Trade and Investments through Global Value Chains (GVC) and Technology Transfer: A Panel Smooth Threshold Regression Approach (PSTR)

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Abstract

The objective of this paper is twice: providing a new indicator of export sophistication index that can be used as a proxy of the level of technology created at home and investigating the effect of interactions through Global Value Chains on technology transfer. Considering China's growing but criticized presence in Africa over the last decades, this paper investigates the effect of the presence of China in Africa (through value-added trade and foreign direct investments) on the level of technological sophistication of African countries' exports independently of the determinants of this presence. Using a panel smooth threshold regression model on 49 African countries from 1995 to 2015, we attempted to identify whether interactions between China and African countries through global value chains have led to technology transfer. Technology transfer was split into direct and indirect technology transfer. The results highlighted the absence of direct technology transfer from China to African countries except for those that are highly endowed with human capital and strong institutions. In addition, evidence existed of indirect technology transfer through imports of intermediate goods by African countries from China. Compared with relevant literature, we used a new approach focusing on domestic value-added export sophistication that allows to measure only technology coming from the value added effectively created by a country, thus withdrawing foreign technology contained in in the index. We also investigated technology transfer resulting from value added created in China and exported to African countries; this prevented us from capturing technology transfer that resulted from China in addition to its trade partners.

Keywords : Global value Chains, Technology transfer, Trade, China, Africa

JEL Code: F14 F23 O33

1 Introduction

International cooperation between countries has long been characterized by profit maximization, risk limitation, dependence on natural resources, as well as political and geopolitical interests. The last decades have been distinguished by the increasing presence of China on the international economic stage and its increasing presence in Africa. This is marked by the presence of Chinese-owned firms in Africa, the increasing volume of trade between the two parties (China has become the first trade partner of overall African countries (Chen et al. (2016a))]) and Chinese loans to these countries as well as the level of Chinese investment in Africa. The presence of China in Africa has long been debated by policy makers and politics in Africa and abroad. Some analysts think that China's increasing interest in Africa is only guided by its need for natural resources to meet energy needs (Cai, 1999; Dollar, 2016). Former US presidential candidate Hillary Clinton warned against "new colonialism" in Africa. However, despite this negative conception of the Chinese presence in Africa, other analysts consider the interaction between China and Africa to be a way for African countries to upgrade and to foster their growth (Dollar, 2016); this is in line with what China's President Xi Jinping declared during the 2018 Beijing summit of the Forum on China–Africa Cooperation: "China does not invest in vanity projects in Africa and is helping the continent build its infrastructure." Therefore, two theories exist regarding the presence of China in Africa. Proponents of the Chinese presence usually argue in favor of its spillover effects on African countries growth (i.e., the resulting learning effects from Chinese experience). Indeed, trade and foreign direct investments (FDIs) through global value chains (GVCs) have become effective channels through which developing economies can upgrade their industrialization process and avoid following the same path that developed countries used to achieve their development. With changes in the production process and international fragmentation, countries have become more connected with each other. Such connection (i.e., openness through GVCs) may be a good opportunity for developing countries to learn from advanced countries and upgrade their technology. This is why some policy makers believe that regardless of the objective behind China's presence in Africa, the relevant question is whether this interaction have been beneficial for African countries. Since its accession to the World Trade Organization in 2001, China has been one of the best examples in Asia as well as globally in terms of technology upgrading, economic development, and GVCs integration. The country's success in trade is partly because of its success in taking advantage of FDIs. However since 2002, minimum wage is increasing in China, and the resulting higher labor costs are encouraging Chinese firms to relocate overseas. The situation was exacerbated by the 2008 global financial crisis, which lowered the demand for Chinese goods. Therefore, China has been planning to change its economic model, providing opportunities for less developed countries in Africa and Asia (Chen et al., 2016b). The presence of multinational enterprises (MNEs) in China was partly because of the low labor costs; the fact these costs are increasing raises the issue of the location of these MNEs and Chinese state-owned enterprises (because of competitiveness concerns). Fan et al. (2018) showed that the increase in the minimum wage can explain approximately 32.3% of the growth in outward investment from China during 2001–2012. Therefore, China is offshoring some firms to countries in Asia and Africa. Thanks to lower transportation and coordination costs, MNEs are now able to maximize their profits even with offshored firms. China's shift from an industrial product-assembling country to a producer of high-tech intermediate goods demonstrates its ability to take advantage from international cooperation (Rueda Maurer, 2015). The aim of this paper is to investigate whether the presence of China in Africa during the past 20 years has led to technology transfer. Through applying a panel smooth threshold regression (PSTR) approach on 49 African countries from 1995 to 2015, this paper determines the empirical effects of Chinese exports to Africa as well as Chinese FDIs on the level of African countries' export sophistication and furnish a new approach of Sophistication index. The results hold evidence of the absence of direct technology transfer with the existence of a threshold of absorptive capacity (human capital and quality of institutions) above which direct technology transfer starts to be effective However indirect technology transfer occurs in the relations between China and African countries via imports of intermediate. This study is a contribution to a large body of extant literature on the spillover effects of FDIs. The remainder of the chapter is organized as follows: Section 2 presents the literature review. Section 3 presents stylized facts; Section 4 presents the methodology used in this paper; Section 5 presents data and sources; Section 6 and 7 summarizes the results of our estimations; Section 8 presents a Panel Smooth Threshold Regression approach and section 9 concludes.

2 Literature review

2.1 Spillover effects of Chinese presence

The literature review will cover all the aspects of the international cooperation–technology transfer nexus. We will first question the literature on the channel through which FDIs and trade can lead to technology transfer and then focus on the key findings of the literature about China's presence in Africa. The effect of interactions between countries (in the context of GVCs) on technology transfer is an old debate that has taken many forms: it has been presented through the spillover effects of FDIs and imports as well as directly through the advantages of integrating GVCs. Technology transfer can occur through licensing and FDIs as well as more indirectly through imports of intermediate goods and/or machinery, transport equipment, and demand effects. Licensing is a way for developing countries to benefit from high technology. However, licensing is said to be risky for the developed country (or lead firm) that provides the license if the receiving country does not have a strong rule of law or strong contract enforcement systems Stone et al. (2015). FDIs are the second way in which interactions in GVCs can lead to direct technology transfer. The literature on technology transfer through FDIs is highly rich and varied. Indeed, this is embodied in the literature on FDIs' spillover effects, from which two types can be distinguished: horizontal and vertical spillover effects. Horizontal spillover effects rely on firms acting in the same sectors; studies have found evidence of negative effects caused by foreign competition that capture market shares to the detriment of domestic firms (Aitken and Harrison, 1999; Stone et al., 2015) . Vertical spillover effects are the most probable and represented by the case of a lead firm deciding to improve the efficiency of the value chain to which it belongs, which it achieves through giving technology to its suppliers and taking advantage of a comparative advantage owned by the supplier in a specific task. In addition, once the lead firm's demand pattern changes and becomes more technology-intensive, the suppliers must follow that evolution and upgrade in technology to meet the demand Stone et al. (2015); Havranek and Irsova (2011) The literature on trade spillover effects shows that capital and the movement of intermediate goods as well as the knowledge they embody can lead to technology transfer. First, imports of capital goods are likely to lead to technology transfer because capital goods mainly comprise machinery transport equipment, which contains high-tech components. Therefore, for developing countries, importing capital goods from developed countries can lead to a technological upgrade Stone et al. (2015); Eaton and Kortum (2001). This positive effect can be explained through the diffusion of knowledge from the use of machinery imported by a firm. In addition, workers can export that knowledge to competitors and spread it through the country. Moreover, firms can use their engineering skills to deconstruct and understand how technology works and attempt to use it in their own production process or make a reproduction of the given capital good. Second, having access to the world market of intermediate goods helps countries obtain access to high-tech inputs that they would not have been able to produce. Thus, countries obtain access to sophisticated inputs, which increase their own productivity and development of new products Amiti and Konings (2007); Goldberg et al. (2010). Another indirect method of technology transfer is demand effects, which pass through demand. When developing countries produce to meet local demand, they tend to be less concerned with quality and standards. However, in the case of GVCs, some countries are integrated in global markets and have to supply developed countries' domestic demand. In that case, they will attempt to follow international standards, which will lead to technology upgrading (Bastos and Silva, 2010; Manova and Zhang, 2012; Atkin et al., 2014).

The literature on the Chinese presence in Africa is well furnished but composed of divergent findings. A growing body of literature considers the presence of China in Africa as a grace because the approach of China differs from those of Western countries, which have a bad reputation in Africa because of their role in the continent's colonial past. Some recent studies have found evidence of positive effects of the presence of China in Africa (Klaver and Trebilcock, 2011; Otchere et al., 2016; Donou-Adonsou and Lim, 2018). However, some less optimistic studies have highlighted the absence of positive spillover effects of China's presence in Africa (Ademola et al., 2009; Klaver and Trebilcock, 2011; Osabutey and Jackson, 2019). Osabutey and Jackson (2019) investigated the effect of Chinese MNEs' presence in Africa, mainly in Ghana. Their findings suggested the absence of specific technology and knowledge transfer policies and strategies in Sino–African relations. Klaver and Trebilcock (2011) analyzed Chinese investment in Africa and identified seven ways Chinese investment contribute to African growth (commodity prices, capacity to extract, infrastructure, manufacturing, employment, market access, and consumers' access to cheap products). Their findings also highlighted the existence of negative effects, because Chinese FDIs may deindustrialize Africa by outcompeting African firms given that African manufacturing is weak and suffers from many ills. Without econometric analyses, Ademola et al. (2009) conclude on the existence of both negative and positive effects but the negative effects may outweigh the positive ones for many African countries. Alfaro et al. (2004), investigate the existence of a channel through which Chinese FDIs may have positive spillover effects focusing on physical or human capital. They find no evidence of physical or human capital as the main channels through which countries benefit from FDIs. However, earlier in in the 90s, Borensztein et al. (1998), highlighted that FDIs positive effects are highly dependent on the level of educated workforce. In a most recent literature, Ademola et al. (2009), used both theoretical and empirical approaches to examine the different links between FDIs, financial markets, and growth. The model shows that increased foreign investment increases output in the investment sector (foreign production) and in the domestic sector (domestic production). Their empirical results indicate that investment contributes to economic growth owing to the development of the local financial market. Using human development index and real GDP per capita as measures of poverty. Following approximately the same method, Gohou and Soumaré (2012) examined the effect of FDIs on poverty reduction in Africa. Their results indicated a significant positive relationship between the two variables. In a different approach (i.e using poverty headcount to measure poverty), Fowowe and Shuaibu (2014) and Fauzel et al. (2015) confirmed the positive relationship between FDIs and poverty reduction. Additional studies have investigated the effects of FDIs on growth. Otchere et al. (2016) in a study of the direction of the causality between FDIs and financial market development find that FDIs has a positive and significant effect on economic growth in Africa. This result is corroborated by Soumaré (2015) when investigating foreign investment and economic development in Northern Africa. Donou-Adonsou and Lim (2018), used fixed-effects and instrumental variable to investigate the effects of Chinese presence. Their results indicate that Chinese investment improves income in Africa. However, they found a more pronounced impact for U.S. and German investment. Most research on direct and indirect technology transfer has been in the form of firm-level–based studies, and the level of technological sophistication is often captured by productivity. Few country-level studies have been conducted on this topic, and those that have tried have focused on the spillover effects of FDIs on productivity, growth and poverty. The aim of this chapter is to study country-level technology transfer using the export sophistication index.

2.2 Literature of sophistication

Several studies attempted to investigate exports sophistication. Most of them follows the same structure and the same methodology of calculation implemented by Rodrik (2006) and Hausmann et al. (2007). This index of exports sophistication has been widely used across the literature (Rodrik, 2006; Hausmann et al., 2007; Bin and Jiangyong, 2009; Lectard and Rougier, 2018; Van Assche and Van Biesebroeck, 2018; Schott, 2008; Lall et al., 2006). Bin and Jiangyong (2009) examined variations in level of export sophistication across China's manufacturing industries. The paper relies on the well-known export sophistication index introduced by Hausmann et al. (2007). More recently Van Assche and Van Biesebroeck (2018) analyzed if there is evidence of functional upgrading in China. They measured industry upgrading from the composition of China's exports across products of different sophistication within a broader sector, building on a method pioneered by Rodrik (2006) and Hausmann et al. (2007). However, several papers assessed innovation and technology upgrading using other type of measures (Wei et al., 2017; Rueda Maurer, 2015; Wang and Wei, 2010). Wei et al. (2017) in their paper, assessed the likelihood of China to make the necessary transition to generate productivity increase, and domestic innovation. One of the key questions the paper answers is what is the growth of innovation by Chinese firms? To answer this question, the paper makes use of data on patents from China State Intellectual Property Office (SIPO), the United States Patent and Trademark Office (USPTO), and World Intellectual Property Office (WIPO). It uses patent applications and patents granted by firms both at home and in the United States as proxy for innovative activities. Wang and Wei (2010) tried to assess if China's exports compete head to head with those of high- income countries. It defined an index for a lack of sophistication by the dissimilarity between the product structure of a region's exports and that of the G3 economies, or the export dissimilarity index (EDI). The sophistication of a city's export structure is measured on a year- by- year basis by its similarity with that of the G3 high- income countries Nevertheless, Rueda Maurer (2015) introduced a new index of export sophistication similar to Hausmann et al. (2007). The paper analyzed how economic integration and the international division of labor have evolved among the $ASEAN + 3$ countries in the last 20 years. It proposed an indicator of the level of technological sophistication based on revealed comparative advantages. Using comparative advantages, the methodology is presented as follow: The number of products with the Balassa (1965) index of Revealed Comparative Advantages is greater than 1 in each category are added up, weighted by the share of each product group in the country's total exports. This weighted sum multiplied by their corresponding category level are added up in the final Technology Sophistication index. The index varies from 0 to 7.7 being the highest level of technological sophistication. Our paper integrates this relevant literature by introducing a new type of sophistication index based on value-added exports.

3 Stylized facts

3.1 History of Sino-African relations

China and Africa have made contact throughout history, and up to 1949 these interactions were more the result of international trade with common trade partners and merchant civilizations (Arabs, Persians, and Turks). Such contact with African countries would later move from passive indirect contact to more involved relationships. The post-1949 relations between China and African countries have been easier because of their common past under Western imperialism. Historically, Chinese interactions with African countries are not recent and started with indirect trade relations. In fact, while not as well documented as Africa's links with Europe, trade relations between China and Africa date back to the first Han emperors of the second century BC Renard et al. (2011); Jinyuan (1984). Indeed, according to Alden and Alves (2008), Chinese interaction with African countries started during the reign of Emperor Wuti (140–87 BC) through an expedition sent west in search of allies. This expedition is said to have reached Alexandria (Egypt), which may have resulted in contact with African civilizations. The major economic achievement of the Han Dynasty (206 BCE–220 CE) was probably the opening of the Silk Road, the routes of which stretched from China through India, Asia Minor, up throughout Mesopotamia, to Egypt, Greece, Rome, and Britain. Africa was a part of this Silk Road trade between different civilizations, and Africa and China may have made contact even indirectly through the Silk Road. This indirect contact via trade was made possible by intermediate that were common trade partners to both parties. Chinese products where imported by African countries through Arabs, Turks and Persian merchants that used to trade with Chinese. These civilizations where in contact with both parties and were trading with them. At the same time, they were selling African products to Chinese. Contacts between China and Africa also occurred during the Tang dynasty (618–907) and were characterized by trade with Arab merchants. In addition, under the Song dynasty (960–1279), indirect contact (via common trade partners as previously described) was made and instances became more frequent. This historical fact was evidenced by archaeological discoveries in eastern Africa and Chinese written records prove it (Alden and Alves, 2008). Chinese knowledge of Africa increased during the Yuan dynasty (1279–1368) due to Chinese contact with the Arabs, Persians, and Turks. The climax of relations between China and Africa was reached during the Ming Dynasty (1368–1644) when China was at the height of shipping technology, leading to a series of expeditions that reached East Africa under the command of Admiral Zheng He (Alden and Alves, 2008). History states that Admiral Zheng He's fleet visited the eastern coast of Africa (Somalia and Kenya) two or three times and made contact with local kings, who reciprocated by sending official delegations to China. This growing friendship was however relatively short because of internal issues, conducing the Ming Dynasty to forbid any overseas contact, simultaneously paving the way to the Europeans' incursions in Africa. This was also the starting point of Western countries presence in Asia. Different to their previous contact and beyond their indirect trade relations, contacts between China and Africa occurred in the early 20th century when European powers used Chinese labor to work in their African colonies. During this period, both China and Africa were colonialism's victims, a situation that would later reinforce the relations between the two. After these periods of contact, it was only with the establishment of the People's Republic of China in 1949 that the Chinese again raised their interest in other developing countries, mainly after the Bandung Conference . However, the presence of China in other developing countries has not been limited to the economic and commercial domains. China has supported the independence process of various less developed countries (Burma, Malaysia, and Vietnam) and it has provided economic assistance to some of them (Mongolia and North Korea). In the post-colonial period, China positioned itself for the least developed countries as an alternative to the former colonialists' power. The need for the Chinese to extend their influence in developing countries made them adopt a strategic plan consisting of sharing a common anti-imperialist doctrine with the least developed countries and proposing alternative solutions that were—or appeared—better. Later, after the establishment of the People's Republic of China in 1949 and the waves of African countries' political independence movements, China found natural allies in these newly independent countries and a potential solution to its legitimacy problems (reinforced by their common colonial links). This was important because China was not a member state of the United Nations (UN) or recognized by the United States (US), which maintained diplomatic relations with the Republic of China on the island of Taiwan, supporting it as the legitimate government of China. At the beginning, China's involvement in Africa was driven by its close relations with the Soviet Union. Its direct involvement was soon confirmed with the Afro-Asian Peoples' Solidarity Organization, created in 1957. The foreign policy of China toward Africa was focused on three main axes: the export of the "Chinese model," the struggle against the superpowers, and China's third world policy (Yu, 1977, 1988). During the first Cold War, several African countries recognized the People's Republic of China as the legitimate government of China, namely Morocco and Algeria in 1958 and Sudan and Guinea in 1959. The following two decades turned out to be much more fertile in terms of international recognition with 14 African countries establishing diplomatic ties with China during the 1960s and 22 during the 1970s (Alden and Alves, 2008). This was the result of the independence movements of African states in the southern Sahara. The official ties of African countries with China consisted of four main categories: Friendship treaties based on the "Five Principles of Peaceful Coexistence"; cultural pacts; trade and payment agreements intended to promote commercial relations; economic aid and technical assistance agreements. However, these great growing relationships between China and Africa did not last long because of the Cultural Revolution in 1966, which saw an end to overt Chinese political activism on the continent. Furthermore, African countries made strategic rapprochements with the US in response to the increasing "Soviet menace" in the 1960s and 70s, as evidenced by Sino–Soviet border clashes in 1969 and the Brezhnev doctrine [1], which was accompanied by the Soviet invasion of Czechoslovakia in 1968, making the Soviet Union China's primary enemy. The evolution of Sino–African diplomatic relations during the Cold War was marked by many diplomatic achievements, which are represented by the following specific cases:

