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Changing Africa's impoverishing economic model: Towards a rewarding sustainable specialization model with a new factor of production[1]

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Abstract

This paper highlights the impoverishing character of Africa's economic model in its world merchandise trade. With a view to reduce the ousting of the wealth of the continent by its trading partners, we develop a neo-factorial specialization model in which we introduce technology and raw materials as endogenous factors of production of manufactured goods. In addition, we distinguish between skilled labor and unskilled. Considering raw commodities as a factor production (natural capital) and making technology and skilled labor factors endogenous allows us to understand why Africa is historically specialized in raw material exports. We show how Africa can, thanks to its advantage in natural resources, accumulate technology and human capital necessary to its industrialization in the second phase of the model, allowing it to eliminate the impoverishing effects of trade. The model predictions are quite optimistic in the second phase of Africa's opening process to the world. Calibrating the model on real data, results are consistent with some goals of sustainable development particularly in its economic and social dimensions. The environmental dimension is however difficult to reconcile with both others.

Keywords: Impoverishing specialization; African economies; Neo-factorial model; Natural resources; Values' chain.

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1. Introduction

The last decade was marked by a sharp acceleration in world merchandise trade. The volume of world merchandise exports increased by 3.5% per year between 2005 and 2012, while the world GDP grew by only 2% a year over the same period.[2] Africa has not remained on the sidelines of globalization. The volume of trade on the continent with the rest of the world rose by 11% in exports and 13% in imports between 2005 and 2012 against an average annual growth rate of 2.01% in exports and -0.57% imports between 1953 and 2003. However, African products to global trade remain poorly diversified (Asiedu, 2006; Harding and Venables, 2010; Cadot *et al*., 2013; Cadot, Carrère, and Strauss-Kahn, 2013; Kaplinsky and Morris, 2014; Anyanwu, 2014) and are mainly composed of primary products, particularly agricultural commodities and natural resources (Jeanneney and Hua, 2013; OCDE-BAD, 2013; Hugon, 2013). In 2010, the share of industrial products in total African exports is about 20% according to Gelb (2010), between 10 and 11% according to Hugon (2013), Jeanneney and Hua (2013) or according to the United Nations Economic Commission for Africa (2013). In other words, 80% of African exports are commodities with over 59% of non-renewable natural resources including oil and minerals. The predominance of raw materials in Africa's export products seem consistent with traditional theories of international trade according to which each country specializes in the production and marketing of goods in which it has an absolute advantage (Smith), relative advantage (Ricardo) or factorial endowment (Heckscher-Ohlin-Samuelson (HOS)).[3] The impoverishing specialization refers to an economic model in where one exports lot of goods and earns less in return in terms of money (see Fosu, 1990).

This paper aims to show, with stylized facts and mathematical proofs, that the current specialization of Africa in world merchandise trade presents facts that contrast with some predictions of international trade patterns. We develop a neo-factorial[4] specialization model which predicts that Africa can move from

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2 Data from the World Trade Organization, available at https://www.wto.org/french/res_f/statis_f/statis_f.htm, last accessed on 09/07/2015.

3 See Krugman (2009); Levchenko and Zhang (2016); Cadot, Carrère,and Strauss-Kahn (2013) for updated discussions.

4 Because of introducing Natural capital including Natural Resources and Agricultural Commodities, as a new factor in the Cobb-Douglas' production function, the model takes the name "neo-factorial specialization model". The model is considered as new, hence the prefix "neo-", because we made the following changes: introduction of natural capital, abstraction of capital factor, which is decisive in the traditional patterns of international trade, and making technology factor endogenous.

an impoverishing specialization in the first period (current specialization) to an enriching global exchange through an optimization of the values chain by industrialization.

The article is organized as follows: Section 2 presents stylized facts of African international trade and defines a specialization rule. Section 3 develops the neo-factorial specialization model. We present the theoretical foundations of the model and its assumptions before analyzing the predictions of the model in terms of new specialization gains and sustainability of African economies. Section 4 concludes by returning to the important results of the model and the future challenges of research on the issue.

2. Stylized facts and specialization rule

The abundance in Natural Resources (NR) and agricultural products in Africa seems to justify its exclusive exports of raw materials. In consequence, agricultural products account for 25% of Africa's GDP. Africa has on average 52 % of global reserves in NR, shared as follows: 12% of global oil reserves; 40% of world gold reserves; 85 to 95% of metal reserves of chromium and platinum group; 85% of phosphate reserves; more than 50 % of cobalt reserves; and a third of bauxite reserves.[5] According to the HOS model of factor endowments, each country gains from international trade by specializing in the production and export of goods that use more factors for which the country is relatively well endowed. The specialization index[6] (SI) can help us to verify the compliance of international exchange facts from Africa with the predictions of specialization models. Let M, raw materials, m, manufactured product, IM_M, IM_m, X_M and X_m, the import and export quantities of both types of goods respectively. We calculate the Africa 'specialization index.

