

Finally, I return once more to Schumpeter. When he proposed the centrality of the 'entrepreneur' for innovation, he stressed that this referred both to the individual actor and his or her agency, but also to a certain kind of psyche and an expected behaviour. In fact, as much as Schumpeter was an economist, he emphasised the non-economic behaviour of

[27] North (2005)
[28] Arthur (2009)

many innovators/entrepreneurs. What drives the entrepreneur, according to Schumpeter, is not the mere satisfaction of purely economic wants. Instead, things like dreams of grandeur, of creating a new dynasty or acquiring social status were as important as simple profit-hunger. Schumpeter draws parallels to the "will to conquer" in sports, and the "joy of creation" in the arts. The existence of entrepreneurs therefore asserts that humankind within economic life is much more complex than the *homo economicus*, the rational and self-centred individual.

I have already several times alluded to the fact that behaviour and attitudes play an important role in evolutionary models for technological change. Nelson and Winter stress the problem of 'bounded rationality'; making decisions in face of imperfect information, and where organisational capabilities inherited from the past influence decision-making strongly through defining a selection behaviour. They also stress that this selective behaviour is often non-economic in its nature. As mentioned, Dosi as well as Arthur underscore the power of learned behaviour within a paradigm or a domain, and the preserving influence it has on choices in relation to innovation. Why then do I argue that behaviour is a key theme in itself?

Behavioural aspects deserve to be treated as a theme, not despite its links to the other themes, but because of just that. Behavioural aspects appear as a cross-cutting theme through evolutionary theory. Furthermore, Although evolutionary theory has tried to downplay the role of Great Innovators and apply a less actor-oriented approach, it is difficult to completely leave them out of the picture. Or as Otto Mayr says in his book review on Basalla's "The Evolution of Technology"; although this approach has its merits, "...it makes the resulting story painfully dull." The evolutionary theory still has to deal with actors and organisations through history, and this is why we also need to look at these actors' behaviour.

In summary, this section has presented a synthesis of evolutionary theory as centred around five key themes: variation, recombination, selection, inheritance and behaviour. Next, I will discuss where the possible problems may present themselves in trying to apply these theories to the context of developing countries by looking at each of these themes in the specific country context of Kenya. For the sake of moving from the general to the specific, I

will also discuss technological change in a particular area; that of technologies for providing water services in urban areas.

3. The context for evolution in a developing country

Developing countries and post-colonialism

For understanding some of the characteristics of an economy in a developing country, it is necessary to also look at the history of these countries. I will therefore first provide an historical introduction. Many of the developing countries have a colonial background, which tends to influence the mechanisms presently at play for innovation and technological change. I will below discuss the case of Kenya in East Africa as an example of a developing country with a colonial past, and how this historical background may affect the applicability of evolutionary theory.

Colonisation of Kenya by the British took off effectively from 1895 when the British East Africa, as it was then called, was declared a Protectorate. The Protectorate formed part of a British strategy to control the source of the Nile, which in turn was the key to control Egypt and the economically important Suez Canal.[29] Investments were made in infrastructure by the colonial administration in order to facilitate trade, agricultural export production and European settlement in the colony, including railways and urban infrastructure such as water and sanitation technologies. Just as in many other colonies, technology was introduced through transfer from the United Kingdom, including technical norms and the associated legal framework[30]. A typical feature of the technology transfer was that it also served a political and moral purpose. It provided the means to control the Empire through e.g. railways and telegraph cables, but also as a physical manifestation of the domination of colonised by the colonisers. For instance, racial segregation could be manifested in urban planning and in the way that urban infrastructure was structured.[31] This way, technology became part of what Gabrielle Hecht has labelled a 'techno-political strategy'.[32] Moreover,

[29] Wesseling 1992
[30] Nilsson and Nyangeri 2009
[31] Headrick 1988
[32] Hecht 1998

the racial stratification of the colonial society could be motivated through making technology and technological advancement a yard-stick for human progress and a racially based hierarchy; the supremacy of European technology was mirrored in the supremacy of the European race.[33]