- 1956: Egypt was the first African country to establish official diplomatic relations with China. China currently maintains diplomatic relations with 54 African states, with Sao Tome and Principe (2016) and South Sudan (2011) being the most recent.
- 1971: China secured a permanent seat on the UN Security Council with support of 26 African states (34% of the General Assembly votes).
- 1970–75: The most celebrated Chinese development assistance project in Africa was the Tazara Railway, requested by the previous Zambian president Kenneth Kuanda and his Tanzanian counterpart, Julius Nyerere.

In recent years, China has continually trumpeted its 50-year-old involvement in Africa as positive, progressive, and grounded in the eternal and principled truths of noninterference (Strauss 2009). However, rigorous analysis of available data must be undertaken to estimate the effect of China's presence in Africa before concluding to any positive effect.

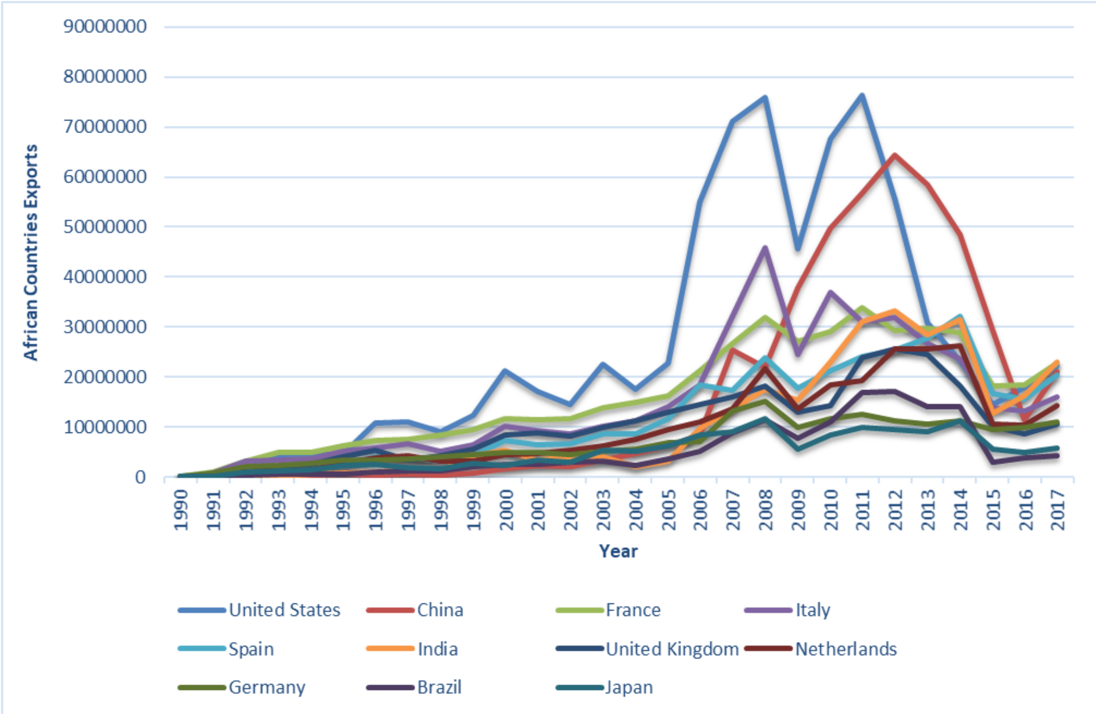
3.2 Trade between China and Africa and motivations of the paper

The configuration of African countries' trade partners has evolved over time. Before 1995, African countries' exports were mostly routed to France, which was the first export partner of overall African countries (African countries' total exports). After 1995, the US was the largest importer of African products, followed by France, positions they would retain until 2012. Data highlight an increasing presence of China as an important trade partner (importer) of African countries over the years. In 2009, China became the second-largest importer of African products, and in 2012, African countries' exports to China reached US$ 64 billion, conferring to China the position of the largest importer of African products, replacing the US until 2016 (Figure 1)

From 1990 to 2006, France was the largest exporter to overall African countries (African countries' gross imports), followed by the US and Germany. In 2006, the US and Germany lost their places to

[1] The Brezhnev doctrine allows Moscow to interfere in any socialist country

Figure 1: Trends in African countries' gross export destinations (top 10 partners) from 1990 to 2017



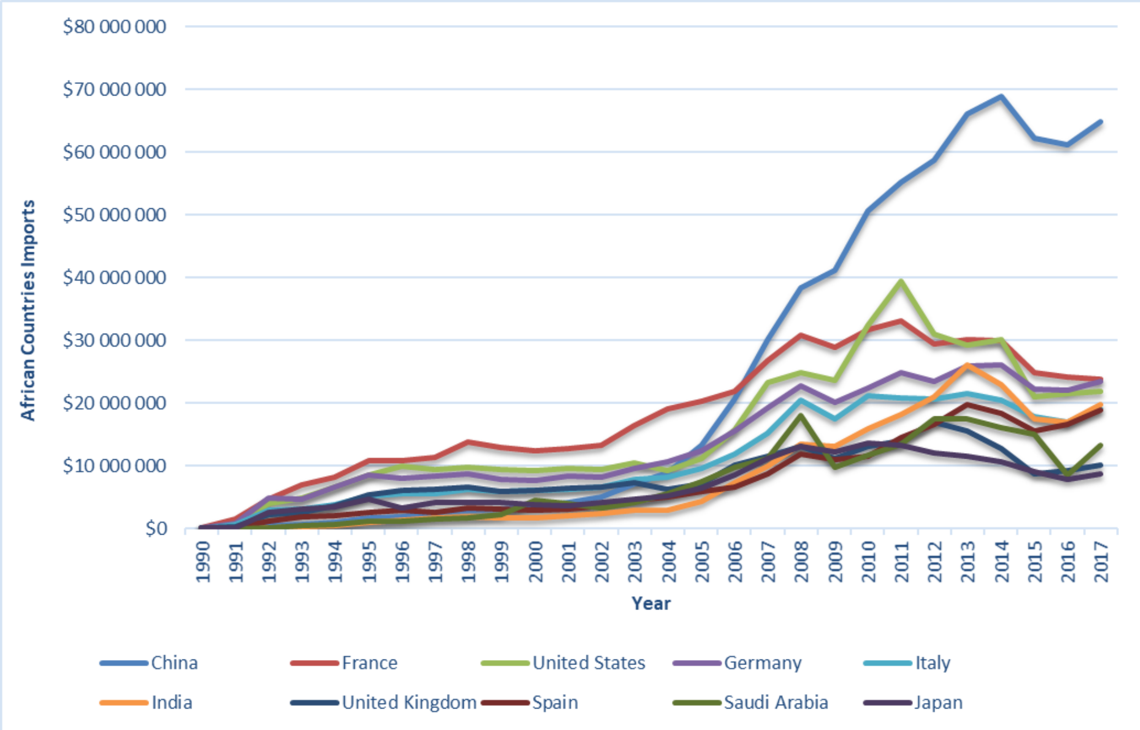
Source: Author's calculation based on UN-COMTRADE data

China, which became the primary exporter to African countries until 2017 (Figure 2). Between 2006 and 2017, African countries' imports from China increased at an annual average growth rate of 10%, going from approximately US$ 20 billion in 2006 to US$ 65 billion in 2017, reaching it highest value in 2014 (US$ 69 billion). This trend of African countries' gross imports shows that China started being a major actor in African countries' economies in 2006, and it is now a major trade partner if not the first. This is why it is necessary to investigate the increasing and deep presence of China in Africa.

The composition of African countries' imports from China by product type is necessary to include when investigating the reasons for as well as the effects of the Chinese presence in Africa. Since the 1990s, African countries' imports from China have mainly comprised manufactured goods, machinery and transport equipment, and miscellaneous manufactured articles. In 2001, 2009, and 2015, the top product types imported by African countries from China were machinery and transport equipment followed by manufactured goods and miscellaneous manufactured articles. The common property of these products is the technology they embody (Figure 3).

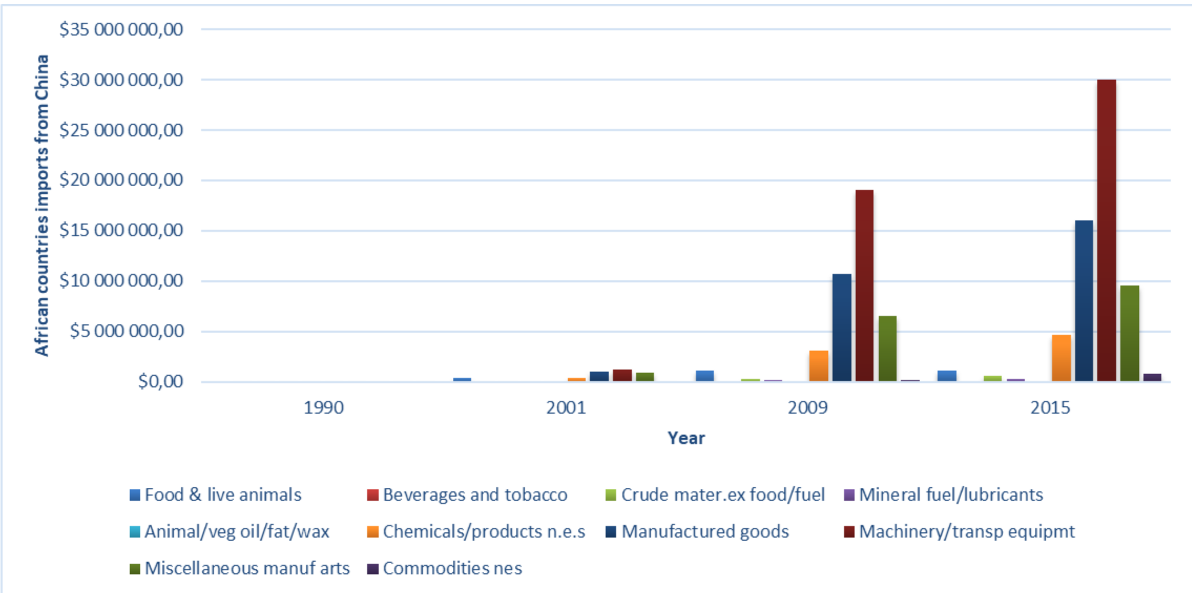
However, the structure of African countries' exports to China is different, which mainly comprise mineral fuel and lubricants followed by crude materials, except food and fuel, and manufactured goods (2009–2015). In contrast to imports from China, these exports are more resource-based (Figure 4). This highlights the objective and the potential gain of China in its trade relations with African countries, namely obtaining market opportunities for their products and natural resources to meet their energy concerns. Therefore, it will be difficult for African countries to take advantage of their exports to China in terms of technology upgrading.

Figure 2: African countries' imports from Asia



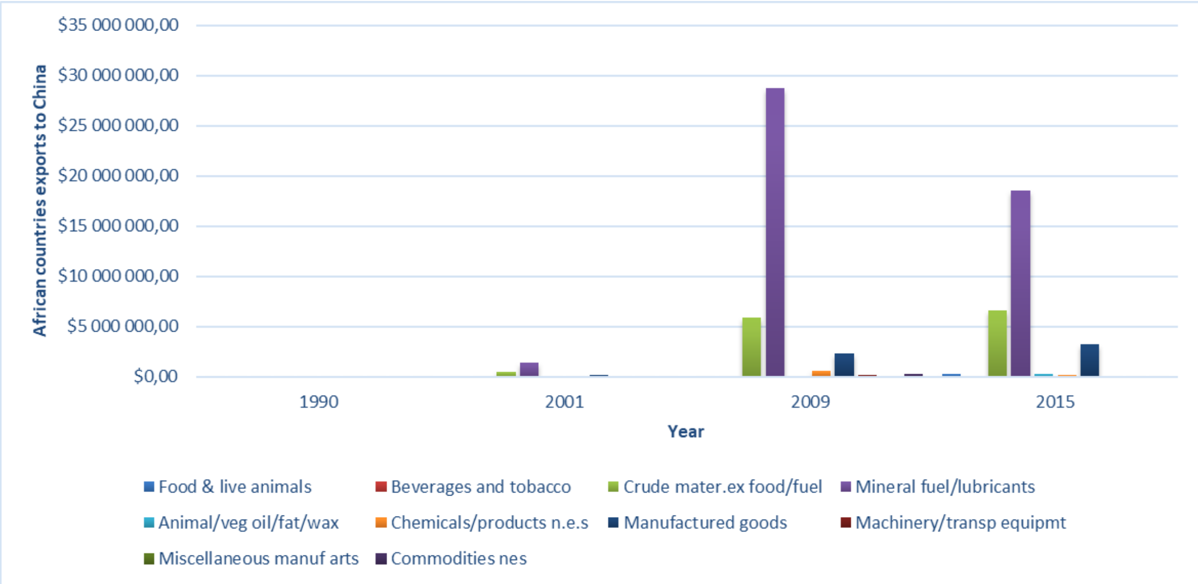
Source: authors calculation based on UN-COMTRADE data

Figure 3: African countries' imports from China by Product Types



Source: authors calculation based on UN-COMTRADE data

Figure 4: African countries' exports to China by Product Types

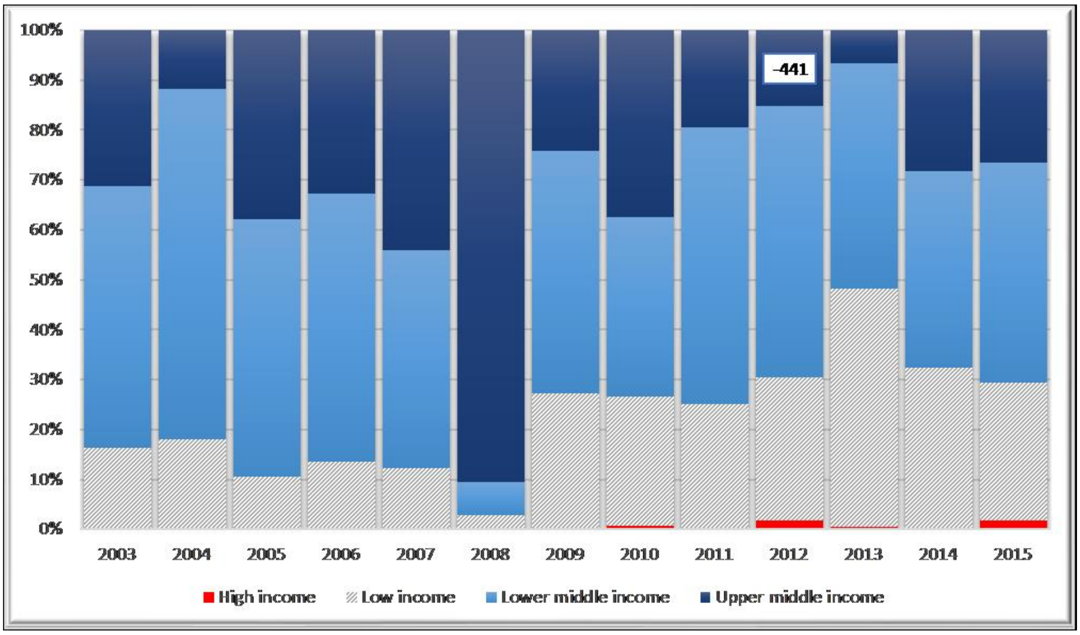


Source: authors calculation based on UN-COMTRADE data

The structure of imports from China is very different from the structure of China's exports from African countries. Figure 4 shows African countries exports to China. Indeed, African countries exports to China is mainly constituted of mineral fuel and lubricants first, second, crude material food and fuel, then manufactured goods (that third part is most true for the years 2009-2015). We remark that African countries exports to China are more resource-based. This highlight the fact that China is interested to Africa because of energetic concerns (China wants to ensure that it will have the necessary energy for its development). Therefore, it will be difficult for African countries to take advantage from their exports to China in term of technology upgrading.