According to the predictions of the HOS model, the M and m goods export ratio ($\frac{X_M}{X_m}$) is greater than the $\frac{IM_M}{IM_m}$ by volume, due to the M-abundance in Africa. It follows that $\frac{IM_M}{IM_m} \Big/ \frac{X_M}{X_m} \leq 1$. In other words, Africa exports more raw materials than it imports. Using the WTO data from 1980 to 2012, the Africa's SI is 0.699. This is obviously in agreement with the predictions of HOS models, also emphasized

5 Source: http://www.afdb.org/en/annual-meetings-2013/programme/africa%E2%80%99s-natural-resources-what-is-the-agenda/ last accessed on 09/07/2015.

6 The specialization index (SI) in raw materials is defined by the reporting imports (exports) raw materials M and finished products m. $SI = {}^{IM_M/IM_m}\!\big/\!{}_{X_M/X_m}$. The SI is based on the logic of calculation of Leontief specialization coefficient and is interpreted in the same way i.e. if a country exports products which are more intensive in factor for which the country is well endowed, its $SI < 0$.

by Prebisch (1984) in the so-called dependence theory or in unequal exchange model (see Arghiri and Charles, 1978). However, do specialization models really justify the exclusive choice exports of raw commodities in Africa with regard to its current specialization's gains? More obvious that may seem, it is difficult to validate the export choice of raw materials based on the foundations of traditional international trade models. First, these models base their analysis on tradable manufactured goods, not raw materials (see an empirical highlighting of Fosu, 1990). There are relative gains when it is exchange of finished products, which generate added value (Fosu, 1996). Then, we can raise a contradiction between the stylized facts of Africa and predictions of specialization models. Indeed, these specialization patterns in international trade predict that all countries, participating in the international merchandise trade, gain. So, there is no loser. However, Africa loses more than it gains.

For proof, it suffices to calculate a Trade Gain Index (TGI)[7] defined as follows: TGI = $\sum_{j=1}^{p}\left(\frac{X_{net}^{AF}}{IM_{net}^{AF}}\right)$ with X_{net}^{AF} and IM_{net}^{AF} net exports and imports in j ; $j = 1,\ldots,p$ tradable products expressed in value. If international trade is favorable to Africa, $\frac{X_{net}^{AF}}{IM_{net}^{AF}} > 1$. In other words, a TGI > 1 means that exports of raw materials without processing enable Africa to import from its trading partners manufactured goods and capital goods that it does not produce. Its exchanges with the rest of the world are in this case enriching. Using WTO data, we find an index of 0.709. Fosu (2011) highlighted similar results. This result suggests that around 30% of expected gains of Africa in the international exchange of tradable goods are ousted by its trading partners. Gross exports of raw materials of Africa are, in view of this result, an impoverishing specialization's way insofar as it is obliged to export more to satisfy its demand for manufactured goods and equipment.

The Prebisch's (1984) center-periphery relationship and the extraversion of African economies of Bayart (1999), Hugon (2008; 2013) can serve to explain the stylized facts about Africa's international trade. In Prebisch (1984), global economic relations can be summarized as a system with two sets. There is the center of the system focused on transformation means and creation of value added products, and the periphery of the system, in charge of providing necessary materials to the center for the production of goods manufactured (see Koulibaly, 2008). In global trade, Africa would incarnate the role of provider of

[7] We prefer the Trade Gains Index (TGI) to the terms of trade (TOT) because the terms of trade are determined by exogenous variables, notably international prices of tradable goods, while the TGI accounts for the structure of the concerned economies

raw materials. For Bayart (1999) and Hugon (2013), the current specialization of Africa in world trade is the result of the colonial pact[8] that continues to exist due to the lack of profound changes in its economic structures after the independences. Assuming that Africans recognize the current trade patterns are impoverishing, the neo-factorial specialization model provides the conditions for a rewarding specialization for Africa and analyzes the possible effects of this new specialization in terms of sustainable development goals.

