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# **Analysing the Development Implications of Technological Innovations from China to SSA economies: A Conceptual Framework**

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# **Analysing the Development Implications of Technological Innovations from China to SSA economies: A Conceptual Framework**

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## **Abstract**

China's relationship with Africa has grown enormously, especially in the last two decades. From trade to foreign direct investment and official development assistance to migration, there are many myths surrounding the relationship between China and Africa, some of which are being dispelled through research. However, the academic community is still at an early stage in researching this evolving relationship and its impact on Africa economies. A significant gap remains in the literature in the area of technology transfer from China to African economies and developing countries in general. This paper seeks to present a literature review on various issues on technology, developing a conceptual framework that will guide future research in analysing the impact of technology transfer from China on recipient developing countries as well as informing policy.

**Keywords: Chinese Technologies, Technology choice, Technology transfer, Developing Countries**

## 1. Introduction

China accounts for a substantial contribution of developing countries' increasing share in global research and development (R&D) activities. Developing countries' share in global R&D expenditure was estimated at 21% at the beginning of the 21st century compared to 2% in late 1960s (Ely and Bell, 2009). A significant share of this expenditure occurred in China, where R&D increased 21% annually in the last decade (Atkinson, 2012), with manufacturing's share in business R&D being 87% in 2008 (McKinsey, 2012). Current estimates of R&D expenditure indicate that China is the third largest R&D performer after United States and Japan (Kim, 2014).

The high growth in R&D activities in China and its associated increases in China's share in global manufacturing value added have been accompanied by innovative capability building in China (OECD, 2007; Atkinson and Ezell, 2012; Orr and Roth; 2012) as well as a significant reduction in poverty numbers in China (Chataway *et al.*, 2013). Casual observation shows that at the heart of the innovation path in China is the development of technologies that appear to be suitable for the operating conditions in China as well as other developing countries:

Spurred by demand from low income consumers, low labour prices and often poor infrastructure, China is becoming a source of appropriate technology, that is, appropriate for the operating conditions of low income economies. But unlike previous vintages of appropriate technology which were diffused by NGOs and were often inefficient, this new generation of appropriate technologies coming out of China ... is a result of profit-seeking capitalist entrepreneurship (Kaplinsky, 2011a p. 7).

Meanwhile, Kaplinsky *et al.* (2007) indicated that China's relationship with Africa has grown enormously in recent years, with important implications for economic growth, distribution and policy. An earlier documentation of China in SSA by Jenkins and Edwards (2006) also suggested that the impact of China and generally Asian Drivers<sup>1</sup> on SSA has been and will be significant, calling for detailed research on individual countries in SSA. In fact, recent data indicate a growing relationship between China and Africa. According to a White Paper from the Chinese Government, China-Africa trade as a percentage of Africa's total foreign trade increased from 3.82% in 2000 to 16.13% in 2012 (People's Republic of China, 2013). The same White Paper shows that there has been an accelerated growth in foreign direct investment (FDI) from China to Africa, with Chinese FDI increasing from US\$1.44 billion to

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<sup>1</sup> This phrase is used in the literature to jointly describe China and India as emerging Asian economies with major implications for both the developing and developed world. They are termed "drivers" in the sense of "driving" international development.

US\$2.52 billion between 2009 and 2012. Moreover, there has been a surge in Chinese development finance to Africa since the beginning of this century, with pledges of assistance doubling at each FOCAC summit: In 2006, US\$ 5 billion was pledged and pledges for 2009 and 2012 were US\$ 10 billion and US\$ 20 billion respectively (Strange *et al.*, 2013). Associated with the upsurge in trade, FDI and development finance is the intensification of migration from China to Africa (Kuang, 2008; Mohan and Tan-Mullin, 2009; Park, 2009; Lampert *et al.*, 2014; French, 2014).

From trade to FDI and official development assistance (ODA) to migration, there are many myths surrounding the relationship between China and Africa, some of which are being dispelled. However, the academic community is still at an early stage in researching this evolving relationship and its impact on African economies. A significant gap remains in the literature in the area of technology transfer from China (and other emerging economies) to developing countries including those in SSA. This gap exists in the literature in spite of the growing relationship between China and African countries in the area of trade, development finance, direct investment and migration, all of which may serve as channels of technology transfer. A recent study by Munemo (2013) however examined the effect of the importation of capital goods from China on economic growth in SSA countries using data from UN COMTRADE. The main findings of Munemo's study have been highlighted in Section 2.4 of this paper.

The aim of this paper is to provide a review of the literature on several issues on technology, which converges around themes such as the meaning of the term of 'technology', technology choice, appropriate technology and technology transfer. The paper also presents a conceptual framework for analysing broader development impact of technology transfer from China on recipient developing countries especially those in SSA. The conceptual framework, which is expected to serve as a guide for future research, is developed based on concepts and facts isolated from the various literature surveyed in this paper. The rest of the paper is organised as follows: Section Two presents the literature review while Section Three deals with the conceptual framework. The final section provides a brief summary of the discussions and offers insights for further research and policy.

## 2. Literature review

### 2.1 What is technology?

The term technology has been used loosely to describe different but related concepts in the literature to the extent that the use of the term is shrouded in ambiguities. Based on Cooper and Sercovitch's (1971) work, Clark indicated that "... 'technology' is not a homogenous concept but is rather a term connoting a wide range of heterogeneous forms or 'elements' ..." (Clark, 1985 p. 183). Writing in the late 1970s, however, Winner noted that in the decades before the time of his writing, technology had a specific and unproblematic meaning in academic and everyday discourse, being used to refer to "practical arts" either individually or in a collective sense and the study of them (Winner, 1978). He further noted that this had changed at the time of his writing such that the term had lost its precision and taken on a ubiquitous nature, leading him to assert: "There is a tendency for those who write or talk about technology in our time to conclude that technology is everything and everything is technology ... the word has come to mean everything and anything ... [and] threatens to mean nothing" (Winner, 1978 p 9-10). In corroborating Winner's observation, Willoughby (1990) indicated that the last century has seen the term expand from something of a limited meaning to one characterised as an all-embracing symbol or concept.