Relevant data on Chinese FDIs to African countries are recent and date back to 2003. Analyzing these data by income group provides an idea about which income group receives the most FDIs from China. Indeed, from 2003 to 2015, Chinese FDIs were directed more to lower-middle-income countries, except in 2008 where approximately 90% of Chinese FDIs in Africa were located in upper-middle-income countries. Low-income countries have also received FDIs from China, starting from 16% in 2003 and increasing to 27% in 2015 with minor fluctuations in the trend. Although we claim that FDIs are located more in lower-middle-income countries, the reparation by income groups tends to be equal with small differences (except in high-income countries) and according to the considered period. In fact, the mean percentages (2003–2015) of Chinese FDIs by income group are as follows: lower-middle-income countries (40%), followed by upper-middle-income countries (35%), low-income countries (24%), and high-income countries (1%). (Figure 5)

Figure 5: Chinese foreign direct investments to Africa by income group (2003–2015).



Source: Author's calculation based on Chinese official reports.

Note: In 2012, net FDIs inflow to upper-middle-income countries was negative (US$ 441 million) meaning that FDIs outflows from Africa upper-middle-income countries into China was higher than FDIs inflows from China.

4 Empirical Methodology

4.1 Theory

In the past, international trade was driven by developed countries (North-North flows). However, in the last two decades, North-South and South-South trade flows have risen considerably. By 2014, the value of South–South trade had reached almost US$ 5.5 trillion, a magnitude close to that of trade between developed countries (North–North) (UNCTAD, 2019; David et al., 2013) . In 2018, goods worth US$6.9 trillion (36%) were exchanged between developed economies (North-North trade), whereas merchandise trade among developing and transition economies (South-South trade) amounted to US$5.4 trillion (28%). Exports from developed to developing economies and vice-versa (North-South, and South-North trade) totaled US$6.9 trillion (36%). This chapter investigates technology transfer in South-South trade and investment relations, and relies on comparative advantages' theory.

The interpretation of the empirical results relies on theoretical foundations, namely the well-known Heckscher–Olin–Samuelson (HOS) model. According to the HOS theory of comparative advantages, countries should specialize according to their production factors' endowment, enabling countries with more skilled labor to specialize in the production of high-tech products, while countries with a higher share of unskilled labor specialize in low-tech products. However, this model no longer expresses the reality of trade because countries specialize in tasks instead of the production of a whole product. Therefore, a country can export high-tech products, but it might not be certain whether this country is richly endowed with skilled labor and technology. The best example is China at the beginning of 2002. It started exporting high-tech products, but this was partly because of its role in the production of low-tech components embodied in imported high-tech goods that were re-exported. This can also be explained by the role of China in assembling high-tech products produced abroad and then reexporting them, which gave the impression that China was producing high-tech products. This comparative advantages' theory is the foundation of our econometric results' interpretation, but it is important to note that it has evolved overtime. It has recently experienced very strong renewed interest from a theoretical as well as an empirical point of view. Matsuyama (2013), Costinot et al. (2012), Donaldson et al. (2013) have review the well-known comparative advantages theory extending it in their studies. Donaldson et al. (2013) investigated the Comparative Advantages' implications for how nations should conduct their trade policy. Their findings suggested that countries have more room to manipulate prices in their comparative-advantage sectors.

Our main question is: Are African countries getting transformed technologically thanks to their interaction with China in Global Value Chains? But the question is dived in sub-question according to the type of technology transfer we considered (direct or indirect technology transfer).

4.2 Empirical methodology

We used the Fixed-effects model (with Country and Time fixed-effects) as basic model, to estimate the effect of FDIs and imports in intermediate goods on sophistication. This first-step estimation will allow us to identify direct and indirect technology transfer between China and African countries. The basic econometric model is presented as follow:

Model 1:

$$\begin{aligned} logTSI_{i,t} &= \beta_0 + \mu_i + \eta_t + \beta_1 logK_{i,t} + \beta_2 logL_{i,t} + \beta_3 logHK_{i,t} \\ &\quad + \beta_4 logFDI_{i,t} + \beta_5 logIMPI_{i,t} + \beta_6 logEXPI_{i,t} + \epsilon_{i,t} \end{aligned} \tag{1}$$

In a second step (second Model), we included interaction effects to equation 1.

Model 2:

$$\begin{aligned} logTSI_{i,t} = \beta_0 &+ \eta_t + \beta_1 logK_{i,t} + \beta_2 logL_{i,t} + \beta_3 logHK_{i,t} + \beta_4 logFDI_{i,t} + \beta_5 logIMPI_{i,t} \\ &+ \beta_6 logEXPI_{i,t} + \beta_7 logFDI_{i,t} \times logHK_{i,t} + \beta_8 logIMPI_{i,t} \times logHK_{i,t} + \mu_i \\ &+ \epsilon_{i,t} \end{aligned} \tag{2}$$

Where TSI represents technological sophistication; K is the level of capital; L represents the level of labor; HK is human capital; FDI represents FDI flows from China; IMPI is the amount of intermediate goods imported by the countries from China and EXPI the amount of intermediate exports to China. Variables FDI, IMPI and EXPI are some proxy of trade in GVC with China and will allow us to say if the interactions between China and the African Countries lead to technology transfer. The coefficient β_4 in front of the variable FDI, if it is positive, represents what we call "the direct technology transfer" whereas the coefficients β_5 and β_6 respectively in front of IMPI and EXPI, if they are positive are considered as "indirect technology transfer".

5 Variables and data sources

5.1 Data

The dataset includes annual data from 1995 to 2015 for 49 African countries. Our variable of interest is the technological sophistication index, which is computed using domestic value added exports and following Rueda Maurer (2015). The explicative variables are mainly trade in intermediate goods, computed using input–output tables, and Chinese FDIs registered in Chinese official reports as overseas FDIs (OFDI) and obtained from the China Statistical Yearbook, which reports data on FDIs to African countries from 2003 to 2015 in US$. The control variables are labor (employed population), which is obtained from the World Bank (World Development Indicators' data); private capital stock, which comes from the IMF Investment and Capital Stock Dataset (2017); and human capital, measured using the ratio of gross enrollment in tertiary education, which comes from the World Bank.

5.2 Imports of Intermediate goods from China

We computed imports of intermediate goods from China using input output data from Lenzen et al. (2013). The process follows the same methodology used by Koopman et al. (2014)to decompose gross exports into different components. Exports of intermediate goods can directly be identified in input–output tables; however, such tables also include domestic intermediate goods produced and used at home..

Table 1: First part of an input-output table: Intermediate goods

		Country 1		Country 2		Country 3	
		Sector 1	Sector 2	Sector 1	Sector 2	Sector 1	Sector 2
Country 1	Sector 1	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}
	Sector 2	a_{21}	a_{22}	a_{23}	a_{24}	$\cdots$	$\vdots$
Country 2	Sector 1	a_{31}	$\vdots$	$\ddots$			$\vdots$
	Sector 2	a_{41}	$\vdots$		$\ddots$		a_{46}
Country 3	Sector 1	a_{51}	a_{52}			$\ddots$	$\vdots$
	Sector 2	a_{61}	a_{62}	$\cdots$	a_{64}	$\cdots$	a_{66}

Exports or imports of intermediate goods are obtained by extracting all intermediate goods from input–output tables and setting to zero (0) domestic intermediate goods produced and used at home

The general formula is as follows:

$$M_{k,i} = \sum_{\substack{j=2i-1 \\ k \neq i}}^{2i+n-2} (a_{j,2k-1} + a_{j,2k+n-2})$$

Where $M_{k,i}$ represents imports of Country k from Country i, and n is the number of sectors.

Reminder: $a_1 3$ represents exports of intermediate goods from Country 1 (sector 1) and used (imported) by Country 2 in its sector 1. Following the general example of Table 1, we can attempt to compute imports of intermediate goods of Country 2 from Country 1. The general formula of imports of intermediate goods of Country 2 from Country 1 is presented as follows:

$$M_{2,1} = \sum_{j=1}^{2}(a_{j,3} + a_{j,4}) = (a_{13} + a_{14}) + (a_{23} + a_{24}) \text{ with } n = 2 \text{ (two sectors)}$$

5.3 Technological Sophistication Index

The Hausmann et al. (2007) export sophistication index [2] is computed using Balassa's Revealed Comparative Advantages (RCA) Index and at the end weighed by the country Gross domestic Product (GDP). Rueda Maurer (2015) followed the same methodology using Revealed Comparative Advantages (RCA) to compute index of technological sophistication without weighting by countries' GDP as in the previous case. This paper introduced a new approach, used only in this paper and for the first time in the literature. This approach is not too far from Rueda Maurer (2015) but is necessary and relevant in this context of GVCs. Indeed, the Technological Sophistication Index (TSI) is computed using the principle of Balassa's RCAs. However, original RCAs' theory has been set up during a period where countries had to follow all the steps of the production and produce the whole product at home [3]. This method have evolved with the phenomenon of Global Value Chains. Countries are now specializing in tasks and they are now exporting in addition to final goods, either intermediate goods that will be used by third countries to produce other goods, either assembled goods that are produced using intermediate goods from third countries. Therefore, using gross exports to compute first RCA index and then TSI is misleading and can over or underestimate countries' level of technological sophistication. In order to overcome this issue, we will use in our study domestic value-added exports instead of using gross exports. Value-added trade is a real proxy of the domestic value added effectively produced by the country that is exported. It allows us to compute TSI that is effectively created by the country. Koopman et al. (2014) provided a framework to decompose gross exports into different elements. Gross Exports are decomposed into different elements: Domestic value-added in direct final goods exports (VAEFD), domestic value-added in intermediate exports absorbed by direct importers (VAEI1), domestic value-added in intermediate re-exported to third countries (VAEI2); these three elements are Value-added exports (VATRD). We also have domestic value-added in intermediate that returns via final imports (VARHF), domestic value-added in intermediate goods that returns via intermediate imports (VARHI), foreign value-added in final goods and intermediate goods exports (FVA) and Pure double counted (two terms). We are interested here to Value-added exports (VATRD) that represents the domestic value-added embodied in gross exports.

As we now have access to domestic value-added exported we can now use it in all the steps of the methodology insteqd of gross exports. The new Balassa RCA index is presented as follow:

$$RCAIndex(VA)_{ip} = \frac{VATRD_{ip}/VATRD_i}{VATRD_{wp}/VATRD_w} \tag{3}$$

[2] Available on: World Integrated Trade Solution (WITS)

[3] Only raw material and commodities were used as intermediate goods imported from abroad

And

$RCAIndex(VA)_{ip}$: is RCA in term of domestic value-added exported;

$VATRD_{ip}$:represents domestic value-added exports of product/sector p from country i;

$VATRD_i$:is total domestic value-added exports from country i;

$VATRD_{wp}$: is world value-added exports of product/sector p;

$VATRD_w$: is the world total value added exports;

VATRD data are obtained using KWW(Koopman et al. (2014)) framework as previously discussed and industry classification follows ISIC Rev3. Following ISIC (3), we determined the level of technological sophistication associated to each sector/industry. Countries will be considered as specializing in a specific product/ sector if the $RCAindex(VA)$ associated to this product is greater than one ($RCAIndex(VA) \geq 1$). After identifying products/sectors in which countries have a RCA, we can start computing the TSI. Sectors with $RCAIndex(VA) \geq 1$ are aggregated into five (5) different level of technological sophistication. We followed ISIC (3) for the classification and we rely on Lenzen et al. (2013) for correspondence between EORA data base sector classification and ISICRev3 classification.

Table 2: Classifications of Technological level base on ISIC (3) classification

Level of technological Sophistication (TS)	Technological Sophistication Code (TS)
Primary sector and services	0
Low technology	1
Medium-low technology	2
Medium-high technology	3
High technology	4

For each country, products/sectors group with $RCAIndex(VA) \geq 1$ belonging each category of technological sophistication are added up, weighted by the percentage of the exported value-added of each product/sector in the country's total value-added exports. In other words, for each country, the share of each product/sector group value added in the country's total value-added exports are added up for each category of technological sophistication. This weighted sum is then multiplied by the corresponding technological sophistication code (From 0 to 4) and the sum gives finally the TSI.

$$TSI_i = \sum_{TS=0}^{4} \Big[TS \times \sum_{p}^{N} \Big(\frac{VATRD_{i,TS,p}}{VATRD_i} \Big) \Big] \tag{4}$$

TS:Technological Sophistication Code;

N: The number of product groups with $RCAIndex(VA) \geq 1$;

$VATRD_{i,TS,p}$:Value added exports of product p with $RCAIndex(VA)_{ip} \geq 1$;

Figure 6: Scatter Export Sophistication Index vs Value-added exported Sophistication Index

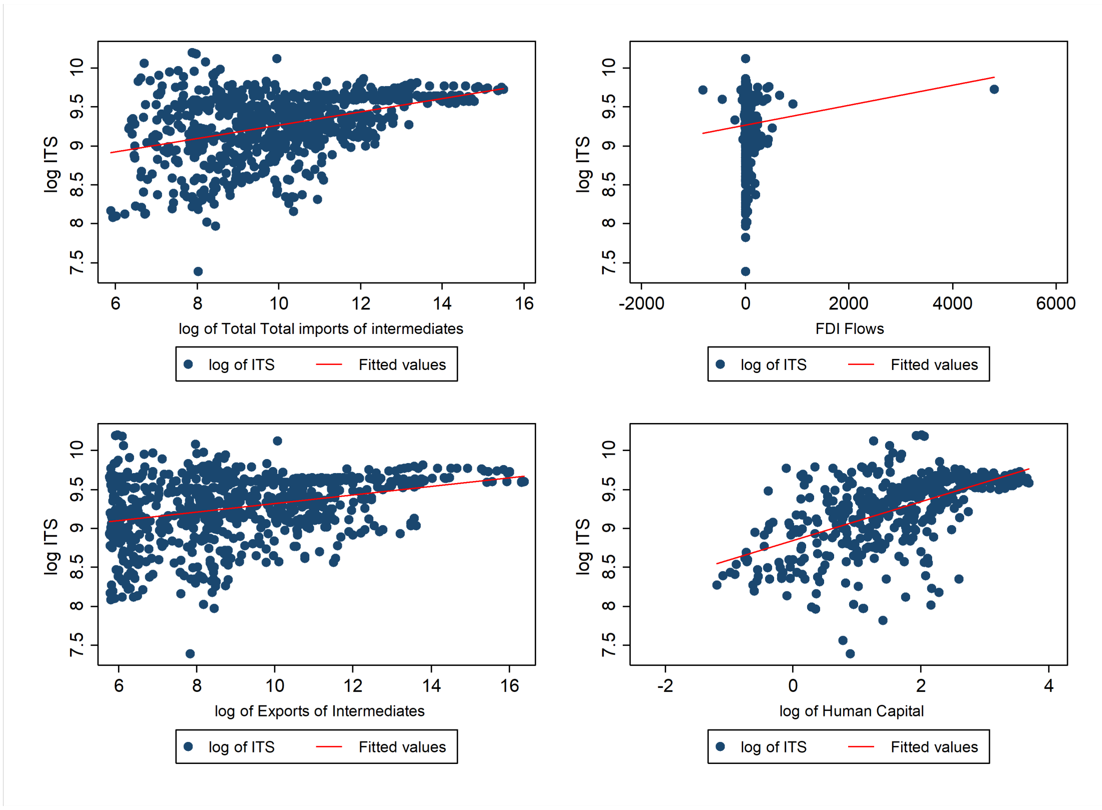
5.4 Descriptive statistics

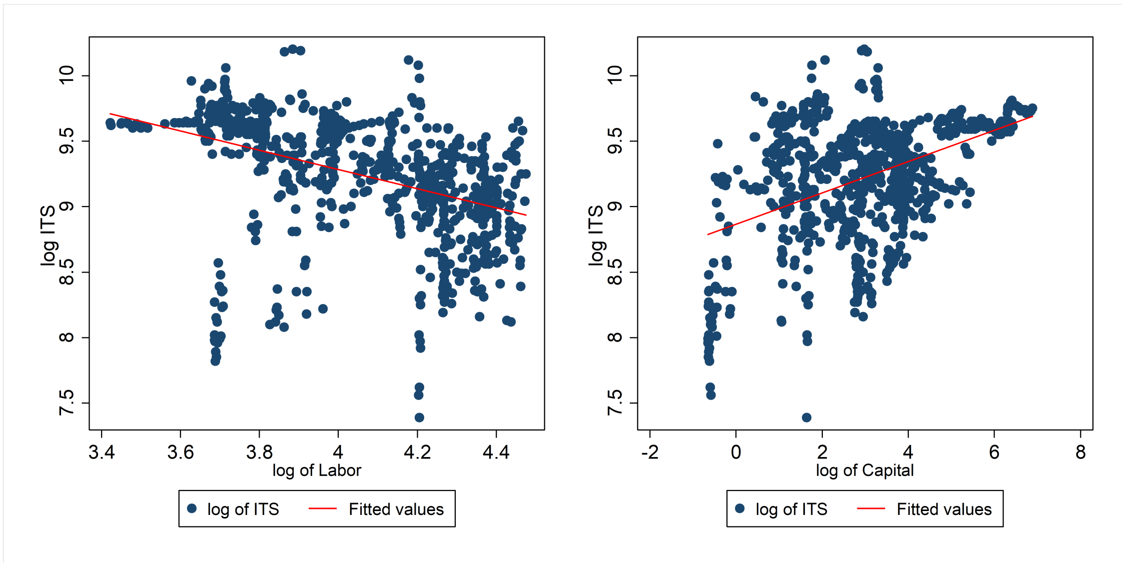
Figure 7 represents scatter plots of our main interests variables and the level of technological sophistication index. The figure give us the trend of the relation between both FDIs net inflows from China, imports of intermediate goods from China and the level of exports sophistication. Indeed, Figure 7 shows a positive correlation between the log of TSI and FDIs inflows from China. This first result state that an increase in FDIs inflows from China will improve the level of TSI. However, it is just a correlation and we can see that this positive effect is maybe the result of outliers. Father estimation will give better results. In addition, we also have a positive correlation between the logarithm of TSI and the level of intermediate goods imports from China. Also, the logarithm of TSI is positively correlated to the level of intermediate goods exports to China. Therefore, according to these scatter plots, direct and indirect technology transfer are maybe effective in interactions between China and African countries. However, we should consider results with control variables before concluding. Focusing now on factor endowments, we can remark that the logarithm of TSI is negatively correlated with labor and positively correlated with capital and human capital. These correlations follow the expected results .