Nevertheless, when Kenya achieved its independence in 1963 it had acquired a relatively well developed infrastructure, with a reasonably good railways system, an international airline carrier and with decent level of public service in the urban centres. The World Health Organisation (WHO) even claimed in a report that close to 100% of the urban population had access to piped water.[34] In 1965, the independent Government adopted Sessional Paper no.10, "African Socialism and its Application to Planning in Kenya" which would provide a development policy blueprint for many years. The aim was to develop the country and its infrastructure in order to become an industrialised country as soon as possible, to do away with the social inequalities that colonialism had brought and lift all Kenyans out of poverty. These overall goals were made operational in the Government's five-year development plans. The "African Socialism" applied in Kenya was not as socialist as in many other African former colonies. Kenyatta's policies were soon regarded as more capitalist-friendly than most other former colonies in Africa. Kenya initially enjoyed economic prosperity with annual GDP growth of around 6% for most of the 1960s, mainly based on agricultural exports such as coffee but also manufacturing and a burgeoning services industry[35]. Although the Kenyan economy was more liberal than other African countries at the time, a state-led planned economy was still the order of the day.

From 1973, economic growth slowed down considerably, while population growth continued at around 3% per year. The per capita GDP growth rate therefore had approached zero around 1990[36]. As the economy slumped, the government investment programmes ground to a halt. At the same time the population grew rapidly in the urban centres: from 671,000 in 1963 to 4,170,000 in 1990[37].

[33] Adas 1989
[34] Nilsson and Nyangeri 2008
[35] Jerven 2011
[36] Nilsson and Nyangeri 2008
[37] See Nilsson and Nyangeri 2008

In 1974, the Government acknowledged that there was a need to develop simpler and more affordable ways for providing urban services and to "adopt standards for urban infrastructure which closely relate to what can be afforded by the country as a whole"[38]. But at least with regards to water supply technology, not much happened in terms of technological change. The Government acceded again in 1983 that the "current design standards for both urban and rural water supplies appear to be too high in relation to needs and the costs"[39]. At the same time, it was increasingly difficult to finance even the costs for existing water supplies. Although the government demanded pricing for recovering full cost for capital, operation and maintenance from the consumers, none of the water utilities covered more than a third of their costs in 1986.[40] This may be explained by the emerging neo-patrimonial political system in Kenya in the 1970s and 1980s. To secure votes, politicians avoided making tariff increases. There was also reluctance from politicians, engineers and bureaucrats to spearhead technological change that could be perceived as 'anti-development'. [41] Even today, the technological solutions applied for urban water supply are basically unchanged since the colonial period, despite the fact that few people can afford the cost. The effect is that today, only 45% of the urban population in Kenya has access to piped water, as compared to the close to 100% reported in 1963.[42]

Applicability of evolutionary theory

So what has all this to do with evolutionary theory? I will now return to the five key themes and discuss them in the Kenyan context, as I have briefly outlined it in the preceding sections. First, let us look at 'variation' and 'recombination'. A large technical system such as an urban water supply system belongs to the group of production systems often classified as a 'natural monopoly'. For this type of technology, there is limited scope for variation since there can only be one setup for each geographical location. Furthermore, the rate of replacement is very low, due to the durability of the infrastructure and long-term nature of

[38] Republic of Kenya (1974:119)
[39] Republic of Kenya (1983: 161)
[40] Hukka, Katko and Seppälä (1992)
[41] Nilsson and Nyangeri (2008)
[42] WASREB (2010)

the investment made.[43] This is not unique for a developing country context but is a general condition for most large-scale technical systems. Variation within the system is therefore not natural, but evolution can still be achieved through directed 'search' activities. The system owner identifies weaknesses in the system and systematically tries to address them through recombination, for example with varieties from other similar systems.[44] However, the big difference here lies in the shallow body of technologies available in a former colony, created by the dominance from the colonising country. A country such as Sweden could copy freely from the more advanced Western countries such as Germany, France and UK when introducing urban water supply technologies. In contrast, during the colonial period in Kenya, the transfer process was centrally directed, used mainly one source of supply for technology (United Kingdom) and mainly were meant to satisfy only the 'wants' of the colonialists. Furthermore, the smaller size of the economy of a developing country also limits the possibilities of establishing variation; the smaller the economy, the smaller number of possible outcomes of technological solutions. Finally, as in many centrally planned command economies, the post-independence state-led period could not benefit from variation resulting from private initiatives, as the sector was dominated by government programmes.