The evolution of the broad meaning associated with technology, according to Winner (1978), may have started with a definition by the 1909 *Webster's Second International* unabridged dictionary, in which technology is said to be "industrial science, the science or systematic knowledge of the industrial art, especially of the more important manufactures" (cited in Winner, 1978 p 8). It should however be noted that an earlier characterisation of technology by Karl Marx was also relatively broad but to the extent that Winner did not mention it may indicate its relative unpopularity compared to the Webster's definition. Marx in his book, *Capital: Critiques of Political Economy*, first published in 1887, said "Technology discloses man's mode of dealing with nature, the processes of production by which he sustains his life, and thereby also lays bare the mode of formation of his social relations, and of the mental conceptions that flow from them" (Marx, 1887 p. 326). Whomever the broad definition originated from, by the 1950s and 1960s many writers had started propounding definitions, which significantly extended the scope of the term. Most of those studies therefore tended to depict technology as a concept with a meaning much greater than the hardware, machines or

individual apparatus normally associated with technology in earlier popular thinking (Willoughby, 1990).

For example, Ellul defines technology as the “totality of methods rationally arrived at and having absolute efficiency (for a given stage of development) in every field of human activity” (1964 p 26). Although Ellul (1964) specifically mentioned using the above phrase to describe *technique* rather than technology, his description is generally consistent with significant aspects of definitions of technology offered by other authors such as Stewart (1982). Stewart (1982) describes technology in a broad sense although no emphasis is explicitly placed on the nature of efficiency as an essential condition. Stewart identifies technology not only with the hardware of production which includes knowledge about machines and processes, but as a concept which encapsulates the skills, knowledge and procedures for ‘making, using and doing useful things’. For Stewart, technology includes methods used in both marketing and non-marketing activities: production, managerial and marketing techniques; product design and how they are produced; manufacturing, agriculture and services (e.g. administration, education, banking and the law); and the organisation of productive units (Stewart, 1982).

Others have stressed knowledge as the main defining characteristic of technology. MacDonald (1983) for example refers to technology as the sum of knowledge, which allows things to be done but frequently through the use of machines (not always, though) and the information the machines possess. In a more recent work, Mokyr starkly observes that “Technology is knowledge” (2005 p 1120), essentially reducing the relationship between technology and knowledge to a mathematical equality. However, Mokyr further notes that the basic unit of analysis of technology is the technique, which he defines as the set of instructions for producing goods and services, and decoupled the techniques from artefacts or machines. In his example, a piano is an artefact; however, what one can do with it depends on the technique the user employs, suggesting that a technique is never the same as the artefact, which aids the deployment of the technique. Contrarily, Willoughby defines technology as the “ensemble of artefacts intended to function as relatively efficient means” (Willoughby, 1990 p 38). He shows that the phrase “function as relatively efficient means” helps to avoid the tendency of equating technology to artefacts and helps to isolate artefacts that are technological from those that are not.

Thus far, artefact-based and procedure/ technique-based definitions have been mainly identified. Rather than being competing ways of defining technology, Dosi and Grazzi (2009) have suggested that the latter representation in many ways complements the former and emphasised the usefulness of the artefact-based definition in two respects: (1) it allows for the dynamic study of innovations which take place by improving or modifying the performance characteristics of each component of the artefact and the whole artefact; and (2) it helps to identify the technical and economic characteristics of specific products, machines, components and intermediate inputs. They however acknowledge the broader scope of the procedure-centred definition by observing that it applies even when technology cannot be represented in the form of a tangible artefact.

The apparent ambiguity, also fuelled by semantic difficulties, led Winner (1978) to avoid any attempt to define technology in any concrete or selected terms. Rather, he provided a typology for the term, based on the different emphases highlighted by different writers. In his typology, technology refers to *apparatus, technique, or organisation (and even the network between organisations)*. Apparatus represents all objects described as technological such as tools, instruments, machines, appliances, weapons and gadgets, which are used for performing a variety of activities. This description corresponds with what other writers have referred to as artefacts. Techniques refer to the body of activities involving skills, methods, procedures and/or routines used for accomplishing tasks. This definition closely aligns with Stewart's and Ellul's views about techniques discussed above. In a similar fashion to Stewart, Winner represents organisations as diversities of technical, rational and productive social arrangements; however, Winner (1978) recognises the network between different productive units as an essential organisational form.

## **2.2 Technology choice**

Apart from being somewhat elusive to define, controversies have existed about the benefits of technology for human existence and ecosystems in both academic and policy circles. Referring to those who hold up the positives of technology as “boomsters” and their opponents as “doomsters”, Ruttan (2001) indicates that commentators (especially those across disciplines) on technological change have largely not agreed on its actual and potential impacts. According to Heertje (1977 p 1-2), “some authors stress the prosperity that technical change brings, while other stress its horrors ... terrifying wars that modern sophisticated weapons permit”. Broadly, however, it is within this controversy that the concept of



technology choice appears to derive its essence (Willoughby, 1990). Willoughby indicates that technology choice “may be seen as an attempt to get beyond the simplistic options of either uncritical acceptance or uncritical rejection of technology” (1990 p 5) and that its use as a focus for analysis acknowledges the existence of inappropriate technologies, around which critical issues converge. In the subsections that follow, the basic elements of two approaches to technology choice are discussed.