Table 3: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Log of Exports Sophistication(EXPY)	9.243	0.45	7.390	10.2	820
FDIs Flows from China	40.468	213.483	-814.91	4807.86	621
FDIs Flows from the Rest of the World	824.443	1666.442	-7344.067	11553.119	617
Imports of intermediate from China	125992.845	459648.255	348.767	5351820	1196
Imports of intermediate from the Rest of the World	2545002.341	6404935.599	41714.22	65972287.11	1196
Value-Added Imports of intermediate from China (%)	0.045	0.033	0.003	0.229	1196
Imports of intermediate from China (%)	0.027	0.027	0.001	0.189	1196
Imports of intermediate from the Rest of the World (%)	0.973	0.027	0.811	0.999	1196
Imports of equipment from China (%)	0.015	0.018	0	0.104	1196
Imports of equipment from the Rest of the World (%)	0.42	0.083	0.073	0.54	1196
Labour	59.58	14.246	30.601	89.242	1200
Private capital PPP	72.801	143.05	0.28	973.077	1222
Gross enrollment ratio, tertiary, both sexes (%)	7.341	8.994	0.094	61.137	689

Figure 7: Scatter plot





Source: authors calculation based on UN-COMTRADE and WITS data

6 Econometric Results and Robustness

6.1 Econometric Results

Table 4 reports the results of our estimations, with estimates corrected for heteroscedasticity. Before giving any interpretation, let us highlight that the coefficient before labor and capital have the expected signs but are not always significant for all the models. Technology is negatively correlated to labor whereas it is positively correlated to capital . The results of our first step analysis with only Chinese FDIs flows, reported in column (1) table 4 show that (equations 1 and 2) Chinese FDIs flows do not have any significant effect on African countries export sophistication; the coefficient is negative but not significant. Then, we are tempted to say at first sight that there is no direct technology transfer in the interaction between Chinese and African countries through global value chains. However, when one considers the level of human capital, results changes. Indeed, using an interaction term in the regression (column (3), (5) and (6)), the more the level of human capital increases, the more the negative effect of Chinese FDIs is decreasing and the effect on technological sophistication is becoming positive. We can then suppose the existence of a threshold of human capital above which it exists direct technology transfer from China to African countries. In a situation of quasi zero level of Human Capital a 1 million US$ increase in Chinese FDIs net inflows decreases the level of technological sophistication by 0.32%. However, the marginal effect of Chinese FDIs is increasing with the level of human capital and become positive at a level of the log of human capital of 3.4 (corresponding to 29.96% of gross enrollment ratio in tertiary school for both sexes). Moreover for the highest level of human capital in the sample (61.14% of gross enrollment ratio in tertiary school), an increase of Chinese FDIs by 1 million US$ increases the level of exports sophistication index by 0.0398%. These results can be explained by the fact that African Countries that have a low level of Human capital cannot take advantages from technology embodied in foreign firms. In addition, most of foreign firms in Africa are resource-based FDIs. These type of FDIs do not increase the competitiveness of local firms and reduce the level of technological sophistication because their activities destroy the industrial tissue of host countries and reduce their ability to upgrade the technology chain. Indeed, Chinese FDIs can affect technological sophistication through many channels. First it can be through supply chains. In this case, technology upgrading can occur when local firms become suppliers of foreign firms. Since the foreign firms produce products that embodied high technology or require a sophistication level to be produced, local firms that are suppliers have to meet the expectations of the foreign firm and therefore FDIs can lead to technology upgrade. Moreover, multinational firms or foreign firms can directly help their local suppliers if in order to ensure that they are using quality inputs; It will be characterized by product design, assisting with technology acquisition and production techniques (Paus and Gallagher, 2008). However, this type of upgrading will be taken into account in the Index of Technological Sophistication in condition that local suppliers also supply local firms that are exporting products, or they also supply foreign firms out of territory. Upgrading in technology can also happen when foreign firms subcontract their activities to some local firms. That are channels through which local firms can upgrade in terms of technology, but they highly depend on the strategy of the foreign firm in term of FDIs (Farole and Winkler, 2014). Chinese FDIs can also lead to upgrading through diffusion effects. Indeed, the entry of a foreign firm in the local market will increase competition between local suppliers and it will lower the prices for the foreign firm. Since the prices become low local suppliers will compete to increase the quality of their products (This channel is conditioned by an existing high human capital level). Therefore, that competition will lead to a technology upgrading in the country.

Focusing now on imports of intermediate from China (column (2)), we remark that imports of intermediate from china increases significantly the level of technological sophistication of African countries. This result highlights the presence of an indirect technology transfer between China and African countries in their trade of intermediate goods. The interaction term between human capital and imports of intermediate from China remain positive but is no longer significant (column (5) and (6)). Indeed, results highlight that an increase of 1% of the imports of intermediate goods from China lead to an increase of 24% of the level of TSI. This effect of imports of intermediate goods is very high and shows the importance of indirect technology transfer in the relation between China and African countries throughout global value chains compared to direct technology transfer. In fact, when countries get access to new efficient markets, they get access to high quality intermediate goods. Therefore, the import of those sophisticated intermediate goods increases the production of new and enhanced products. The result follows Goldberg et al. (2010) that found that liberalization in India give them access to more sophisticated intermediate goods at lower prices and that led to an increase in their productivity. Moreover, this positive effect of intermediate imports from China can be increased by the capacity of African countries to use technology embodied in intermediate goods to produce other products. Also, imports of intermediate goods can increase competition between domestic producers of intermediate goods and foreign producers. For survival concerns, domestic companies will have to upgrade in technology in order to follow the trend.

Finally, in column (5) and (6) human capital has a negative sign but is not significantly different from zero. As previously discussed, the negative correlation between human capital and technological sophistication is due to the fact that the increase of technological sophistication in African countries is not due to factors endowment but is the result of technology transfer through global value chains.

Table 4: Results of the first and second steps regressions using fixed effect

VARIABLES	(1) Fixed Effects	(2) Fixed Effects	(3) Fixed Effects	(4) Fixed Effects	(5) Fixed Effects	(6) Fixed Effects
FDICH Flows$_t$	-0.000168		-0.00174**		-0.00151*	-0.00186***
	(0.000153)		(0.000653)		(0.000781)	(0.000621)
log ImportsCH$_t$		0.241***		0.247***	0.234*	0.243*
		(0.0796)		(0.0772)	(0.126)	(0.127)
log HK $\times$ FDICH Flows$_t$			0.000581**		0.000455*	0.000549***
			(0.000215)		(0.000246)	(0.000198)
log HK $\times$ log ImportsCH$_t$				-0.00577	0.0403	0.0380
				(0.0159)	(0.0321)	(0.0319)
log Exports$_t$						-0.0478*
						(0.0237)
log Labour$_t$	-0.0442	-0.452	-0.196	-0.391	-0.460	-0.447
	(0.605)	(0.335)	(0.547)	(0.345)	(0.519)	(0.512)
log Capital$_t$	0.116	0.107	0.138	0.100	0.229	0.229
	(0.191)	(0.146)	(0.189)	(0.157)	(0.219)	(0.216)
log HK$_t$	0.00257	-0.000964	0.0200	0.0514	-0.366	-0.334
	(0.0682)	(0.0487)	(0.0675)	(0.142)	(0.331)	(0.328)
Constant	9.059***	8.655***	9.586***	8.383***	8.129***	8.383***
	(2.401)	(1.580)	(2.182)	(1.438)	(2.050)	(2.066)
Observations	298	444	298	444	283	283
R-squared	0.073	0.174	0.114	0.175	0.190	0.199
Number of id	41	42	41	42	39	39
Country FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Corrected for heteroscedasticity.

6.2 Robustness

6.2.1 New approach of TS Index : Value-added Exports Sophistication

In a context of global value chains, given that gross exports contain imports from third countries that are re-exported or that are used as intermediate goods to produce new products for exports; TS Index already contain a part of these intermediate goods imports. Therefore, imports from China may be significant because a part of those exports are embodied in African countries gross exports that are used to compute TS index. To solve this problem, we used the new index of technological sophistication presented above. As discussed in section 5.3, gross exports are composed of value-added exports, that represent domestic value added embodied in gross exports (i.e. value added created in the domestic country); value added that return home; pure double counted, and foreign value added. Our data on imports from china may be embodied in the last element (because imports of intermediate that are used to produce new exports are considered as foreign value added embodied in gross exports). Therefore, the innovation is to use value-added exports instead of gross exports to compute our Exports Sophistication Index. This index will be therefore computed on the basis of value-added that is created at home and then exported. Using the new approach of technological sophistication, we get results that are not so fare from the previous one. Coefficient in front of FDIs is negative and significant at 1% (column (1)), it means that there are no spillover effects of Chinese FDIs on African countries' sophistication and more FDIs are source of decrease in the level of technology domestically produced in African countries. However, the interaction term of China FDIs flows, and the log Human Capital is positive and significant at 1%. This result means that China FDI flows lead to technological transfer in condition that the host country hold a minimum stock of human capital. Countries should be able to keep the technology brought by foreign firms. Focusing on indirect technology transfer, i.e. technology transfer from trade through GVCs between China and African countries. Using technological sophistication index that is Computed with value-added exports and that does not contain foreign value added, the coefficient in front of Imports from China is negative and significant, but the interactive term is positive and significant. This result shows that indirect technology transfer to African countries from their trade interaction is also conditioned by the level of human capital. In column (3) and (4), the coefficient in front of the human capital remain significant and negative. Also, the interactive terms (With FDIs flows and imports from China) remain positive and significant and this mean that there is direct and indirect technology transfer depending on the level of human capital of African countries.

6.2.2 Value-added imported from China instead of intermediate goods imports

We tried in the previous section to use an original TS index that considers only the domestic value added exported in our estimation. This approach allows us to capture the real technological sophistication coming from the country and not from tier countries that supply the domestic countries in intermediate or final goods into the same value chain. In the same way TS index could have been influenced by foreign value added embodied in export, the variable that capture indirect technology transfer namely imports of intermediate from China may contain foreign value-added (from other countries); if then, the effect

Table 5: Results with the new approach of TS Index

VARIABLES	(1) Fixed Effects	(2) Fixed Effects	(3) Fixed Effects	(4) Fixed Effects
FDICH Flows$_t$	-0.00149***		-0.00121**	-0.000928
	(0.000564)		(0.000561)	(0.000611)
log HK $\times$ FDICH Flows$_t$	0.000553***		0.000423**	0.000348*
	(0.000193)		(0.000194)	(0.000205)
log ImportsCH$_t$		-0.269***	0.0514	0.0363
		(0.0897)	(0.120)	(0.120)
log HK $\times$ log ImportsCH$_t$		0.0298**	0.0512***	0.0526***
		(0.0126)	(0.0177)	(0.0177)
log Exports$_t$				0.0389
				(0.0338)
log Labour$_t$	0.0139	-0.00585	0.00594	0.00606
	(0.00878)	(0.00857)	(0.00905)	(0.00904)
log Capital$_t$	0.0227	0.0486	0.113	0.112
	(0.127)	(0.108)	(0.128)	(0.128)
log HK$_t$	-0.248***	-0.316**	-0.750***	-0.770***
	(0.0759)	(0.129)	(0.186)	(0.187)
Constant	-2.463***	0.210	-2.889**	-3.074**
	(0.704)	(0.954)	(1.430)	(1.437)
Observations	222	457	222	222
R-squared	0.357	0.206	0.389	0.394
Number of id	28	35	28	28
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Corrected for heteroscedasticity.

would not be only technology transfer between China and African countries, but it would be technology transfer between African countries and China and other tiers countries. To avoid this confusion, we decided in that section to use African countries' imports from China in terms of value-added i.e. Chinese domestic value added embodied in their exports of intermediate goods to African countries. This variable is computed following Koopman et al. (2014) methodology as previously discussed in section 5.2. Table 6 summarizes the results of our empirical estimations using value-added imported from China and the new approach of technological sophistication index. Results are different from the previous one and gives us information about the real degree of technology transfer between China and African countries. Indeed when using the new approach of TS index and value-added imported from China at the same time, the results show that direct technology transfer is conditioned by the level of human capital in the economy.

However in that case, the coefficients in front of FDIs flows from China and its interaction with human capital are no longer significant at 1%. Therefore direct technology transfer is quasi nonexistent in this case.

In addition, when focusing now on the indirect technology transfer, we remark that the coefficient in front of value-added imported from China is no longer significant (column (2), (3) and (4)) only the coefficient in front of the interactive term is significant. This also means that real domestic technology upgrade resulting from trade between China and African countries is conditioned by the level of human capital.

Table 6: Results based on the new approach of TS Index and value-added imported from China as Indirect technology transfer channel

	(1)	(2)	(3)	(4)
VARIABLES	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects
FDICH Flows$_t$	-0.00149***		-0.00126**	-0.000998*
	(0.000564)		(0.000552)	(0.000602)
log HK $\times$ FDICH Flows$_t$	0.000553***		0.000439**	0.000369*
	(0.000193)		(0.000191)	(0.000201)
log VA_ImportsCH$_t$		-0.0676	0.108	0.105
		(0.0795)	(0.0894)	(0.0894)
log HK $\times$ log VA_ImportsCH$_t$		0.0230*	0.0543***	0.0549***
		(0.0137)	(0.0184)	(0.0184)
log Exports$_t$				0.0362
				(0.0332)
log Labour$_t$	0.0139	-0.00465	0.00384	0.00406
	(0.00878)	(0.00875)	(0.00910)	(0.00909)
log Capital$_t$	0.0227	0.0191	0.101	0.101
	(0.127)	(0.109)	(0.126)	(0.126)
log HK$_t$	-0.248***	-0.291*	-0.859***	-0.873***
	(0.0759)	(0.153)	(0.213)	(0.213)
Constant	-2.463***	-1.396	-3.349***	-3.635***
	(0.704)	(0.923)	(1.196)	(1.224)
Observations	222	457	222	222
R-squared	0.357	0.190	0.401	0.405
Number of id	28	35	28	28
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Corrected for heteroscedasticity.

6.2.3 Use of the lags of interests variables to fix the potential endogeneity

In this section, we tried to fix the potential endogeneity problem by integrating lags of our interest variables. Table 7 presents the results of our estimation considering the lag of intermediate imports. The result follows the previous findings and Value Added imports from China continue having a positive and significant effect on the level of technological sophistication . The results are robust but evidence of indirect technology transfer is more robust than that of direct technology transfer.