3. The neo-factorial specialization model

3.1. The theoretical foundations of the model

The model is based on the postulate that there are technology endowment and natural resources abundance differences between countries. It further postulates that the distinction between skilled and unskilled labor in the production of tradable goods internationally is relevant. Unlike traditional specialization models, advanced or technological endowment gives country preferential gains in international exchange. Finally, the model postulates that the industrialization of Africa is a necessary condition to reverse the situation of Bhagwati's (1958) *impoverishing specialization* and pointed out in Obeng-Odoom (2013).

3.1.1. Technological differences and specialization of countries

Taking into account the technological differences between countries in the specialization models is not new. It is even the source of theories of specialization of Smith and Ricardo. Vernon (1966) already highlighted the technological differences in the production of tradable goods through its product cycle model. [9]

Based on spatial analysis, Mérenne-Schoumaker (2011) supports that large urban areas in developed countries often gather the conditions conducive to launching new products while peripheral areas especially the "Third World" meet the requirements to accommodate the manufacture of products in maturity. This is the design "center-periphery" of international trade (Prebisch, 1984) in which innovations and new technologies start from developed countries (center) and then spread to the rest of the world while the periphery supplies raw materials for the development application of these discoveries.

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[8] The colonial pact is a device conceived at the time of colonization by settlers in which economies under colonial rule had to resolve to produce enough exotic products, raw materials and resources and then, should export them to the mainland to feed and support as long as possible the economic structures of the invader.

[9] For specific literature about technology in tradable goods production, see Aliouat (1996); Ciroth *et al*. (2002); Perrain and Testas (2014); Huet, Ashraf,and Roger (2014); Rousseau (1977); Bessen (2002); Madsen, Saxena, and Ang (2010); Taylor and Copeland (2009).

Feenstra and Rose (2000) empirically validated the model of Vernon by US data. However, the rapid mutations in technology reduce the relevance of the analysis. Indeed, technological advances in R & D, particularly the boom in ICT, make that the time required for a discovery to become obsolete is relatively short. So, other countries benefit from the invention at the same time as its inventor. The recent illustration is Asian countries including China (Wolf, 2016; Kaplinsky, 2009; Busse, Erdogan and Mühlen, 2016; Anyanwu, 2014; Sindzingre, 2016; WTO, 2011)

Technology is the foundation of dynamic models (Solow, 1956). Indeed, studying the sources of growth in the US over a long period (1909-1949), Solow realizes that much of the economic growth is not explained by the sum of the relative contributions of rates traditional growth factors namely capital and labor. The growth of capital per capita for 40 years in the United States has explained a seventh of the growth of total production.

Solow concludes that other unseen factors influence total factor productivity. Those include such factors as the technical advances in the broad sense in that subsequent studies have highlighted the Solow residual differences following the country's level of development (see Mankiw *et al*., 1992). Empirical evidences indicate that this residue is only 14% of the Total Factor Productivity (TFP) in a sample of 145 countries, while TFP reaches 34% for developed countries (Mankiw *et al*., 1992).

More recent analyzes have also attempted to capture the technological differences between countries, showing that there is a technological gap between the North and the South (Hellier, 2012) or between Asian emerging countries and African countries (Kaplinsky, 2009; WTO, 2011; Busse, Erdogan, and Mühlen, 2016; Anyanwu, 2014; Sindzingre, 2016; Wolf, 2016). These differences, according to the authors, lead to differences in terms of productivity gains in a first time and then a catch of seconds by the firsts in the case of North-South analysis, through a learning process and adaptation (learning-by-doing). In this latter case, technology is an exogenous factor in the production and is analyzed in terms of contribution to overall productivity factors.

If the models that consider technology help explaining differences in productivity, neo-factorial model makes this factor endogenous as in Stadler (1990); Xu (2001); Gerlagh and van der Zwaan (2003); Gil Moltó, Georgantzís, and Orts (2005); Taylor and Copeland (2009); Madsen, Saxena, and Ang (2010) or in Anzoategui *et al*. (2016). Make technology endogenous helps us to explain why most of African countries do not produce high value-added goods. This consideration helps explaining how the availability or not of technology influences the specialization rule.

3.1.2. Natural resource endowment and specialization in the production of manufactured goods

Excepted the Stiglitz's (1974) model in where NR are partially considered as factors of production, or the Russo's (2003), Giraud and Olivier (2015) framework analyses integrating natural capital, it exists, to our knowledge, very few models which put NR as factor of production. The criticism on African economies' extraversion (Bayart, 1999) finds that Africa resolves to export only its natural resources without developing an economic modeling of this type of exchange. In this model, we make distinction between natural resources (renewable and non-renewable) and land as factors of production. The latter served as the analytical basis of Thünen, (1826) and HOS models.