With regards to selection, I noted in the previous section that regardless of whether the selection process is seen to be rational and based on learning or just recursive and based on 'trial-and error', it can always be defined in term of improved performance. But performance of what? In the examples used in the evolutionary theory, it is typically assumed that economic efficiency is always part of the selection criteria, although not always as the dominant factor. However, in the Kenyan situation, political motives completely obscured economic motives. Technological change towards simpler and more affordable technology, which would have been more economically efficient, was resisted by the 'owners' of the systems; the politicians. For these decision-makers, political power was an a priori objective while economic efficiency was given little attention.

It is understandable that there is a high degree of path dependency in developing countries. Perhaps, there could even be stronger tendencies than in more developed economies, as

[43] Nilsson (2005)
[44] Hughes (1989)

there also tends to be a shortage of skilled manpower in poor countries. The low level of cultural diffusion of technology during the colonial period left the former colonies with a backlog of development of the human resources, which was difficult to compensate for during the economic recession after the oil crisis in the 1970s.[45] In the words of Nelson and Winter, the organisational capabilities of the Kenyan post-independence economy was highly restricted, thus leading to path dependence. Using Dosi's terminology, one could argue that a technological paradigm emerged, for which there were no strong forces at play for initiating change. In all, different forms of inheritance seem to play a key role in the trajectory of urban water technology in Kenya.

Finally then, can we say something about behaviour as a cross-cutting theme in the Kenyan context? By now, it should be obvious that those in a position to influence whether new technology should be invented, selected and adopted have not acted primarily as the *homo economicus* that mainstream economics assume. Instead, we are dealing with a *homo politicus* whose interest lies mainly in reproducing the prevailing power structures, be they in an imperial system or in a post-colonial society.

4. Conclusions

In summary, I have suggested that evolutionary theory for technological change builds on the themes variation; recombination; selection, and; inheritance, with behavioural aspects as a cross-cutting theme. In my examination of how this can be applied in a developing country, I have looked at urban water supply technology in Kenya. This examination indicates that there are some particular characteristics in the Kenyan society - to a large extent shaped by its colonial history – that need to be taken into account for an application of evolutionary theory. First, the scope of technological variation is smaller in the Kenyan context, making the number of alternatives easily available for a sub-sequent recombination smaller. Second, the selection mechanism for what is deemed to be an improved technology and what therefore could lead to innovation is not straightforward. Economic considerations were not given high priority in the post-independence period, where instead

[45] Headrick (1988) uses the expression 'cultural diffusion' to indicate transfer or investment in the skills base and the soft components of technology; the ability to understand and use the technology transferred.

political considerations were more important. This is closely related to behavioural aspects; here the key actors seem to be maximizers of political power rather than profit-maximizers. If we shall talk about entrepreneurs in this context, Kenya seems to be more endowed with political entrepreneurs pursuing techno-political strategies rather than classical economic entrepreneurial activities as described by Schumpeter. Finally, inheritance or 'path dependence' seems to be strong in the chosen example. This is explained by the transfer of a technological paradigm from Britain in the colonial period, but with few forces that have stimulated technological change.

My investigation thus suggests that evolutionary theory is indeed useful for understanding technological change – or more precisely, the lack of it – also in the Kenyan context, provided that the analysis carefully takes the historical and economic peculiarities into consideration.

Literature

Adas, Michael (1989), *Machines as the measure of men. Science, technology, and ideologies of Western dominance*, Cornell University Press, New York.

Arthur, W. Brian (2009), *The nature of technology - What it is and how it evolves*, Penguin Books, London.

Basalla, George (1988), *The Evolution of Technology*, Cambr. Univ. Press.

Constant, Edward (2000), 'Recursive practice' in Ziman, John (2000), *Technological Innovation as an Evolutionary Process*, Cambridge University Press, Cambridge, Mass.

David, Paul A. (1997), 'Path dependence and the quest for historical economics: one more chorus of the ballad of QWERTY', Discussion Papers in Economic and Social History, Oxford University.

David, Paul A. (2000), 'Path dependence and varieties of learning', in Ziman (ed, 2000).