Table 7: Robustness 3: Use of the lag of intermediate imports from China

VARIABLES	(1) Fixed Effects	(2) Fixed Effects	(3) Fixed Effects	(4) Fixed Effects
FDICH Flows$_t$	-0.00174***		-0.00156***	-0.00185***
	(0.000486)		(0.000482)	(0.000529)
log HK × FDICH Flows$_t$	0.000582***			0.000541***
	(0.000172)			(0.000178)
log ImportsCH$_{t-1}$		0.230***	0.278***	0.272***
		(0.0613)	(0.0910)	(0.0910)
log HK × log ImportsCH$_{t-1}$		-0.00513	0.0428***	0.0412***
		(0.00772)	(0.0132)	(0.0132)
log Exports$_t$				-0.0388
				(0.0294)
log Labour$_t$	-0.00497	-0.00763	-0.00842	-0.00850
	(0.00768)	(0.00475)	(0.00764)	(0.00763)
log Capital$_t$	0.141	0.106	0.235**	0.235**
	(0.0996)	(0.0659)	(0.104)	(0.103)
log HK$_t$	0.0184	0.0456	-0.363***	-0.341**
	(0.0583)	(0.0773)	(0.130)	(0.131)
Constant	9.083***	7.340***	6.397***	6.781***
	(0.562)	(0.613)	(1.058)	(1.095)
Observations	298	444	283	283
R-squared	0.115	0.172	0.205	0.212
Number of id	41	42	39	39
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Corrected for heteroscedasticity.

6.3 Miss-specification and potential omitted variables

The aim of the paper is to identify if the relations between China and African countries led to technology transfer. In order to achieve this goal we considered FDIs from China as a measure of direct technology transfer and used imports of intermediate goods from China as a proxy of indirect technology transfer. This specification rise a problem of omitted variable because technology sophistication index is a general index computed with countries exports and reveled comparative advantages obtained thanks to these gross exports (or value-added exports). Therefore, there is no evidence that the increase of our Technological Sophistication Index variable is due or only due to the interaction of African countries with China. It can only be the results of the relations between African countries and their neighbors or the results of the relation between African countries and other emerging or developed countries. Therefore, we should consider in our estimations FDIs from the rest of the world or use a variable that measure the share of Chinese FDIs in percentage of total FDIs. In this section we tried to give more robust estimation by using other variables to capture direct and indirect technology transfer.

6.3.1 Integration of FDIs and Imports of intermediate goods from the Rest of the World (RW)

Do not consider the Rest of the World (RW) will lead to biased results. In this section, we present the results when we integrates FDIs from the RW (that are obtained by subtracting net inflows from China from overall net inflows) and imports of intermediate coming from the RW (obtained by subtracting imports of intermediate goods from China from overall imports of intermediate goods). Moreover, in that approach imports of intermediate goods from China are expressed in percentage of total imports of intermediate goods. Those estimations consider more FDIs and imports coming from other countries and make sure that the affect is not biased by committing variable. The new model is presented as follow :

$$\begin{aligned} logTSI_{i,t} = \beta_0 + \beta_1 logK_{i,t} + \beta_2 logL_{i,t} + \beta_3 logHK_{i,t} + \beta_4 logFDICHINA_{i,t} \\ + \beta_5 logFDIRW_{i,t} + \beta_6 logIMPICHINA_{i,t} + \beta_7 logIMPIRW_{i,t} \\ + \beta_8 logEXPI_{i,t} + \mu_i + \eta_t + \epsilon_{i,t} \end{aligned} \tag{5}$$

With FDICHINA that represents FDI flows from China and FDIRW represents FDI flows from the Rest of the World; IMPICHINA is the amount of intermediate goods imported by the countries from China and and IMPIRW is the amount of intermediate goods imported by the countries from the Rest of the World; EXPI is the amount of intermediate exports to China (optional).

Table 13 presents the results of the new specification. The results follow the previous one and show that FDIs from China have a negative and significant effect on the level of technological sophistication whereas FDIs from the RW do not have a significant effect on the level of technological sophistication. In addition, when considering the level of human capital (multiplicative term) the sign is positive and illustrate the presence of a positive effect of FDIs from China on the level of technological sophistication for African countries that have a high level of human capital (Table 13 model 2). In addition, the percentage of imports of intermediate goods from china is significant and positive (In table 13 we used the first difference of the share of imports of intermediate goods from China in total imports of intermediate because the variable contains a unit root) . This result, follows the first step estimations and highlight the presence of direct and indirect technology transfer in the relations between China and African countries toward global value chains.

6.3.2 Use of variation of FDIs and FDIs in perentage of GDP

The results are also robust to the measure (specification) of the interest variable. Indeed, we tried to identify the effect of the variation of the level of FDIs on the level of technological sophistication. We remark that changing the specification of one of the interest variable does not change the results. The effect of FDIs variation remain negative and significant but still increase with the level of human capital. In addition, the variation of imports of intermediate goods still have a positive and significant effect on the level of technological sophistication (Table14). In the literature FDIs are always normalized to GDP (e.g. Busse et al. (2014)). In that section we used FDIs net inflows in percentage of countries GDP to check if our results are robust to the specification of the interest variables. Using FDIs net inflows in percentage of GDP does not change the results. The effect of FDIs is negative and significant whereas the interactive term with the level of human capital remain positive and significant(Table15). Moreover the coefficient in front of the share of intermediate goods imports from china remain positive ((Table15). Therefore, in conclusion there is negative impact of China FDIs on the level of technology sophistication for African countries excepted those who have a high level of human capital (Direct technology transfer is conditioned by the countries absorptive capability) whereas imports of intermediate goods from China by African countries contribute to an increase in the level of technological sophistication.

6.3.3 Use of the variation of Chinese FDIs stocks

An alternative to the use of the level of Chinese FDIs net inflows and FDIs net inflows from the rest of the world is to use the variation or the growth rate of the share of Chinese FDIs stock in percentage of total FDIs. This variable considers directly FDIs from the rest of the world and allows us to have estimates without omitting variables. Table 18 summarize the results of the estimations using the growth rate of the share of Chinese FDIs stocks in percentage of total FDIs. Results are similar to the previous one with a significant evidence of direct technology transfer for countries with high level of Human capital. This result highlights the robustness of our findings and shows that the capacity of the country to take advantage from the technology coming from abroad is determinant for technology transfer. However, even if the coefficient in front of imports of intermediate goods is positive it is not significant.

These robustness estimations show that our results are robust to both the specification of our interest and dependent variable. However, addressing the issue using value-added exports gives us more information about the real effect of the interactions between the two parties and the real technology upgrade. Thanks to this value-added approach we get an evidence that direct technology transfer through FDIs does not work but is only a transiting technology due to backward integration into global value chains. However indirect technology transfer through intermediate goods is effective.

7 Sensitivity

In the previous section, we highlighted that our result were to robust to the specification of variables. However it is important to look for the sensibility of the results according to the level of development of countries (Income groups) and the regions of location.

7.1 Location of African countries: by region

We conduced our estimations subdividing the sample into two group Sub-Saharan African (SSA) Countries and Middle East and North Africa (MENA). That division does not give us any significant information because the sample is mainly constituted of Sub-Saharan African Countries. Therefore, with no surprise the previous results are true for the Sub-Saharan African Countries sample (Table16) whereas there no significant coefficient in the MENA sub-sample. As this subdivision is very asymmetric, we study the effects regarding the heterogeneity of African countries across income groups

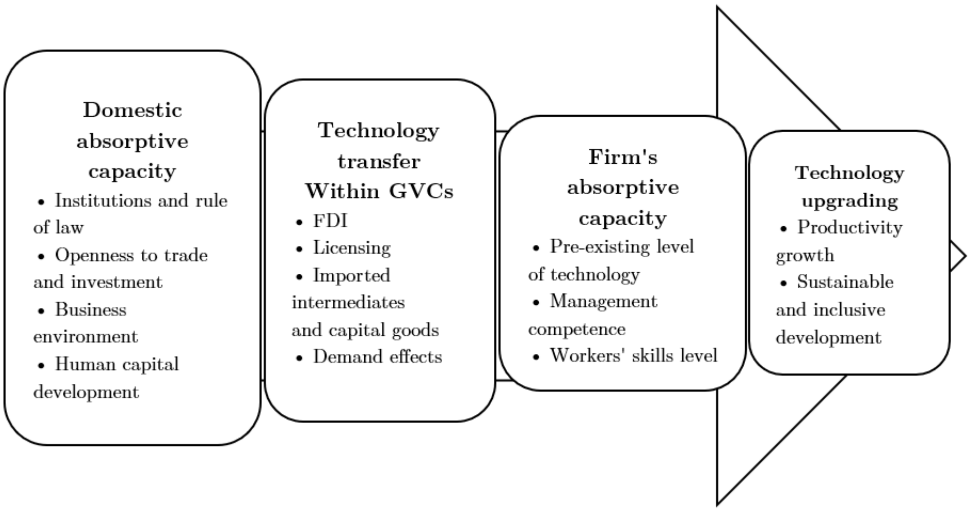
7.2 The level of development of African countries: by income group

Considering the World Bank classification of countries according to their level of development or the level of their income, we conduced our estimation using sub-sample according to that division. Therefore, we will use four type of income groups that will be aggregated together. The World Bank income groups classification is made of *low income countries*, *lower middle income countries*, *upper middle income countries* and *high income countries*. In our estimation, in order to have a minimum of symmetry across the groups, we kept three class of income groups putting upper middle income and high income groups together. The results (Table17) show that for low income countries, FDIs from China have a negative effect however the more countries have the high level of human capital, the more positive the effect of FDIs net inflows from China become. That result shows that for African low income countries, their interaction with China into Global Value Chains lead to technology transfer if they are well endowed of human capital. Moreover, an increase in the share of intermediate goods from imports from China also lead to an increase in the level of technological sophistication index. However, the coefficient significant at 10%. The rest of the two income groups does not have significant coefficients. Indeed for the rest of income groups the effects of FDIs net inflows and intermediate imports from China are not significant. Therefore, the positive indirect technology transfer resulted from the relation between African countries and China is only true for low income countries.

8 A Panel Smooth Transition Regression (PSTR) approach

In this section we used a PSTR approach to model technology transfer resulting from international interaction between China and Africa taking into account human capital and governance (absorptive capacity of African countries). Absorptive capacity can be defined as the ability of an organization or region to take advantages from its interactions between other entities by identifying, assimilating and exploiting knowledge from the environment (Cohen and Levin (1989)). The literature on technology transfer has continuously highlighted the role of countries absorptive capacity in capturing technology embodied in FDIs and Imported products (Stone et al. (2015) ; Fu (2008)). When discussing absorptive capacities' role in technology transfer we should keep in mind that there is two kind of absorptive capacity: the first one refers on firms and organizations' absorptive capacity (Girma (2005); Cohen and Levin (1989)); the second one refers to country level absorptive capacity (Stone et al. (2015); Fu (2004); Balasubramanyam et al. (1996)) Figure 8 from Stone et al. (2015), describes the basic mechanism and the importance of the

Figure 8: From technology diffusion to national upgrading:the role of absorptive capacity.



Source: Illustrative figure obtained from Stone et al. (2015)

different types of absorptive capacity i.e. firm level and country level absorptive capacity in the establishment of an effective technology transfer, and then how firms benefit from these flows of technology. All this literature off technology transfer highlight the role of domestic economy in fostering technology transfer. Therefore, it appears that the role of FDIs and Imports on technology transfer is not linear, that is why we find it relevant to use a PSTR approach to identify the role of China in African countries technology upgrading.

8.1 Presentation of PSTR model

Threshold regression models draw a jumping character or a structural break in the interaction(relation) between two variables. They consider that individual observations can be splatted into classes based on the value of an observed variable (Hansen (1999)). They are developed for non-dynamic panels with individual fixed effects. Therefore, threshold regression models are some kind of regime-switching models that are characterized by a changing slope parameter according to the regime. Indeed, the first Threshold regression developed by Hansen (1999) assumes a brutal transition between regimes. However, panel threshold regressions models (PTR) do not really traduce the reality. Rather than being brutal, the transition between regimes should be smooth if we want the model to be closest to reality. The PSTR method overcome this reduced scope of the PTR. It has been proposed González et al. (2004) and contrary to the PTR it assumes a gradual transition between regimes. Thus, the transition function, instead of being an indicator will be a continuous function. The PSTR model is presented in the following form:

$$Y_{it} = \alpha_i + \beta_0 X_{it} + \beta_1 X_{it} g(q_{i,t};\gamma;c) + \theta_3 W_{i,t} + \epsilon_{it} \tag{6}$$

Where α_i represents the individual fixed effects, ϵ_{it} the error term which is independent and identically distributed, Y_{it} is the explained variable represented here by the logarithm of Technological Sophistication Index, X_{it} represents the explicatives variables, q it is the transition variable, that will be represented here by two type of variables namely human capital and government effectiveness (Political stability, government effectiveness, rule of law, control of corruption). These two variables are said to be representatives of the absorptive capacity and W_{it} a vector of control variables composed of labor and capital. We followed González et al. (2004), Granger et al. (1993) by supposing that the transition function $g(q_{i,t};\gamma;c)$ is a logistic function with a single threshold.

$$g(q_{it};\gamma;c) = \Big(1 + exp\Big(-\gamma \prod_{j=1}^{m}(q_{it} - c_j)\Big)\Big)^{-1},\ with\,\gamma > 0,\ c_1 \leq \ldots \leq c_m \tag{7}$$

With $c = (c_1 \leq \ldots \leq c_m)$ that represents a vector (dimension m) of location parameters (threshold parameters) and γ the slope of the transition function.

According to the different values taken by the slope parameter and the location parameters, we have many cases:

1st case: With $m = 1$ and $\gamma \longrightarrow \infty$, (equation 6) and (equation 7) represent the two-regime PTR (Panel Threshold Regression, Hansen (1999)).

2nd case: With $m > 1$ and $\gamma \longrightarrow \infty$, the number of identical regimes is two, and the function switches between zero and one at $c_1, \ldots, c_m$.

3rd case: With $\gamma \longrightarrow 0$, the transition function (equation 7) is constant and the model is the standard linear fixed effect model.

In our study, we will keep $m = 1$ with $\gamma \in [0, \infty[$, and that lead to a single monotonic smooth transition with c_1 the threshold value. Therefore, the marginal effect is given by:

$$\frac{dY_{it}}{dX_{it}} = \beta_{it} = \beta_0 + \beta_1 g(q_{it};\gamma;c) With \beta_0 \leq \beta_{it} \leq \beta_0 + \beta_1 \tag{8}$$

In this case we have two extreme values β_1 that is the effect of FDIs and Imports of intermediate from China on the level of technological Sophistication if $g(q_{it};\gamma;c) = 0$ and $\beta_0 + \beta_1$ that represents the effect if $g(q_{it};\gamma;c) = 1$. However, if the transition function takes any value between 0 and 1 (if $g \in]0, 1[$), the effect is given by $\beta_{it} = \beta_0 + \beta_1 g(q_{it};\gamma;c)$. This PSTR model can be generalized to $r + 1$ extreme regimes. Therefore, the model becomes:

$$Y_{it} = \alpha_i + \beta_0 X_{it} + \sum_{j=1}^{r} \beta_j X_{it} g_j(q_{it};\gamma_j;c) + \theta_3 W_{it} + \epsilon_{it} \tag{9}$$

and

$$g(q_{it};\gamma;c) = \Big(1 + exp\Big(-\gamma \prod_{j=1}^{m}(q_{it} - c_j)\Big)\Big)^{-1},\ with\,\gamma > 0,\ c_1 \leq \ldots \leq c_m \tag{10}$$

The estimation of the parameters (marginal effects) of the PSTR model consists in using the fixed effect estimator and the nonlinear least squares (NLS) to the previous transformed model (González et al. (2004) or Colletaz and Hurlin (2006)). Before estimating the PSTR model, following González et al. (2004), we used a testing procedure in order to test first the linearity against the PSTR model and second to determine the number, r, of transition functions, and this, by using the appropriate tests. The tests are presented as follow: They consist of testing the linearity of the model firstly without introducing the transition function. The hypothesizes are as follow: $H0 : r = 0$ Linear model without introducing the transition function (Linearity) $H0 : r = 1$ Model with threshold effects with a minimum of a transition function If $H0$ is rejected it means that there is no linearity and we have at least one transition function in the model. Then, three statistics are computed: the LM, LMF and pseudo LRT

$$LM = \Big(\frac{TN(SSR_0 - SSR_1)}{SSR_0}\Big) \tag{11}$$

$$LM_F = \Big[\frac{(SSR_0 - SSR_1)/Km}{SSR_0/(TN - N - Km)}\Big] \tag{12}$$

$$LRT = \big(log(SSR_0) - log(SSR_1\big) \tag{13}$$

With K the number of explanatory variables; SSR_0 the panel sum of squared residuals under $H0$ (linearity) and SSR_1 the panel sum of squared residuals under $H1$; N the number of countries and T the time. The LM and the Pseudo-LRT statistics have a $\chi^2(mK)$ distribution under null hypothesis whereas the F-statistic (LM_F) has an approximate $F(mK; TN - N - mK)$ distribution under null hypothesis. After this test the next step increases in the hypothesis the number of values that r can take, in order to find the number of transition functions that should be admitted in the model. Therefore, the consist in test in an iterative way the number of possible significant transition functions from two (when $r = 1$) to $r + 1$ possible transition functions.