### ***2.2.1 The neoclassical approach***

In the neo classical framework, technology choice is made from an infinite set of technically efficient techniques. The framework is based on a number of assumptions: The state of technological knowledge is defined by a continuous production function; there are two factors of production – capital and labour – which are homogenous in producing a homogenous output; factor and product markets are perfect so that the factors of production are rewarded with the value of their marginal products; and firms maximise profits. The consequence is that in producing a given output, capital and labour could be combined in an infinite number of ways with no regard to the level of returns to scale. The model regards technology choice as deciding between technically efficient techniques of varying factor intensities. Based on the relative factor price, firms choose techniques that minimise their production cost; hence, with a given production function, the relative factor price becomes the sole determinant of technology choice.

An important implication of the neoclassical framework is that insofar as the relative factor price reflects factor endowment, countries with different factor endowments will choose different techniques. That is, capital-endowed countries will select capital-intensive techniques while labour-endowed countries will select labour-intensive techniques (Clark, 1985).

The neo classical model has been described as a special case, which has limited relevance in practice (Stewart, 1982). Many of the criticisms are associated with the realism of its assumptions. The paragraphs below highlight a few of the shortfalls while helping to unravel other factors, which in addition to relative factor price, are important to understanding the nature, outcome and implications of a technology choice:

1. Factor prices may not be perfect in the real world, with the effect that the prevailing relative factor price may deviate from that of a perfect competitive market. Reasons

cited for this includes information asymmetry in factor markets, monopoly control of resources and minimum wage legislation (Clark, 1985). Another factor identified as being a culprit for distortion in relative factor price is *shirking* – a moral-hazard situation where workers do less than what they agreed on with their employers. Using empirical data on private farms, operating in Jewish Palestine, Depken II *et al.* (2001) show that while shirking is a likely reason for distorted relative factor prices, it also leads to greater labour hoarding, an evidence for technical inefficiency. They concluded that when shirking causes allocative inefficiency, then technical inefficiency arises endogenously as a rational response.

2. The model tends to ignore any influence that scale of production or the technology may have on choice. Scale can lead to an important difference between the efficiency of different techniques even if factor prices remain unchanged or are not distorted (Stewart, 1982; Kaplinsky, 1990).
3. Capital and labour are obviously not the only inputs in production and may not be homogenous (Stewart, 1982). The homogeneity assumption also renders the decision-making problem too simple because it “helps” to neglect the qualitative differences within the broad categories of inputs (capital and labour) we observe in the real world (Stewart, 1982). The fact that different technologies may have varying requirements in terms of inputs suggests that technology choice in reality will be influenced by the availability of a wide range of inputs.

### ***2.2.2 Appropriate technology***

The concept of technology choice finds meaning in the idea that some technologies may not be appropriate, thus, the term appropriate technology, which according to Kaplinsky (2011a) evolved as a response to the pitfalls of the neoclassical framework. Its evolution has roots in the development philosophies of India’s Mahatma Ghandi (Akubue, 2000). However, it was Schumacher’s seminal work “Small is beautiful”, published in 1973, that popularised the concept and guaranteed it a place in policy and development thinking, particularly during the 1970s and a greater part of the 1980s (Kaplinsky, 1990).

With inspiration from his progenitors, particularly Ghandi, and his professional experience as an economist advising several governments of developing countries (Willoughby, 1990; Schumacher, 2011), Schumacher recognised that production in advanced countries was

largely driven by capital-intensive technologies that suited large-scale mass production. This form of production, according to him and his many sympathisers (McRobie, Stewart, Kaplinsky, Willoughby, just to mention a few), were unsuitable for developing economies due to factors such as low income levels, limited market size, high unemployment and limited infrastructure; hence, it was a major culprit for underdevelopment. To remedy this problem, Schumacher insisted on the development and application of what he termed intermediate technologies:

If we define the level of technology in terms of 'equipment cost per workplace', we can call the indigenous technology of a typical developing country - symbolically speaking - a £ 1 -technology, while that of the developed countries could be called a £1,000-technology. ... If effective help is to be brought to those who need it most, a technology [a £100- technology] is required which would range in some intermediate position between the £1-technology and the £1,000- technology. ... Such an intermediate technology would be immensely more productive than the indigenous technology (which often in a condition of decay), but would also be immensely cheaper than the sophisticated, highly capital-intensive technology of modern industry". (Schumacher, 1973 p 148)

The ideas of Schumacher resonated among some academics and policy think tanks so much so that appropriate technology became a movement, but with several strands, which reflect the multiple meanings attached to the concept (Kaplinsky, 1990). The multiple meanings given to the concept spins off into three main lenses of appropriateness: *social, economic and environmental*. The consequence is that appropriateness becomes relative and linked to the dynamic of the political economy of the country concerned (Kaplinsky, 1990). Thus, the critical question is: whose interest or what end defines the appropriateness of the means – technology – and the choice to be made?

With inspiration from the appropriate technology concept, Stewart (1982) provided an analytical framework for technology choice. Following her definition, as mentioned in Section 2.1, Stewart distinguished between technology available to a particular country and technology in use in that country. Technology available to a country refers to the body of techniques that the country potentially has knowledge about and would be able to acquire and each technique in the available set is associated with a set of characteristics. These techniques constitute a subset of all known techniques in the world. Technology in use, on the other

hand, consists of a subset of the available techniques the country has acquired. A country may not have access to all known techniques in the world and that is usually the result of weak communication restricting the international diffusion of some of the world's techniques. Another reason is that techniques may be known but they may not be available to a country because no one is producing the machinery or other inputs required. These two factors, according to Stewart (1982), limit the options in the technology basket available to a country.

However, the diffusion of certain techniques may also be limited by other factors such as institutional protection (property rights) and corporate secrecy. This omission however does not limit the main conclusion from Stewart's analysis, which is: "If the technology in use is thought to be inappropriate, it may be inappropriate because world technology is inappropriate or because inappropriate subset is available to the country or because inappropriate selection is made or for some combination of the three reasons" (Stewart, 1982 p 3).