To test empirically relevance of NR as factor of production, Ayres *et al*. (2003) showed that the growth factors in an economy are diverse and cannot be limited to only those factors identified in traditional growth models. They showed that, unlike the conventional designs according to which the consumption of raw materials is a consequence of economic growth, these raw materials, in particular energy, are the cause of the economic growth. The availability in NR allows producing at reduced costs and quality of inputs allows for economies of scale. In a competitive situation, the drop in production costs and economies of scale induce a fall in prices of goods that result. Overall demand increases inducing new investments, which in turn stimulate overall production. From the spatial point of view, as "the territories appear more and more as resources that companies can activate" (Mérenne-Schoumaker 2011 p.239-240), the greater or lesser availability of NR, including those used in finished products, becomes an important advantage to be taken into account in the models of production and international trade.

First, it should be noted that NR are not ubiquitous: some areas are better endowed in resources than others. This characteristic is a first point of difference in factor endowment.

Any industrial company which comes closer to raw materials' place of supply can be more competitive than its potential competitors since transport costs are negligible (see Bouvard and Million, 2008). The proximity to raw materials allows companies that settled to expand their potential market: the countries possessing these resources are also a significant potential[10] market flow of tradable goods. The China-Africa economic relationships illustrate this new configuration of the international exchange.[11] Indeed, the volume of manufactured exports towards some developing countries in particular towards Sub-Saharan Africa countries has dramatically increased. According to Jeanneney et Hua (2013), China's exports of manufactured goods to Africa represents 95% of African imports in 2010 while Chinese exports to the rest of the world account for only 23% of total Chinese exports the same date. In return, China imports 90% of African primary products, mainly raw materials for Chinese industries of which 59% oil and 26% minerals (Park *et al*., 2016). China diverts Africa from its old economic partner namely Europe. However, the increase of this southern market – from the perspective of growth – is not accompanied by an improvement in the purchasing power of the population that is relatively very low.[12]

Then, the issues related to the depletion of raw materials oblige to rethink economic development models. Studies indicate that firms are relocating to escape purely environmental regulations considered very restrictive in the North: "Measures relating to the protection of the environment are becoming an obstacle for the most polluting companies. But regulations concerning pollution vary across countries, cities and regions. The most polluting companies move of the most regulated areas towards the more tolerant." (Bouvard and Million, 2008, p.28). However, note that environmental costs are very marginal in total costs, the environment constraints are not the main justifications of the factories' relocation. Environmental constraints and the depletion of natural resources make that they will become less and less available following the rule of Hotelling (1931). But experiences show that exogenous prices determined by raw materials market are inefficient to regulate NR depletion (see Ruta and Venables, 2012; Chamaret, 2007). The challenge in this economic renewal is to ensure that consumption of raw materials is the cause of economic growth and not the consequence. In that vision, the raw materials should be considered as factors in the economic model

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[10] The African population represents 15.7% of the world population in 2014 and will be 25% in 2050, see http://esa.un.org/unpd/wpp/Excel-Data/population.htm

[11] See Kaplinsky (2009); WTO (2011); Anyanwu (2014); Sindzingre (2016); Busse, Erdogan,and Mühlen (2016); Wolf (2016);Park, Lampert, and Robertson (2016).

[12] The average income per capita in purchasing power parity in Sub-Saharan Africa was $ 2,480 (PPP2005) against $ 30,007 in the euro area and $ 33,000 in the OECD higher income countries . In 2014, revenues are respectively $ 3,613 in Sub-Saharan Africa, $ 38 694 in the euro area and $ 42,707 in the OECD. Data from http://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD last accessed on 09/07/2015.

of production as well as physical capital or labor. This amounts to more explicitly assign a price to a such endogenous factor.

3.2. Model hypotheses

The model is based on three assumptions: the sovereignty of Africa in the extraction and trading of its natural resources, a difference in endowment of production factors, a difference in goods in international exchange and finally the existence of a supranational regulator.

H1: the model assumes that Africa is sovereign of the rational use of its natural resources and agricultural raw materials M. It has the opportunity to decide how much quantity to produce. This implies that Africa can decide to transform its NR noted M locally into manufactured goods m before export. This assumption is fundamental to the validation of the model results.