$H0 : r = j$ Model with threshold effects with a minimum of j transition functions. With $j \geq 2$.

$H0 : r = j + 1$ Model with threshold effects with a minimum of $j + 1$ transition functions.$j \geq 2$.

As in the previous cases, we used the three statistics LM, LM_F and pseudo-LRT and they can be computed according to the same definitions. The procedure ends when the null hypothesis $H0$ is accepted and the conclusion is that there are j transition functions. However, if the null hypothesis of linearity is rejected and the null hypothesis of $H0 : r = 2$, we have a situation of non-linearity with one (1) transition function. Then, if $m = 1$ ass previously supposed for this case, we have a PSTR with two regimes.

8.2 Results of the Panel Smooth Transition Regression

In all the test the first things to see is the linearity test and the number of transition function identified in the model. Testing the linearity of the model with all the possible threshold variables and using the LM, LM_F and pseudo LRT statistics shows that there is at least one (1) transition function. Therefore, the model is not linear, and we can look for threshold effects.

As previously explained the same test will be repeated with increasing values of r ($H0 : r = j$ and $H1 : r = j + 1$ with j≥2) until we accept the null hypothesis. Therefore, the second step consist in identifying the number of transition functions that should be retained in the model.

Table 8: Linearity Tests

H0: Linear Model and H1: PSTR model with at least one Threshold Variable (r=1)					
Threshold Variables	Human Capital	Government Effectiveness	Political Stability	Rule of Law	Control of Corruption
Wald Tests (LM):	47,437***	19,077 ***	13,616**	16,035***	12,066**
Fisher Tests (LMF):	10,601***	3,722 ***	2,145 **	3,082**	2,275**
LRT Tests (LRT):	52,674***	19,951 ***	14,054 **	16,646***	12,408**

*** p<0.01, ** p<0.05, * p<0.1

In the second step table in annex 2 presents the results of LM, LM_F and pseudo-LRT statistics tests. All the test concludes to a nonlinear model with a single threshold i.e. r=1 excepted when the threshold variable is *"Rule of Law"* (Where the number of thresholds equal 2). In this study the interest's variables that should be affected by the threshold (absorptive capacity) are FDIs from China and Imports of intermediate from China. However, the PSTR model applies the threshold regression to all the variable (including controls variables). Therefore, we will focus on the interest's variables, but it does not prevent us from having a look at on controls variables in the second regimes.

8.2.1 Results: The threshold variable is Human Capital

When considering the level of Human capital as the threshold variable, we can se that in regime 1 FDI have a negative effect on the level of technologycal sophistication whereas it has a positive effect on technologycal sophistication in regime 2. Indeed, FDIs received by African countries from China have a negative effect on technologycal sophistication when the level of Human Capital is below the threshold (threshold: log (HK) = 1,3133 i.e. HK = 3,72) this result highlight that when African countries reach a gross enrollment ratio in tertiary of 3,72%, FDIs from China start increasing the level of technological sophistication. The return point of Human Capital necessary for an effective technology transfer from China's FDIs is 3,72% of enrollment in tertiary school. The negative effect of China FDI's on the level of technological sophistication is due to the fact that countries with low human capital level attract FDI that are lower skilled labor-intensive and that does not encourage the increase of human capital. When lower skilled-labor intensive companies enter a country, the need for low skilled worker will increase the level of the mean wage for low skills and decrease the mean of high skilled wage. Therefore, that situation will increase people preferences for low skilled jobs and will have negative effect on human capital and also on the level of sophistication of the country.

8.2.2 Results: The threshold variable is Government effectiveness index

The interaction between China and African countries toward global value chains lead to a technological transfer after a certain threshold of government effectiveness. In the literature of technology transfer the level of institutional development is said to be a key determinant of technological transfer. Indeed, in Regime 1 FDIs and Imports of intermediate from China have a negative and significant effect on the level of technological sophistication of African countries. However, after a certain threshold of government effectiveness FDIs from China and Imports of intermediate have a positive effect on Technological sophistication. From this estimation, we should retain that there is no direct and indirect technological transfer in the interaction between China and Africa until the level of government effectiveness (GE) of African countries reach a certain level (Threshold GE = -0,7129 with GE $\in [-2,445876, 2,436975]$ for all the countries). After that threshold, interactions between China and Africa starts leading to direct technological transfer through FDIs and indirect technological transfer through imports of intermediate (positive and significant effect).

8.2.3 Results: The threshold variable is Political Stability or Rule of law

Political stability is a part of countries absorptive capacity because it is among proxies of institutional development. Then, it is relevant to look for technological transfer regarding the level of political stability and the absence of violence. Indeed, this variable is very intuitive because instability has a negative effect on countries' capacity to take advantages from their interaction in global value chains. The results of the PTSR show that there is a threshold of political stability PS = -0,2445 (with PS $\in [-3,314937, 1,961483]$ for all the countries) and below this threshold (Regime 1), the coefficient in front of FDI is negative but not significant and the coefficient in front of imports of intermediate is positive and not significant. However, in regime 2 the coefficient in front of FDI is positive and not significant whereas the coefficient in front of imports of intermediate is positive and significant. In that case, the estimation does not show any significant direct technology transfer from China; but there is a significant indirect technology transfer from China when the threshold variable is political stability. This result can be explained by the fact that political instability does not prevent the country from receiving FDIs and sometimes firms are interested in countries with low political stability in order to take advantages from this situation. That is why there no significant effect for direct technology transfer (through FDIs). The result is the same when using rule of Law as threshold variable. There is no significant evidence for a direct technological transfer for both regime 1 and regime 2 whereas the log of imports of intermediate is significant and positive at regime 2. That means that there is an indirect technological transfer when the level of rule of law is above RL = -0,7956 (with RL $\in [-2,06445, 2,100273]$).

8.2.4 Results:The threshold variable is control of corruption

Corruption control is a necessary element in the level of the quality of institutions. Then, it can be considered as a proxy of absorptive capacity. The PTSR shows that in regime 1 there is a negative and significant effect of both FDIs and Imports of intermediate on the level of technological sophistication. The effect becomes positive and significant at regime 2. This positive effect means that there is both direct and indirect technology transfer in the relations between China and Africa toward global value chains. In other words, interactions between China and Africa starts leading to technology transfer only when the level of control of corruption reach a certain threshold (CC = -0,9071 with CC $\in [-1,868714, 2,469991]$. Below this threshold we assist in a direct and indirect technological transfer from China to Africa, other things being equal.

8.2.5 Results: The threshold variable is Political Stability or Rule of law

In that section we tried to use the level of GVC integration as a threshold variable. For this we are going to see only the effect of China FDI on the level of technological sophistication without taking into account indirect technology transfer. The reason of not considering indirect technology transfer is that this way through which African countries get technology from China channels through intermediate imports and exports that are integrated in the determination of GVC integration Index.

9 Conclusion

In this paper, we have investigated the question of technology transfer through global value chains; focusing on the case of China and African countries. Regressions suggest that there is no direct technology transfer through FDIs in the relations between China and African Countries excepted when African countries are well endowed of human capital. Deep analysis using the PSTR model show the existence of a threshold of absorptive capacity of African countries (human capital level and institutional concerns) above which direct technology transfer (FDIs) through global value chains is effective. Despite the difficulty to add heterogeneity we found that this effect is true for low income countries. Moreover, results also show the existence of indirect technology transfer (Imports of intermediate goods) that is robust to many specifications and the method. However, our analysis gives a new and innovative approach of sophistication using trade in value-added to obtain the real level of sophistication. The results highlight the existence of indirect technology transfer through imports of intermediate and value-added imported whereas direct technology transfer is not robust and always depend on the level of human capital.

In terms of policy, African countries should first work to improve their absorptive capacity because it matters from to beginning to the end of the process. Indeed, good institutions will make sure upstream that that FDIs are growth and development-friendly and will favor efficient contract enforcement. Moreover, the level of human capital is crucial for technology upgrade through global value chains; therefore policy makers should try to invest more on tertiary education by giving a wide range of education and training programs if they want to take advantage in term of technology upgrading from future FDIs inflows. The remaining question is whether African countries will benefit from the competition between Chinese and Western countries investments.

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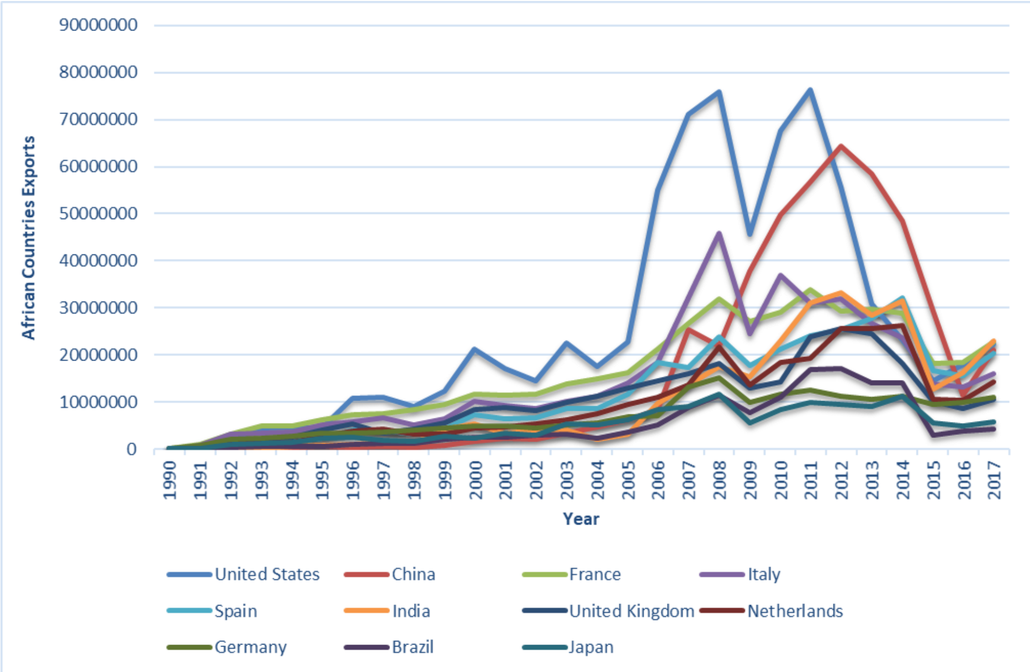
10 Annex

10.1 Annex 1: Tables and figures

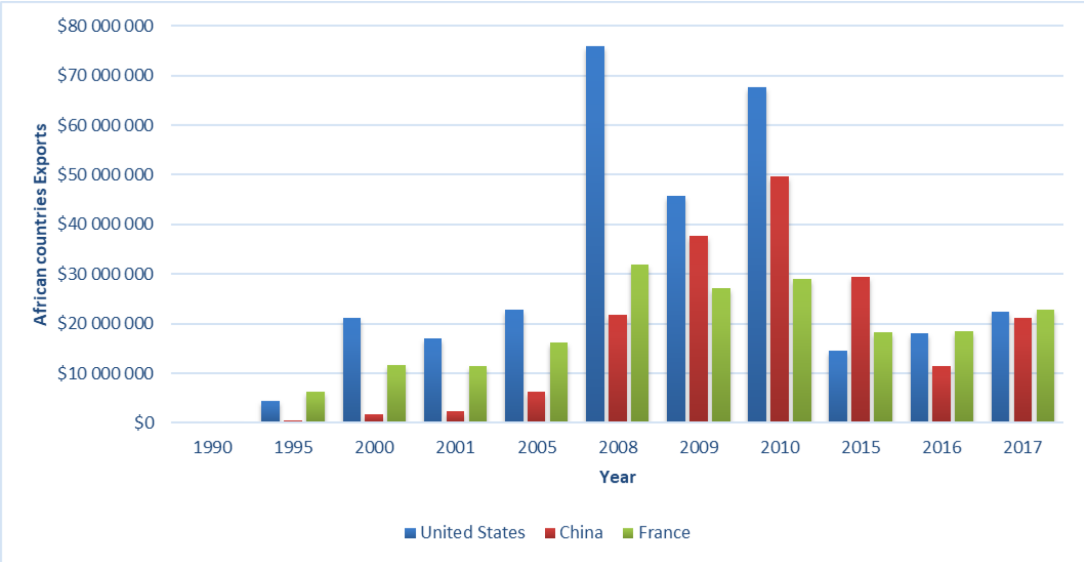
Figure 9: African countries' exports



Source: authors calculation based on UN-COMTRADE data

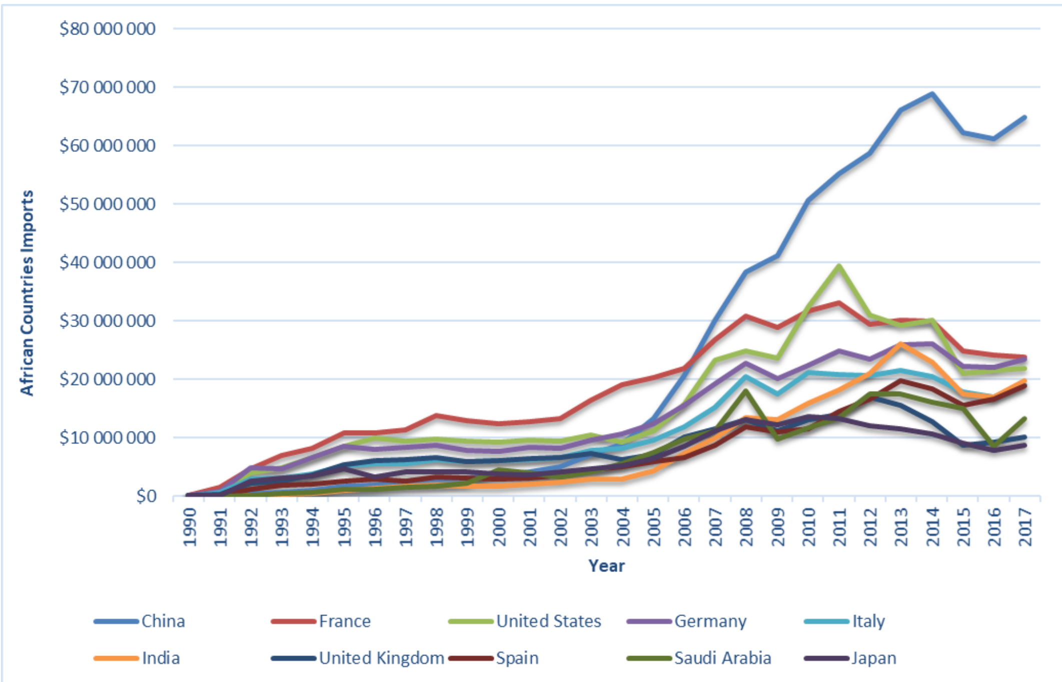
FDICH Flows$_t$ log ImportsCH$_t$ log HK $\times$ FDICH Flows$_t$ log HK $\times$ log ImportsCH$_t$ log Exports$_t$ log Labour$_t$ log Capital$_t$ log HK$_t$

Figure 10: African countries' exports to France, USA and China



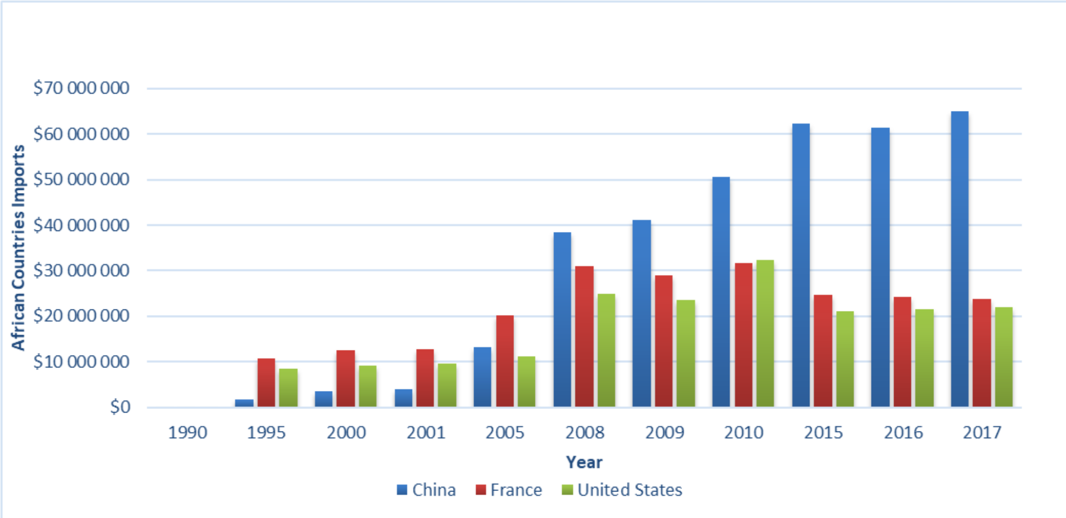
Source: authors calculation based on UN-COMTRADE data