### **2.3 Other determinants of technology choice/ adoption**

As can be gleaned from the above discussion, the characteristics of technology such as scale, the nature and cost of the required inputs and availability of the technology are important determinants of technology choice. However, there other important factors as well. Daniels and Robles (1992) argue that technology choice occurs in a multivariate setting where many factors at the country and industry level as well as product and innovation specific variables are important. In this section, other determinants such as firm characteristics as well as government's macro and meso policies are discussed.

#### ***2.3.1 Firms' characteristics and target market***

In reality, firms are not homogenous as assumed in the neoclassical analysis but may differ in many ways. They may differ with respect to their objectives, size, knowledge about available technologies, resources available to the firm, which include material inputs, labour of various skills, and capital equipment (Stewart, 1982, 1987; and Stewart and Ranis, 1990). For example, a government-owned corporation may have other aims apart from profit maximisation (e.g. employment expansion) compared to a locally owned public enterprise, and this may have implications for technology choice (Stewart, 1982). Thus, the

characteristics of firms may influence technology choice since firms are not homogenous in reality.

Many other studies including empirical work point to the fact that firms' heterogeneity has important implications for technology choice. Using empirical data on looms for cotton textile weaving in Korea, Rhee and Westphal (1977) found evidence that firm characteristics (such as size, ownership and location) have implications for the choice between semi-automatic and automatic loom technologies and between domestic looms and imported looms. A recent empirical study by Bertschek *et al.* (2013) on German firms also confirms that firms' heterogeneity can lead to different technology choice. Brandt and Zhu (2005) used survey data on 250 firms in Shanghai and found that a firm's attributes such as age, size and human capital influence its technical capacity, which in turn affects the firm's decision to adopt a technology or not. Brandt and Zhu's study further shows that among firms with the same technical capacity, the ones with better access to cheap bank credit are more likely to embark on larger technology projects and invest more in imported equipment from technologically advanced countries. Similarly, with an empirical analysis based on data from five Latin American countries, Hasan and Sheldon (2013) confirm that firms face credit constraints in technology adoption.

Negri and Brooks (1990) examined the determinants of farmers' choice between two irrigation technologies with a national cross sectional data on US farms. They found that farm size had a significant and differing impact on the selection of the two irrigation technologies, although soil characteristics of the farm appear to dwarf the impact of all other factors for the two technologies including size. Moreno and Sunding (2005) examined how a farm characteristics and technology characteristics affect the adoption of irrigation technology in a nested logit model, using data from Kern County in California. Their results indicated that farm characteristics, (and hence, generally the characteristic of unit for which the choice is made) are important for technology choice or adoption.

Other studies have also emphasised the importance of firm size as a determinant of technology choice. Hannan and McDowell (1984) studied factors which influence banks' adoption of ATM technology and found that larger banks had a higher probability of adopting ATM technology, all things being equal. Dorfman (1987) suggested that firm size plays a key and positive role in the level of innovative activities of firms, an argument that Hall and Khan (2003) believe is applicable to the adoption of a new technology.

Much earlier studies on technology adoption (such as Ryan and Cross, 1950; Griliches, 1957; and Mansfield, 1961) showed that the extent of contact between users and potential adopters of a technology has a major influence on the potential adopters' choice in favour of that technology. While these earlier studies' main focus was to explore the rate of diffusion of innovations, the factors they identified to influence diffusion inherently underpins technology choice or adoption (at the micro level) by firms. Other studies on diffusion such as Salter (1960), Davies (1979) and Karshenas and Stoneman, (1993) have also emphasised the importance of firm heterogeneity particularly with respect to factors such as the firms' age, size, capital vintage, corporate status and R&D expenditure. It has also been recognised that firms may also differ in terms of their access to a fixed critical input needed for a technology (Ireland and Stoneman, 1985; Fundenberg and Tirole, 1985). Moreover, strategic interactions between firms are also important for adoption behaviour (Reinganum, 1981; Quirnbach, 1986).

The discussion thus far shows that one of the most important determinants of technology choice is firm size. Reasons given in the literature for the importance of firms size to technology adoption include: (1) large size allows for appropriating the benefits of scale economies given that the new technologies may be scale-enhancing (Hannan and McDowell, 1984; Dofman, 1987), (2) the possible differences in managerial attitudes and risk exposure for firms of different sizes (Hannan and McDowell, 1984). However, Hall and Khan (2003) note that large size can negatively affect a firm's adoption decision because larger firms tend to have sophisticated bureaucracies that may also slow down the adoption decision.

Other factors that may affect a firm's adoption of technology include the target market of the firm, which may also be considered as an attribute of the firm. Daniels and Robles (1992) examined the relationship between export commitment of textile firms in Peru and their adoption of capital-intensive technologies. These authors found a positive relationship, for which their explanation was that exporters appear to be more concerned with product quality perceptions and reliable delivery outcomes. Stewart (1987) also argues the nature of markets (with regards to size, industry and type) that a firm faces also affect technology choice. By "type" of market, she referred to the various segment of the consuming market that a firms produces for, which could be high-income or low-income market on one hand and local or international markets on the other hand. She however noted "... the market is also a variable that can be changed by the activities of the firms" (Stewart, 1987 p 6).

Relatedly, Hall and Khan's study (2003) suggests that a secure customer base for a firm may positively affect its technology adoption decisions. Similarly, in a study on the adoption of computerised and numerically controlled (CNC) machines by firms in the auto component supply industry in the US, Helper (1995) found that a firm's relationship with customers (a form of guarantee for future demand) influences the firms' choice in favour of the CNC machines.

### ***2.3.2 Government policy/regulation and macroeconomic conditions***

The external environment of a firm influences its technology choice although the actual decision usually takes place at micro level (i.e. by the firms) (Stewart, 1987). Government may directly intervene in particular investment decisions in technology as well as indirectly influence the technology choice of micro units (or firms) by using macro and meso policies to alter the external environment within which the firm operates (Stewart, 1987; Stewart and Ranis, 1990).