Dosi, Giovanni, (1988), 'The nature of the innovative process', in Dosi et al, *Technical change and economic theory*, Pinter publishers, London, pp 221-238.

Easterly, William (2006), *The white man's burden: Why the west's efforts to aid the rest have done so much ill and so little good*, Penguin books, New York.

Gunnarsson, Christer and Mauricio Rojas (1995), *Tillväxt stagnation kaos: en institutionell studie av underutvecklingens orsaker och utvecklingens möjligheter*, SNS förlag, Stockholm.

Headrick, Daniel R. (1988), *The tentacles of progress. Technology transfer in the age of imperialism*, Oxford University Press, Oxford.

Hecht, Gabrielle (1998), *The Radiance of France. Nuclear power and national identity after World War 2*, MIT press, Cambridge Massachusetts.

Hughes, Thomas P. (1989), 'The evolution of Large Technical Systems' in Wiebe E. Bijker, Thomas P. Hughes and Trevor Pinch (eds), *The social construction of technological systems. New directions in the sociology and history of technology*, MIT Press, Cambridge Mass.

Hukka, Jarmo, Tapio Katko and Osmo Seppälä (1992), *Kenya Water Sector - A Position Paper*, Tampere University of Technology, Tampere.

Jerven, Morten (2011), 'Revisiting the consensus on Kenyan economic growth 1964-95', Journal of Eastern African Studies, 5:1, pp 2-23.

Kenya Water Services Regulatory Board (WASREB, 2010), Impact Report, WASREB, Nairobi.

Kuhn, Thomas (1962), *The structure of scientific revolutions*, University of Chicago press, Chicago.

Laestadius, Staffan (1992), *Arbetsdelningens dynamik*, Arkiv förlag, Lund.

Landes, David (1969), *The Unbound Prometheus. Technological Change and Industrial Development in Western Europe from 1750 to the present*, Cambridge Univ Press, Cambridge.

Landes, David (1998), *The Wealth and Poverty of Nations, Abacus, London.*

Marx, Karl (1867), *Das Kapital*, Swedish translation from 1969, A-Z Förlag, Lund.

Mokyr, Joel (1990), *The Lever of Riches - Technological Creativity and Economic Progress*, Oxford Universtiy Press, Oxford.

Nelson, Richard R. and Sidney G. Winter (1982), *An evolutionary theory of economic change*, The Belknap Press of Harvard University Press, Cambridge, Mass.

Nilsson, David (2005), "The Evolution of Urban Water and Sanitation in East Africa from a public goods perspective" published in J W N Tempelhoff (ed), African Water Histories. Trans-disciplinary Discourses, Coral Publishers, Vanderbijlpark, South Africa, pp 317-345.

Nilsson, David and Ezekiel Nyangeri Nyanchaga (2008), 'Pipes and politics: a century of change and continuity in Kenyan urban water supply', Journal of Modern African studies, 46:1, pp 133-158.

Nilsson, David and Ezekiel Nyangeri Nyanchaga (2009), 'East African Water Regimes: The Case of Kenya' in J W Dellapenna and J Gupta (eds), *The Evolution of the Law and Politics of Water*, Springer, pp 105-120.

North, Douglass C. (2005), *Understanding the process of economic change*, Princeton University Press, Princeton.

Republic of Kenya (1974), *Development Plan 1974-1978, Part 1*, Government Printer, Nairobi.

Republic of Kenya (1983), *Development Plan 1984-1988*, Government Printer, Nairobi.

Schumpeter, Joseph (1911), *The theory of economic development*, English translation from the German, 1934, reprinted 2008, Harvard University Press, Cambridge, Mass.

So, Alvin and Stephen Chiu (1995), *East Asia and the World Economy*, Sage, London.

Veblen, Thorstein (1919), 'Why is economics not an Evolutionary Science?' reprinted 2003.

Vicenti, Walter (2000), 'Real World variation-selection' in Ziman (ed, 2000).

Wesseling, Henk (1992), *Söndra och härska. Uppdelningen av Afrika 1880-1914*, Swedish translation from Dutch original 2006, Historiska media, Lund.

Ziman, John (2000), *Technological Innovation as an Evolutionary Process*, Cambridge University Press, Cambridge, Mass.