Figure 11: African countries' imports



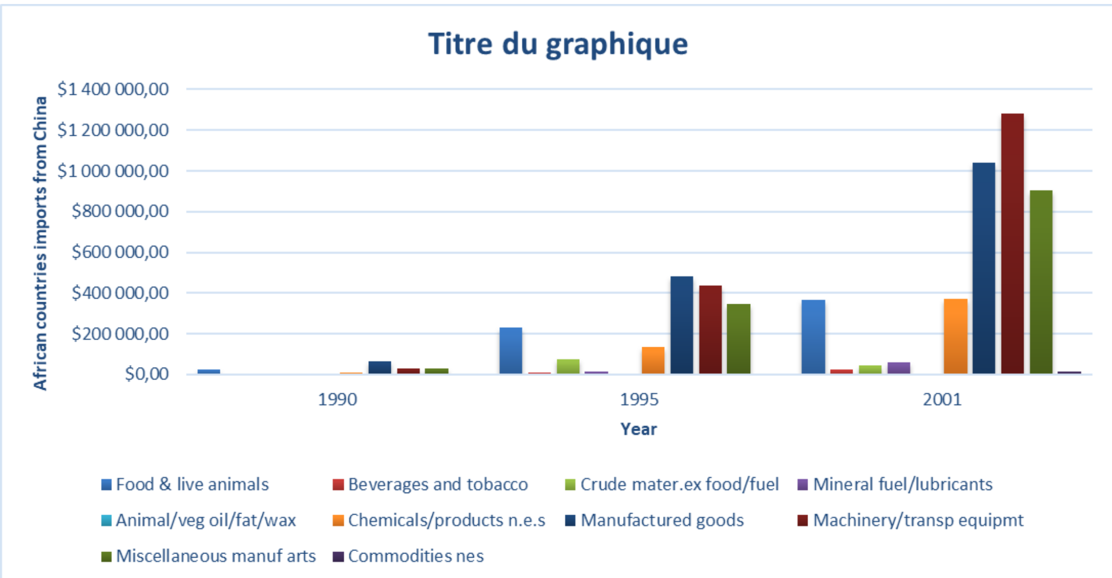
Source: authors calculation based on UN-COMTRADE data

Figure 12: African countries' imports from France, USA and China



Source: authors calculation based on UN-COMTRADE data

Figure 13: African countries' imports by Product Types from 1990 to 2001



Source: authors calculation based on UN-COMTRADE data

Table 9: Correspondance between EORA codes data and ISICRev3 codes

Sector Name	Code	ISICRev3
Agriculture	1	1, 2
Fishing	2	5
Mining and Quarrying	3	10, 11, 12, 13, 14
Food & Beverages	4	15, 16
Textiles and Wearing Apparel	5	17, 18, 19
Wood and Paper	6	20, 21, 22
Petroleum, Chemical and Non-Metallic Mineral Products	7	23, 24, 25, 26
Metal Products	8	27, 28
Electrical and Machinery	9	29, 30, 31, 32, 33
Transport Equipment	10	34, 35
Other Manufacturing	11	36
Recycling	12	37
Electricity, Gas and Water	13	40, 41
Construction	14	45
Maintenance and Repair	15	50
Wholesale Trade	16	51
Retail Trade	17	52
Hotels and Restaurants	18	55
Transport	19	60, 61, 62, 63
Post and Telecommunications	20	64
Financial Intermediation and Business Activities	21	65, 66, 67, 70, 71, 72, 73, 74
Public Administration	22	75
Education, Health and Other Services	23	80, 85, 90, 91, 92, 93
Private Households	24	95
Others	25	99
Re-export & Re-import	26	NA

Source : Lenzen et al. (2013) correspondance EORA data and ISICRev3

Table 10: Correspondence between MRIO EORA data sector classification, ISICRev3 and the level of technological sophistication used in this paper

Code	ISICRev3	Technological Sophistication Code	Manufacturing Technology Level
1	1, 2	0	Primary sector and services
2	5	0	Primary sector and services
3	10, 11, 12, 13, 14	0	Primary sector and services
4	15, 16	1	Low technology
5	17, 18, 19	1	Low technology
6	20, 21, 22	1	Low technology
7	23, 24, 25, 26	2	Medium-low technology
8	27, 28	2	Medium-low technology
9	29, 30, 31, 32, 33	4	High technology
10	34, 35	3	Medium-high technology
11	36	1	Low technology
12	37	1	Low technology
13	40, 41	0	Primary sector and services
14	45	0	Primary sector and services
15	50	0	Primary sector and services
16	51	0	Primary sector and services
17	52	0	Primary sector and services
18	55	0	Primary sector and services
19	60, 61, 62, 63	0	Primary sector and services
20	64	0	Primary sector and services
21	65, 66, 67, 70, 71, 72, 73, 74	0	Primary sector and services
22	75	0	Primary sector and services
23	80, 85, 90, 91, 92, 93	0	Primary sector and services
24	95	0	Primary sector and services
25	99	0	Primary sector and services
26	NA	0	Primary sector and services

Source: ISIC (3)

Table 11: Results of the first and second steps regressions using fixed effect

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects
Flows	-0.000168		-0.00174***		-0.00151***	-0.00186***
	(0.000140)		(0.000486)		(0.000489)	(0.000534)
lTotalImports		0.238***		0.244***	0.231**	0.240**
		(0.0616)		(0.0622)	(0.0972)	(0.0970)
lGERTFlows			0.000582***		0.000452***	0.000548***
			(0.000172)		(0.000171)	(0.000180)
lGERTlTotalImports				-0.00605	0.0401***	0.0379***
				(0.00762)	(0.0140)	(0.0141)
lexpiTochina						-0.0482
						(0.0296)
Labour	-0.00281	-0.00792*	-0.00497	-0.00686	-0.00870	-0.00864
	(0.00781)	(0.00454)	(0.00768)	(0.00473)	(0.00770)	(0.00767)
lkpriv_rppp	0.116	0.115*	0.141	0.107	0.235**	0.235**
	(0.101)	(0.0647)	(0.0996)	(0.0657)	(0.104)	(0.104)
lGERT	0.000792	-0.00176	0.0184	0.0533	-0.365**	-0.334**
	(0.0593)	(0.0347)	(0.0583)	(0.0775)	(0.141)	(0.142)
Constant	9.049***	7.299***	9.083***	7.206***	6.797***	7.108***
	(0.574)	(0.608)	(0.562)	(0.619)	(1.132)	(1.143)
Observations	298	444	298	444	283	283
R-squared	0.073	0.174	0.115	0.175	0.190	0.200
Number of id	41	42	41	42	39	39
Country FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Corrected for heteroscedasticity.

Table 12: Use of both TS Index computed with value-added exports and lags of Intermediate imports from China

VARIABLES	(1) Fixed Effects	(2) Fixed Effects	(3) Fixed Effects	(4) Fixed Effects
Flows	-0.00149***		-0.00126**	-0.000960
	(0.000564)		(0.000557)	(0.000608)
c.lGERT#c.Flows	0.000553***			0.000355*
	(0.000193)			(0.000203)
L.lTotalImports		-0.238***	0.0400	0.0415
		(0.0879)	(0.112)	(0.111)
c.lGERT#c.laglTotalImports		0.0300**	0.0513***	0.0525***
		(0.0129)	(0.0167)	(0.0167)
lexpiTochina				0.0411
				(0.0335)
Labour	0.0139	-0.00501	0.00540	0.00556
	(0.00878)	(0.00859)	(0.00905)	(0.00904)
lkpriv_rppp	0.0227	0.0561	0.114	0.115
	(0.127)	(0.108)	(0.128)	(0.128)
lGERT	-0.248***	-0.312**	-0.727***	-0.746***
	(0.0759)	(0.130)	(0.173)	(0.173)
Constant	-2.463***	-0.0998	-2.747**	-3.123**
	(0.704)	(0.930)	(1.320)	(1.354)
Observations	222	457	222	222
R-squared	0.357	0.203	0.391	0.396
Number of id	28	35	28	28
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Corrected for heteroscedasticity.

Table 13: Fixed effect estimations taking into account FDIs (In US$) and Imports of Intermediate goods from the Rest of the World

VARIABLES	(1) Fixed Effects	(2) Fixed Effects	(3) Fixed Effects	(4) Fixed Effects
Flows		-0.00172**	-0.00185***	-0.00180***
		(0.000650)	(0.000614)	(0.000636)
FlowsRW		-6.21e-06	-6.05e-06	-5.46e-06
		(1.25e-05)	(1.22e-05)	(1.18e-05)
c.Flows#c.lGERT		0.000573**	0.000597***	0.000586***
		(0.000215)	(0.000188)	(0.000194)
D.lICHN	0.226		0.320**	0.361**
	(0.208)		(0.149)	(0.144)
D.lIRW	0.0176		6.801	6.616
	(6.693)		(5.458)	(5.598)
D.lIEqCHN				-0.609
				(0.370)
D.lIEqRW				0.670
				(0.688)
lkpriv_rppp	0.0930	0.143	0.161	0.176
	(0.153)	(0.188)	(0.213)	(0.211)
lGERT	0.00842	0.0236	0.0271	0.0335
	(0.0509)	(0.0649)	(0.0671)	(0.0662)
Constant	10.64***	9.559***	10.07***	9.816***
	(1.555)	(2.160)	(2.189)	(2.130)
Observations	444	298	283	283
R-squared	0.148	0.115	0.144	0.153
Number of id	42	41	39	39
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Corrected for heteroscedasticity.

Table 14: Fixed effect estimations taking into account variations of interests and controls variables

VARIABLES	(1) Fixed Effects	(2) Fixed Effects	(3) Fixed Effects	(4) Fixed Effects
D.Flows	-4.14e-05	-0.00111***	-0.00131***	-0.00125***
	(8.17e-05)	(0.000404)	(0.000300)	(0.000299)
D.FlowsRW	-1.89e-06	-1.04e-06	-1.46e-06	-5.48e-06
	(5.34e-06)	(5.55e-06)	(6.09e-06)	(6.69e-06)
cD.Flows#c.lGERT		0.000378***	0.000445***	0.000426***
		(0.000135)	(0.000100)	(9.79e-05)
D.lICHN	0.225	0.303**	0.453***	0.579***
	(0.161)	(0.117)	(0.112)	(0.135)
D.lIRW				5.274
				(5.569)
D.lIEqCHN	-0.175	-0.236	-0.556	-1.113
	(0.515)	(0.519)	(0.610)	(0.662)
D.lIEqRW				1.590
				(1.009)
D.lEXCH			-0.178	-0.179
			(0.112)	(0.106)
lkpriv_rppp	0.323	0.311	0.355	0.336
	(0.257)	(0.257)	(0.275)	(0.267)
lGERT	-0.0196	-0.0111	-0.0283	-0.00712
	(0.0776)	(0.0781)	(0.0917)	(0.0917)
Constant	8.736***	8.911***	5.721**	5.761**
	(2.810)	(2.777)	(2.487)	(2.245)
Observations	259	259	218	218
R-squared	0.109	0.134	0.213	0.228
Number of id	37	37	31	31
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Corrected for heteroscedasticity.

Table 15: Fixed effect estimations taking into account FDIs in percentage of GDP

	(1)	(2)	(3)	(4)
VARIABLES	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects
FlowsGDP	-9.515***	-15.90***	-16.02***	-16.01***
	(3.424)	(1.829)	(1.924)	(1.951)
FlowsRWGDP	-0.186	-0.167	-0.190	-0.105
	(0.402)	(0.402)	(0.419)	(0.347)
c.FlowsGDP#c.lGERT		4.334***	4.352***	4.847***
		(0.917)	(1.049)	(1.022)
D.lICHN			0.322**	0.428***
			(0.152)	(0.147)
D.lIRW			6.341	5.330
			(5.093)	(4.790)
D.lIEqCHN				-0.776*
				(0.430)
D.lIEqRW				1.462
				(0.964)
D.lEXCH				-0.0933
				(0.104)
lkpriv_rppp	0.110	0.0944	0.120	0.184
	(0.187)	(0.186)	(0.207)	(0.212)
lGERT	0.0125	0.00779	0.00877	0.0233
	(0.0622)	(0.0626)	(0.0645)	(0.0736)
Constant	9.564***	9.672***	10.25***	6.999***
	(2.090)	(2.112)	(2.143)	(1.734)
Observations	298	298	283	239
R-squared	0.120	0.137	0.163	0.224
Number of id	41	41	39	33
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Corrected for heteroscedasticity.

Table 16: Fixed effect estimations by regions

	(1)	(2)
VARIABLES	Sub-Saharan Africa	Middle East & North Africa
Flows	-0.00183***	-0.000440
	(0.000640)	(0.000443)
FlowsRW	-1.91e-05	-1.02e-07
	(3.72e-05)	(7.76e-07)
c.Flows#c.lGERT	0.000646***	0.000103
	(0.000210)	(0.000129)
D.lICHN	0.383**	0.126
	(0.143)	(0.153)
D.lIRW	6.844	2.953
	(6.759)	(1.717)
D.lIEqCHN	-0.709	-0.0139
	(0.444)	(0.260)
D.lIEqRW	0.980	-0.916
	(0.742)	(0.669)
lkpriv_rppp	0.242	-0.223***
	(0.270)	(0.0134)
lGERT	0.0311	0.00535
	(0.0686)	(0.0232)
Constant	10.34***	11.41***
	(2.537)	(0.457)
Observations	235	48
R-squared	0.173	0.781
Number of id	34	5
Country FE	YES	YES
Year FE	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Corrected for heteroscedasticity.

Table 17: Fixed effect by Income groups (World Bank delimitation)

	(1)	(2)	(3)
VARIABLES	Low income	Lower middle income	Upper middle and High
Flows	-0.00256***	-0.00345	0.000946
	(0.000466)	(0.00303)	(0.000708)
FlowsRW	-7.38e-05*	8.50e-07	-2.54e-05
	(3.77e-05)	(1.10e-05)	(2.56e-05)
c.Flows#c.lGERT	0.00133***	0.00129	-0.000278
	(0.000401)	(0.00111)	(0.000203)
D.lICHN	0.309*	-0.550	0.141
	(0.156)	(0.404)	(0.270)
D.lIRW	7.267	-2.064	-2.036
	(9.105)	(5.711)	(1.576)
D.lIEqCHN	-0.506	0.287	0.0428
	(0.468)	(0.781)	(0.639)
D.lIEqRW	0.336	3.111	0.205
	(0.843)	(1.790)	(0.316)
lkpriv_rppp	0.440	-0.166	-0.188
	(0.381)	(0.288)	(0.177)
lGERT	-0.100	0.0918	0.0291
	(0.0888)	(0.0806)	(0.100)
Constant	13.75***	9.862***	9.591***
	(4.723)	(2.971)	(0.936)
Observations	140	101	42
R-squared	0.270	0.268	0.443
Number of id	18	15	6
Country FE	YES	YES	YES
Year FE	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Corrected for heteroscedasticity.

Table 18: Use of variation of the share of Chinese FDIs Stocks

VARIABLES	(1) Fixed Effects	(2) Fixed Effects	(3) Fixed Effects	(4) Fixed Effects	(5) Fixed Effects	(6) Fixed Effects
var_fdistock_China	-0.000124		-0.00142**		-0.000213	-0.00152**
	(0.000133)		(0.000591)		(0.000176)	(0.000590)
c.lGERT#c.var_fdistock_China			0.000475**			0.000458**
			(0.000192)			(0.000184)
lTotalImports		0.241***		0.247***	0.149	0.138
		(0.0796)		(0.0772)	(0.140)	(0.138)
lGERTlTotalImports				-0.00577	0.0646*	0.0563
				(0.0159)	(0.0356)	(0.0356)
lexpiTochina						-0.0411*
						(0.0214)
lLabour	0.0518	-0.452	0.0898	-0.391	-0.321	-0.350
	(0.536)	(0.335)	(0.540)	(0.345)	(0.559)	(0.526)
lkpriv_rppp	0.124	0.107	0.289	0.100	0.349	0.363
	(0.140)	(0.146)	(0.225)	(0.157)	(0.234)	(0.233)
lGERT	-0.102	-0.000964	-0.00819	0.0514	-0.644*	-0.544
	(0.109)	(0.0487)	(0.0754)	(0.142)	(0.377)	(0.378)
Constant	8.857***	8.655***	8.105***	8.383***	8.042***	8.576***
	(2.075)	(1.580)	(2.160)	(1.438)	(2.242)	(2.104)
Observations	273	444	273	444	259	259
R-squared	0.021	0.174	0.141	0.175	0.189	0.232
Number of id	40	42	40	42	37	37
Country FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Corrected for heteroscedasticity.