According to Stewart (1987), the macro-policies that may affect firms' technology choice range from those that are geared towards major economic aggregates such as money supply and credit creation, interest rates, budget deficits and trade protection to policies that influence technology supply and market access. Meso policies are however concerned with the distributional and sectorial implications of macro policies and are also used as a tool to influence technology choice (Stewart and Ranis, 1990). Based on the results from many empirical studies, Stewart and Ranis (1990) show how macro and meso policies indirectly affect firms' technology choice through their impact on the firms' objectives, resource availability and cost, markets in which they operate, and technology availability. For example, government policies to increase interest rate will lead to an increase in the cost of borrowing to finance machine acquisition while government-subsidised credit facility for investment in farm machinery, for example, may encourage farmers to invest more in mechanisation techniques.

Other empirical studies that have found a significant influence of the regulatory environment on technology choice or adoption include Hannan and McDowell (1984) and Gray and Shadbegian (1998). Hannan and McDowell's study shows that the regulatory environment for banks affects their decision to adopt a technology. In Gray and Shadbegian's study, they found that technology choice by firms in the US paper and pulp industry was affected by changes in environmental regulations that took place in the US between the 1970s and 1980s.

Government policy and regulations cannot be overemphasised but also important is nature of the macroeconomic environment, which is in part conditioned by government policies. For example and as noted earlier, a firm's access to finance is critical for technology choice; however, credit constraint at the micro level is also embedded or conditioned by the dynamics within the aggregate financial system, of which the neoclassical framework for technology choice pays no attention to. Interestingly, studies such as Hicks (1969) and Bencivenga *et al.* (1995) showed that the behaviour of financial markets can affect the equilibrium choice of technology. Hicks (*ibid*) argued that it was the financial revolution in the first half of the 18<sup>th</sup> century Britain that paved the way for the industrial revolution, which started in the second half of that century, and that the latter revolution did not happen merely due to the advent of newly discovered technologies. He observed that a highly significant part of the technical innovations associated with the industrial revolution had already existed before the start of the industrial revolution. However, they were not in use because they required large-scale illiquid capital investments, which were unattractive because well-functioning financial markets were absent. According to him, England by the 1750s had developed financial markets, which would support the adoption of technologies with high sunk cost. Bencivenga *et al* (1995) formally examined the theoretical implications of Hicks' observation in an overlapping generations model with production and shows how the cost of financial market transactions affect the set of technologies in use and the equilibrium growth rate of the economy.

Munro (1989) places much emphasis on the importance of macroeconomic conditions on technology choice. He argues that "... the whole gamut of macro economic structures are relevant to the choice of techniques" (1989 p 22). His study on Bhutan found that macroeconomic and environmental conditions of Bhutan have important implications for technology choice and that labour intensive technologies generally deemed appropriate for developing country were inappropriate in the context of Bhutan.

## **2.4 Technology transfer**

Grosse (1996) defines technology transfer as the diffusion of a technology from the place of its introduction to another. Having emerged in the late 1960s, this subject has received much attention especially in academic circles; hence, the literature on the subject is vast and varied (Contractor and Sagafi-Nejad, 1981).



Technology transfer can either be vertical or horizontal, as discussed in Mansfield (1975) and Grosse (1996). Vertical technology transfer occurs when knowledge from basic science is used in applied research and that from applied research results in product development and finally production (Mansfield, 1975). The process by which the famous US hybrid corn technology<sup>2</sup> was developed and applied for commercial maize production encapsulates the idea of vertical technology transfer. The hybrid corn was developed in the laboratory of the Iowa State Agricultural Experiment Station in 1928 and was later adopted by the majority of corn growers in Iowa. Horizontal technology transfer, on the other hand, involves transferring a technology used in a place, organisation or context for use in another place, organisation or context (Mansfield, 1975). The type of technology transfer that occurs when multinational corporations set up subsidiaries in foreign countries is a specific form of horizontal technology transfer. A study by Noisi and Zhegu (2010) provides a good example of this type of technology transfer within the commercial aircraft manufacturing industry. They show that commercial aircraft manufacturing technologies from their places of origin (Western Europe and North America) have been transferred to newly industrialising countries such as Brazil, Russia, India and China (BRICs). They further note that these new entrants into the aircraft manufacturing industries are doing so well that the North American and Western European industries risk losing their dominance to their developing country counterparts.

While both vertical and horizontal transfers incite much inquiry, this paper focuses on horizontal technology transfer. Analysing mainly from the perspective of firms, particularly multinational companies (MNCs), a strand of the literature on horizontal technology transfer has focused on the transfer process and the effectiveness of the transfer. Examples are the work by Al-Ghailani and Moor (1995), Djeflat (1988), Godkin (1988), Kumar (1995), Dahlman and Westphal (1981), Mockler (1995), just to mention a few. Another set of the literature has however concentrated on the mode (or mechanism) of the transfer and factors determining the choice of a particular transfer mode. This paper focuses on the latter set of the literature, of which the survey for this paper shows that the mode of technology transfer can take several forms, depending on the governance structure between the transferor and the transferee (Contractor and Sagafi-Nejad, 1981; Grosse, 1996; Steenhuis and de Bruijn, 2005; Chen, 2005). Generally, the transfer can take place through arm's length market, direct investment and through the network forms between firms, which may be global in the case of international technology transfer.

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<sup>2</sup> Details on the hybrid corn technology can be found in Ruttan (2001)

### Arm's length market

Arm's length market as a mode of transfer involves a firm selling a product, process or skill to another (Grosse, 1996). For transfer across international borders, the arm's length arrangement involves importation or more generally trade. Many studies therefore consider trade as a mode of technology transfer (examples include Saggi, 2002; Das, 2000; Groizard, 2002; Mayanja 2003; Le, 2008; de la Tour *et al.*, 2011), which is generally synonymous with the arm's length market mode.

Trade in both consumption and capital goods can serve as a means of technology transfer because domestic firms get the opportunity to absorb technological knowledge embodied in the imported goods (Saggi, 2004; Hoekman *et al.*, 2004). The literature however shows that trade in capital goods that are used for manufacturing consumer and intermediate goods produce higher benefits than trade in consumption goods (Saggi, 2004; Xu and Wang, 1999). Kim (1991) showed that capital goods importation served as a major channel for technology transfer from Japan, the US and other advanced economies to South Korea between the 1960s and 1980s, with the imports from these sources increasing significantly throughout that period. A more recent study by Munemo (2013) also provides empirical evidence supporting the idea that trade in capital goods serves as a significant technology transfer channel. Using trade flow data from UN COMTRADE, Munemo (2013) found that increases in SSA countries' importation of capital goods from China enhances economic growth in Africa, advocating for trade liberalisation policies that attract Chinese capital goods on a non-preferential basis.

For disembodied technologies such as process techniques, patents, trade secrets and industrial designs, the transfer usually involves licensing agreements between the buyer and the seller of the technology item. Chen (2005) however suggests that even where licensing is used, it is not the only market arrangement through which the technology can be transferred but represents only one option under market based governance structures underpinning technology transfer. He argues that the transferor or technology developer and the recipient (or transferee) may have complementary capabilities in the sense that marketing the final product (manufactured by the transferee) may provide opportunity for the transferor to also market its technology as if it were a separate product. In this way, the two parties can carry out *co-marketing* to customers while maintaining an arm's length relationship.

### **Direct investment**

In addition to arm's length market arrangement, internalisation theory of the firm with its focus on transaction cost analysis suggests that technology transfer can take place within a firm through direct investment (including foreign direct investment in the case of international technology transfer) where the transferor establishes a subsidiary. Many studies such as Contractor (1984), Anderson and Gatignon (1986), Gatignon and Anderson (1988), Chen *et al.* (2001), Rugman and Verbeke (2003) and Niosi and Zhegu (2010) have emphasised direct investment as an important entry mode for firms seeking opportunities in foreign markets and at the same time transferring technologies to those markets.

### **Network modes and global value chain (GVC) governance structures**

The arm's length market/trade and direct investment were the modes initially emphasised in the literature. For example, Contractor's (1984) examination of the factors influencing mode of transfer only focused on the choice between licensing (an example of arm's length market mode) and direct investment. A major difference between these two modes relates to the degree of control exercised by the transferor over the transferee. At one extreme of the spectrum of control is licensing, which involves very little or no control, and at the other extreme is direct investment, representing absolute control. In other words, the governance structure between the transferor and transferee is what delineates the different modes of transfer (Saliola and Zanfei, 2007). Between these extremes are hybrid forms of governance relationship, defining other modes of transfer such as joint venture and crossing licensing (Anderson and Gatignon, 1986; Hernnat; 1988; Chen; 2005).

The role of the governance structure between the transferor and transferee in defining the different modes of transfer has been emphasised in the global value chain (GVC) framework. A GVC is a value chain<sup>3</sup> whose various links are fragmented over different parts of the world. Gereffi *et al.* (2005) identifies five GVC governance types – hierarchy, captive, relational, modular and market. These different structures reflect the varying degrees of “explicit coordination” and “power asymmetry” between the firms that are participating in the different links and sub links within the chains. Characterised by a high degree of explicit coordination and power asymmetry, hierarchy structures involve vertical integration through

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<sup>3</sup>Kaplinsky and Morris describe a value chain as “...the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use” (2001 p 4). Production for example forms a link within the chain and each link within the chain may also have sub-links.

direct investment, thus, hierarchy is synonymous direct investment channel discussed earlier. For captive structures, suppliers in the chain become dependent on lead firms, who monitor and control their activities while a relational structure is usually characterised by a high degree of mutual dependence and asset specificity. In the case of modular structures, the suppliers in the chain make products to customer's specification, taking responsibility for technology usage and investment. The market structure involves arm's length relationship, as described earlier, with very low explicit coordination and power asymmetry.

After the seminal work of Gereffi *et al.*, more recent studies (e.g. Palit, 2006; Saliola and Zanfei, 2007; Brach and Kappel; 2009; Pietrobelli and Rabellotti, 2011) have specifically attempted to understand international technology transfer mechanism using the governance structure in GVC framework, as outlined above. Saliola and Zanfei (2007) suggest that all the types of governance structures correspond with different modes by which international technology transfer can occur. Brach and Kappel (2009) show that long term contracts and subcontracting within global value chains have emerged as important forms of transnational cooperation, hence, as important channels for technology transfer. They indicate that for non-OECD countries these channels are critically important since such countries attract limited amount of foreign direct investment and undertake little to no original research and development. Pietrobelli and Rabellotti (2011) corroborate this observation by noting that participating in GVC is important for small firms, operating in developing countries because it provides "...crucial means of obtaining information on the type and quality of products and technologies required by global markets and of gaining access to those markets" (2011, p 1262). In Niosi and Zhegu's (2010) study, they provide empirical evidence on GVCs as a major channel for the transfer of commercial aircraft manufacturing technology from North America and Western Europe to the BRICs.

### **Other modes of transfer**

In addition to the modes already discussed, other modes of transfer can be identified in the literature. These include migration, franchising, turnkey projects, technical consultancy and official development assistance between nations (Jafarieth, 2001; and Buckley, 1985; Kim, 1991). Thus, a thorough survey of the literature reveals many different modes of transfer, which are partly due to the existence of a variety of technology forms, as discussed earlier in Section 3.1. For specific forms of technology, therefore, some of the modes discussed may

not apply. Maskus (2004) suggests that the bulk of technology transfer mainly occurs through FDI, trade and licensing contracts.