10.2 Annex 2: PSTR Results tables and figures

Table 19: Wald Tests (LM)

Hypothesis on the Number of Thresholds using Wald Tests(LM)	Threshold Variables				
	Human Capital	Government Effectiveness	Political Stability	Rule of Law	Control of orruption
H0: r=0 vs H1: r=1	47,437 ***	19,077 ***	13,616**	6,035***	12,066**
H0: r=1 vs H1: r=2	2,807	4,219	6,228	11,897**	1,758
H0: r=2 vs H1: r=3	NA	NA	NA	NA	NA

*** p<0.01, ** p<0.05, * p<0.1

Table 20: Fisher Tests (LMF)

Hypothesis on the Number of Thresholds using F-Tests(LMF)	Threshold Variables				
	Human Capital	Government Effectiveness	Political Stability	Rule of Law	Control of orruption
H0: r=0 vs H1: r=1	10,601***	3,722 ***	2,145 **	3,082**	2,275**
H0: r=1 vs H1: r=2	0,49	0,728	0,889	2,128*	0,3
H0: r=2 vs H1: r=3	NA	NA	NA	NA	NA

*** p<0.01, ** p<0.05, * p<0.1

Table 21: Pseudo LRT

Hypothesis on the Number of Thresholds using LRT-Tests(LRT)	Threshold Variables				
	Human Capital	Government Effectiveness	Political Stability	Rule of Law	Control of orruption
H0: r=0 vs H1: r=1	52,674***	19,951 ***	14,054 **	16,646***	12,408**
H0: r=1 vs H1: r=2	2,823	4,260	6,318	12,229**	1,765
H0: r=2 vs H1: r=3	NA	NA	NA	NA	NA

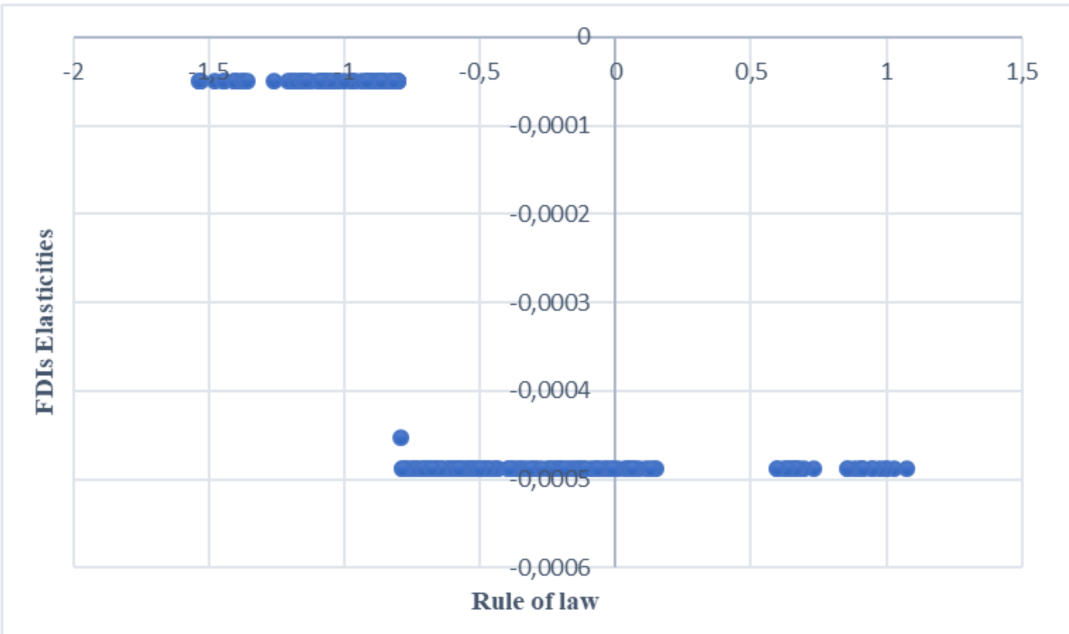
*** p<0.01, ** p<0.05, * p<0.1

Table 22: PSTR results : Threshold variable is Human Capital

Threshold variable: log of Human Capital		
	Coefficient Estimate	
	Régime 1	Régime 2
FDI	-0,0023***	0,0022***
	-0,0005	-0,0005
log Imports of Intermediate	0,1168***	-0,1540***
	-0,0337	-0,026
Labor	-0,0128**	0,0147***
	-0,006	-0,0025
Capital	0,0519	0,2024***
	-0,0891	-0,0381
Log Exports of Intermediate	0,0197*	-0,0268**
	-0,0125	-0,0128
Transition Functions		
	Estimated Transition Parameter	
Slope parameters (γ)	6,8940	
Threshold (c)	1,3133	

*** p<0.01, ** p<0.05, * p<0.1

Figure 14: Transition function



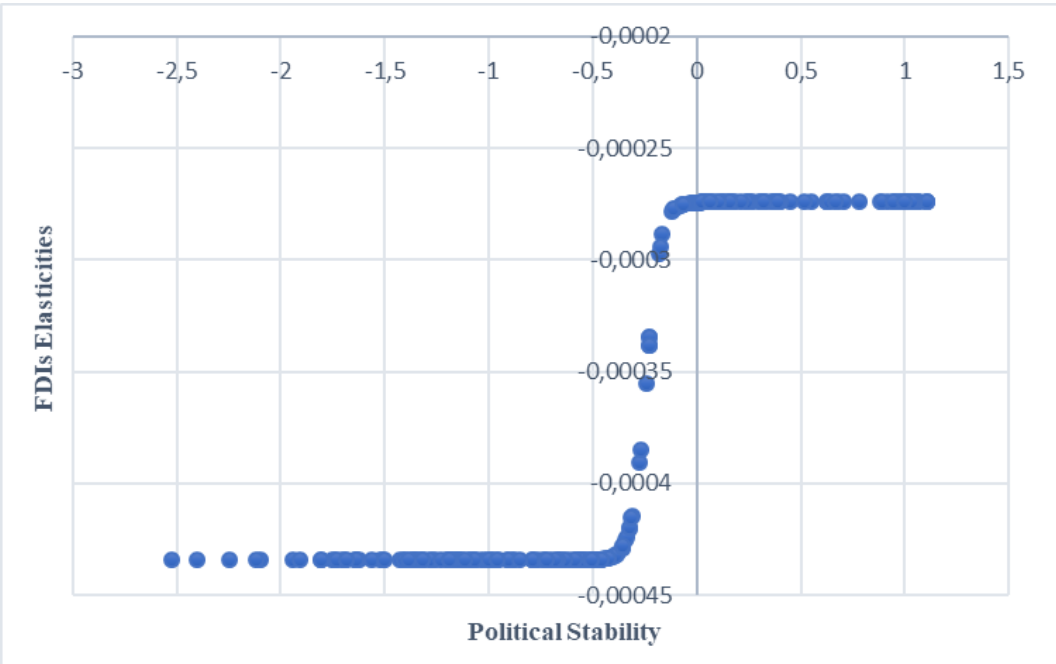
Source: authors calculation based on estimations' results

Table 23: PSTR results : Threshold variable is Government Effectiveness Index

Threshold variable: Government Effectiveness Index		
	Coefficient Estimate	
	Régime 1	Régime 2
log FDI	-0,0027***	0,0025**
	-0,0011	-0,0011
log Imports	-0,0573*	0,1455***
	-0,0374	-0,0287
labor	0,0100**	-0,0154***
	-0,0057	-0,0025
Capital	0,2621***	-0,1331***
	-0,1026	-0,0711
Log Exports	0,0006	-0,0031
	-0,0063	-0,0075
Transition Functions		
	Estimated Transition Parameter	
Slope parameters (γ)	10,7052	
Threshold (c)	-0,7129	

*** p<0.01, ** p<0.05, * p<0.1

Figure 15: Transition function



Source: authors calculation based on estimations' results

Table 24: PSTR results : Threshold variable is Political Stability and Absence of Violence

Threshold variable: Political Stability and Absence of Violence		
	Coefficient Estimate	
	Régime 1	Régime 2
log FDI	-0,0004	0,0002
	-0,0003	-0,0004
log Imports	0,0273	0,1950***
	-0,0349	-0,0416
labor	0,0094*	-0,0131***
	-0,006	-0,0031
Capital	0,4207***	-0,3447***
	-0,1012	-0,0637
Log Exports	0,0016	-0,002
	-0,0064	-0,0085
Human Capital	-0,2156***	-0,0112
	-0,0648	-0,0683
Transition Functions		
	Estimated Transition Parameter	
Slope parameters (γ)	29,1382	
Threshold (c)	-0,2445	

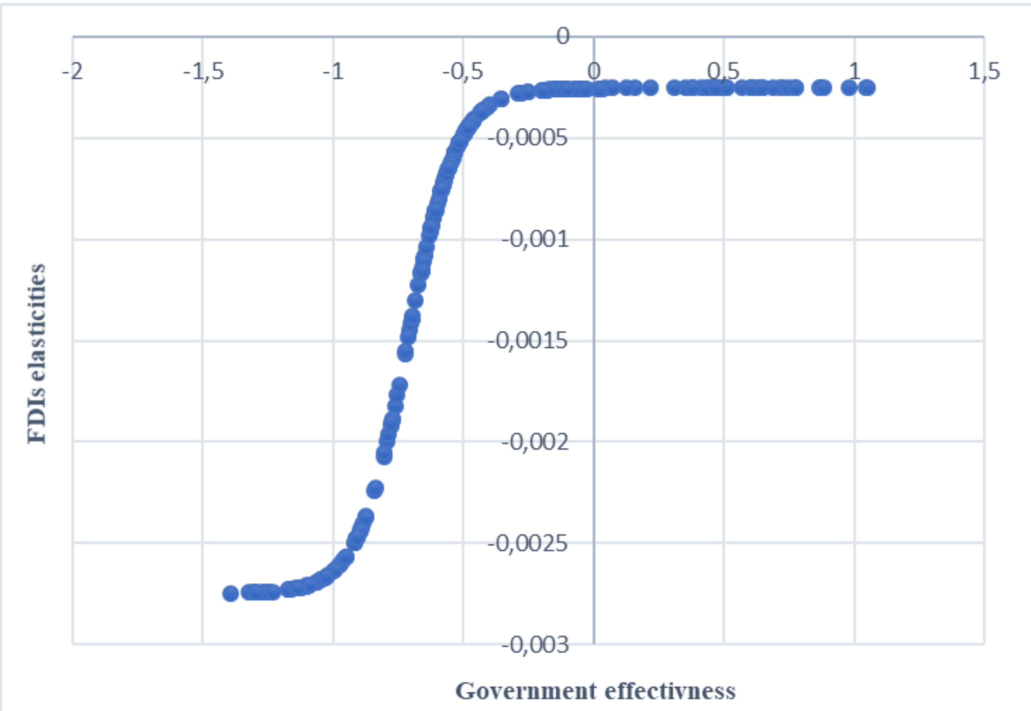
*** p<0.01, ** p<0.05, * p<0.1

Table 25: PSTR results : Threshold variable is Rule of Law

Threshold variable: Rule of Law		
	Coefficient Estimate	
	Régime 1	Régime 2
log FDI	-0,000	-0,0004
	-0,0006	-0,0007
log Imports	-0,0342	0,0948***
	-0,034	-0,0236
labor	0,0079*	-0,0066***
	-0,006	-0,0018
Capital	0,2554***	-0,1451***
	-0,0861	-0,0446
Log Exports	-0,0053	0,0086
	-0,0072	-0,0088
Transition Functions		
	Estimated Transition Parameter	
Slope parameters (γ)	1,1693e+03	
Threshold (c)	-0,7956	

*** p<0.01, ** p<0.05, * p<0.1

Figure 16: Transition function



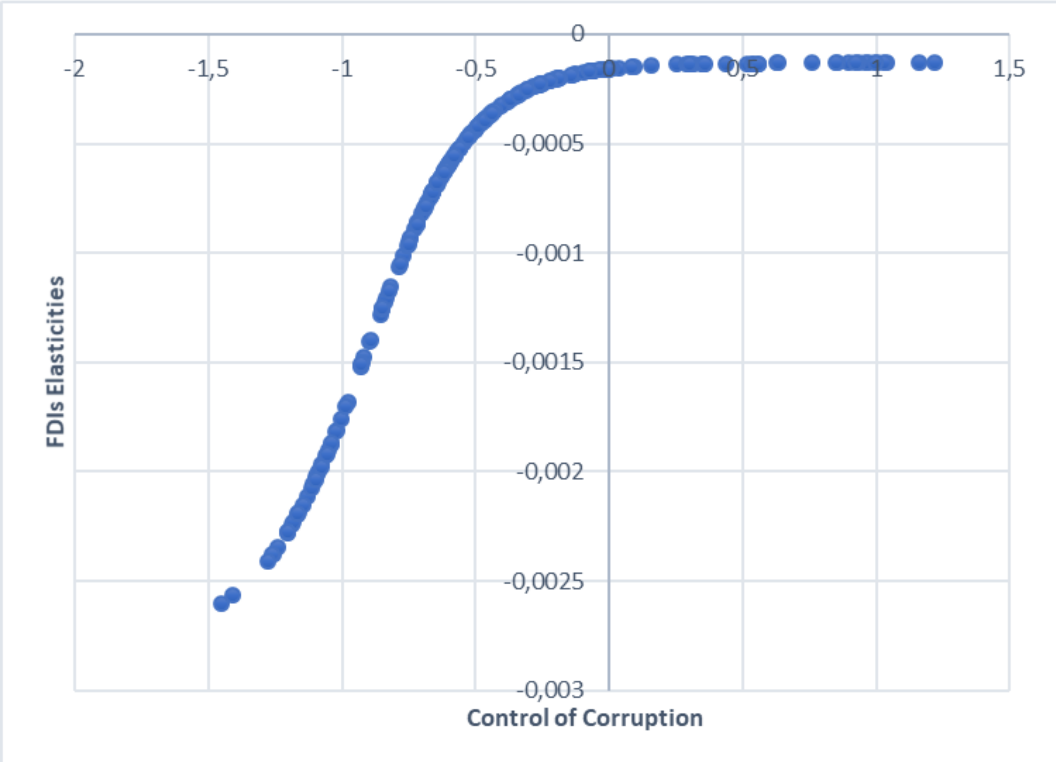
Source: authors calculation based on estimations' results

Table 26: PSTR results : Threshold variable is Control of Corruption

Threshold variable: Control of Corruption		
	Coefficient Estimate	
	Régime 1	Régime 2
log FDI	-0,0028**	0,0026**
	-0,0014	-0,0014
log Imports	-0,1190**	0,2192***
	-0,0687	-0,0765
labor	0,0235***	-0,0266***
	-0,0098	-0,0088
Capital	0,1559	-0,103
	-0,125	-0,1449
Log Exports	-0,0011	-0,0043
	-0,0076	-0,0105
Transition Functions		
	Estimated Transition Parameter	
Slope parameters (γ)	5,0221	
Threshold (c)	-0,9071	

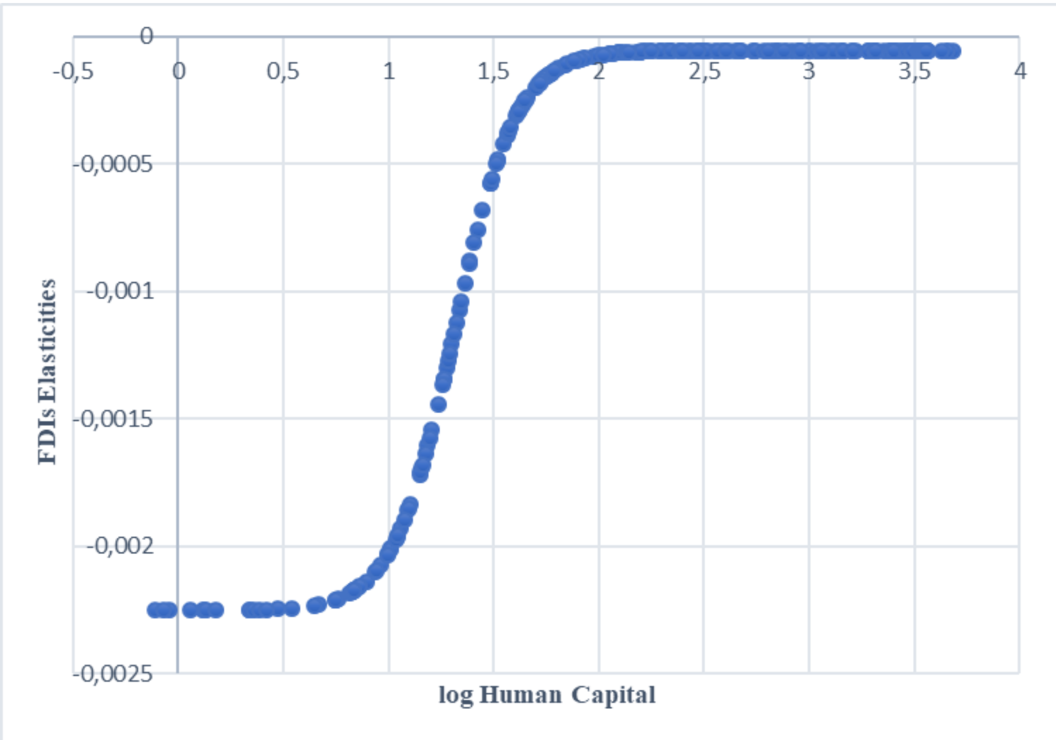
*** p<0.01, ** p<0.05, * p<0.1

Figure 17: Transition function



Source: authors calculation based on estimations' results

Figure 18: Transition function



Source: authors calculation based on estimations' results