#### ***2.4.1 Choosing a mode of technology transfer***

Dating back to the work of writers such as Mansfield (1975), Teece (1977), Contractor and Sagafi-Nejad (1981) and Contractor (1984), the literature shows that the primary determinants of the choice of a transfer mode are the cost associated with the technology transfer and the degree of appropriability of the proprietary advantage associated with the technology at the destination. Rather than referring to the royalty costs or rents that must be incurred merely to gain access to the technology, Teece (1977) defined transfer cost as the cost of transmitting and absorbing all of the relevant disembodied knowledge, that may either be associated with embodied technology or may represent the entire transfer object. Appropriability involves the extent to which the transferor can maximise and extract the returns including any likely monopoly rents (Contractor, 1984). Contractor further indicates that the corporate choice amounts to a comparison of the risk-adjusted net present values of the income stream realisable from a destination under the various modes applicable.

The transfer cost and returns are in turn determined by many factors relating to the characteristics or type of technology, the characteristics of the firms (transferor and transferee) involved, the characteristics of the industry, the characteristics of countries of both the transferor and transferee with respect to government policies, markets, and economic, political and cultural conditions in general (Caves, 1971; Davies, 1977; Contractor 1984; Davidson and McFetridge, 1985; Grosse, 1996, Teece 1977). For example, Davidson and McFetridge (1985) suggest that internal transfer mechanisms through direct investment may be preferred to arm's length market transaction if the technology being transferred is new with limited transfer history and the parties involved have little or no experience in similar transactions. With regards to GVC governance modes, Gereffi *et al.* (2005) specifically mentioned three factors – the complexity of transactions, ability to codify transactions and the capabilities in the supply base – as the determinants of the choice or the evolution of a particular governance mode.

### **3. The conceptual framework**

This section presents the conceptual framework for analysing the development implications of technology transfer from China to SSA based on insight from the various literature

discussed. Figure 1 diagrammatically depicts the framework. Indicated in the figure are the likely determinants of technology choice, the extent of diffusion of a technology (shown in the figure as the aggregate level of adoption) and the transfer mode. The factors influencing technology choice may be grouped into five categories: the characteristics of the decision maker (or say, the firm); the characteristics of the technology; the nature of final markets; government policies; and macroeconomic conditions that may affect the operations of the decision maker or firms.

The diagram shows two other sources of technologies (indigenous and advanced country sources) in addition to China. An oval has been placed around the Chinese and advanced country technologies in the figure just to indicate that they are imported. Advanced country technologies generally refer to technologies from any of the member states of the Organisation of Economic Cooperation and Development (OECD). It should be noted that while three sources of technologies are used in the diagram, the framework could accommodate other sources, whether it is a single country or a group of countries.

The figure shows that the factors which influence technology choice can also determine the choice of a transfer mode, that is, whether a technology is transferred through arm's length market, direct investment or through the transferee's participation in the global value chain (that is, governed GVC structures) or any form of network between firms such as joint venture. Conceptually, these factors can influence the choice of a transfer mode in two main ways: They can *directly* affect the choice of a transfer mode or *indirectly* through the choice of technology. A decision maker may think about these factors in relation to the technology options and the various transfer modes simultaneously, in which case these factors have direct impact on the choice of the transfer mode. On the other hand, another decision maker may first decide on the technology to choose after which he/she will decide on the mode or channel to use. In this case, the technology choice mediates the factors and the choice of the transfer mode.

While the choice of technology may influence the choice of the mode of transfer, it should be noted that the availability or accessibility of a particular mode to a decision maker may also influence technology choice, as indicated by the two arrows pointing back to the technology choice in the diagram. Thus, there could be an endogenous relationship between technology choice and the choice of transfer mode. This is true for instances where the decision maker thinks simultaneously about the technology options and the transfer modes. The reason for

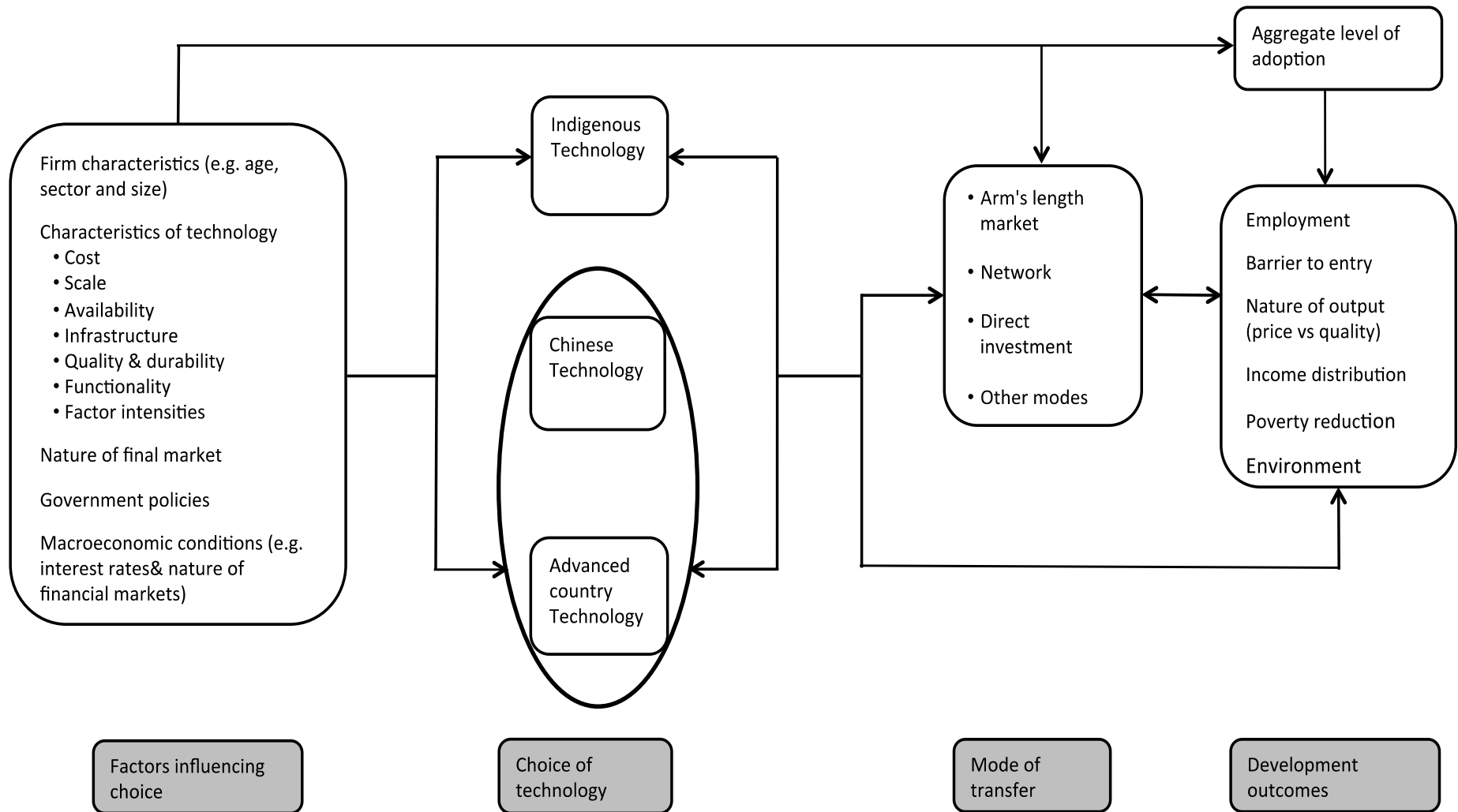
the endogenous effect is that the nonexistence or inaccessibility of a transfer mode may make certain sources of technology unattractive for some of the firms. In the case where the decision making process is largely linear and unidirectional, the endogenous effect of the transfer mode on technology choice may not exist.

In terms of development implications, the chosen technology with its characteristics may directly influence development outcomes such as employment, income distribution and poverty reduction as indicated in the diagram. At the same time, the choice of technology may indirectly affect development outcomes through the mode of transfer used. This is because the choice of technology, as noted earlier, may determine the mode of transfer selected while each mode of transfer may lead to different development outcomes.

If we make allowance for choices or decision making to be carried out in more than one time horizon (i.e. inter-temporal choice process), then, the resulting development outcomes of choices, say, in the first period may affect the choices in the second period via government policies/programmes. Another likely channel for such feedback effect is the firm's social responsibility programmes if they are built into the firm's technology choice. For example, in order to create more employment a firm may choose to use labour intensive technologies particularly if such technologies are not less efficient than capital intensive ones available. It should be noted that one would need to collect data, spanning at least several time horizons in order to study the dynamic relationship between choice and the development outcomes. For other relationships discussed, however, a cross sectional data as well as qualitative data collected at a point in time may suffice.

The factors affecting firms' choice will essentially determine the extent of diffusion or the aggregate adoption of a technology within the industry. The framework highlights the aggregate level of adoption because it indicates the extent to which the use of a particular technology is affecting aggregate development outcomes. For example, if Chinese technologies are distinctive and produce desirable development outcomes, then the level of adoption will inform us about the potential aggregate development impact within the industry. It therefore gives additional insight into the findings obtained from whether a firm has adopted the Chinese technology or not and why. If very few firms use the technology that produces the desirable development outcomes then that may prompt policies to encourage the adoption of that technology.

Figure1: Conceptual framework



Source: Author



#### **4. Conclusion**

An important way by which Chinese rising influence may affect SSA economies may be technology transfer from China, which has in recent years recorded a phenomenal growth in innovative capabilities. This paper sought to review literature on various issues concerning technology, informing a conceptual approach to analysing the development implications of such potential transfer of technologies from China to developing economies especially those in SSA.

The literature review started with the various meanings given to the term technology and it has been shown that technology can stand for an artefact, a technique (or a process), a form of organisation and the network between organisations. Technology choice and its associated concept of appropriated technology were reviewed. These two concepts highlight the fact that even if technologies from China possess characteristics amenable for development in SSA economies, a choice has to be made, which can go in favour of inappropriate technologies depending on the factors determining the choice. Thus, these factors are crucial because they can lead to the selection of inappropriate technologies and foster a development trajectory that is not pro-poor. The determinants range from the characteristics of the technologies available, the characteristics of firms or the decision maker and final product markets to government policies or regulatory environment, nature of financial markets and economic conditions in general. To varying degrees, each of these factors constitutes a window for policy interventions that can facilitate appropriate choice of technology.

The literature review also showed that technology transfer occurs through a multiple of channels such as arm's length trade, direct investment and the network structures that characterise global value chains. These channels may have different implications in terms of the effectiveness of the transfer and wider development outcomes. The selection of a transfer mode also depends on certain factors which include the characteristics of the technology being transferred, the characteristics of the transferor and transferee, and the socio-economic conditions including government policies in the transferor's and the transferee's environment.

While the different transfer modes may have different implications for development, the choice of the transfer mode may exhibit a bi-directional relationship with the choice of technology. The implication is that choice of technology and choice of transfer modes should be studied together in order to have an appreciable understanding of the development

implications of technology transfer from any of the sources and the potential impact of any policy intervention. It also serves an insight for framing the required policies to direct technology choice.

However, empirical research is needed to validate the relationships derived in the framework. The research agenda, among others, can focus on the following research questions: What are the major technologies types (artefacts, process, etc.) being transferred from China to SSA economies, how distinctive are they and in what sectors? What transfer mechanisms do they use? What is their impact in terms of development and in what ways are they more or less appropriate compared to technologies from other sources? How do existing government policies and economic conditions affect the transfer process?

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