H2: there are three factors of production namely endogenous technology A, skilled labor H, unskilled labor L, raw materials M. Factors A_M and L are necessary for the extraction of raw materials M. Analogically to the message send by the KLEM models (see van der Werf, 2008; Löschel and Otto, 2009), we consider technology (A) endogenous all along this model. As in the Malthusian classical production, factors A_m, H and M are required to produce manufactured good m. Only factors A and M are internationally mobile. The stock of human capital ($L + H$) is very little mobile. Following the idea of fluid capital in nowadays (Taylor, 2000), factor capital is assumed to be 1. Indeed, Mérenne-Schoumaker (2011) supports that if the cost and availability of capital have played a major role in the start of industrialization, this role has currently decreased at regional and local level due to the very high fluidity of this input.

Taking into account the considerations above allows us to understand why Africa is historically specialized in raw material exports and how to improve the trade gains under sustainable development goals considerations.

The production of goods M and m generates different levels of pollution, proportionally to the quantities Q_M and Q_m of raw materials and manufactured goods produced. Technology is assumed to be constant returns to scale. Production functions are given by:

$$F_M\ (A_M, L) = A^{a_M} L^{\beta_M} = (1+e_M)Q_M \quad (1)$$

$$F_m\ (A_m, H, M) = A^{a_m} L^{\beta_m} M^{\eta_m} = (1+e_m)Q_m \quad (2)$$

with $0 < \alpha \leq \beta \leq \eta < 1$, factors production yields ; $0 < e_M < e_m$, pollution factors in the production of goods *M* and *m*. Thus, we assume that the production of manufactured goods is less virtuous from environmental standpoint than raw materials extraction. The production functions of the two goods are Cobb-Douglas type ($0 < \alpha \leq \beta \leq \eta < 1$). The endogenous technology respects the properties of Cobb-Douglas functions.

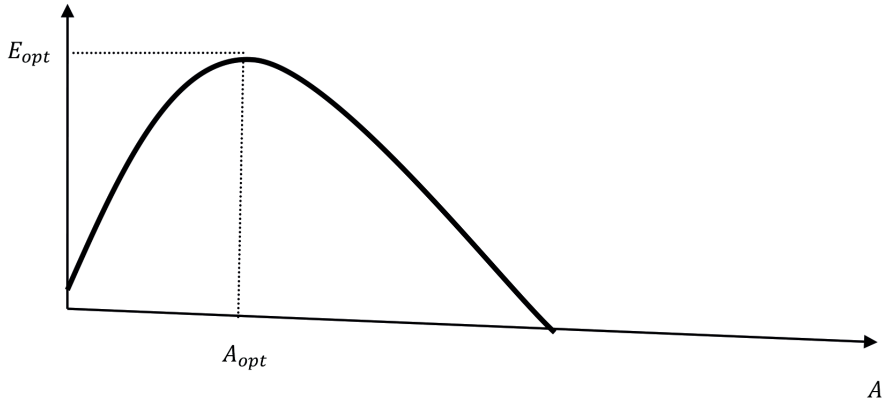
Africa specializes in the exclusive export of *M* and *m* in period 1 and 2 respectively. Raw materials *M* are considered as goods when they are exported in the state, and are considered as factor when they enter in the production of manufactured goods *m*.

H3: there is a public and supranational regulator (African Union) who plans the exploitation of NR and spreads them over three periods (T1 to T3). It also regulates the level of tolerable pollution $\bar{E}$ in Africa. Although studies indicate that regulation by carbon markets is economically more efficient than emission standard, the lack of this type of market in Africa (Thiombiano, 2004) leads us to retain the standard. The environmental constraint is given by $\sum^{n}_{=1} e_i \ Q_i \leq \bar{E}$. In the event of a pollution proportional to economic activity, environmental constraint indicates that the pollution emitted by all economic activities should not exceeded the tolerable standard set by the regulator.

One assumes that in period T1, Africa has neither the technology *A* nor enough skilled labor *H* to produce goods m. It specializes in the production and export of *M*. The regulator sets exploitation contracts of share of NR planned for the period 1. The regulator receives a share a of NR extracted as an annuity ($0 < \alpha < 1$). In addition, contracts are indexed to changes in global commodity prices *r*. The negotiated unit rent is αr. Let NR_1 the share of NR extracted at T1. The total rent got by the regulator is αrNR_1. The total rent is assigned to cover both technology *A* and labor *H* training costs at T2. At period 2, Africa has all the factors essential to produce both goods *M* and *m*. However, goods *M* is used as factor, so Africa exports only manufactured goods.

Reserves in NR in the period T3 imposed by the regulator are assumed to be used in the same conditions as described at T2. The optimization program over the two firsts periods and the optimal equilibria are showed in Appendix 1, Appendix 2 and Appendix 3.

Figure 1: Relationship between Employment and Technology in Endogenous Growth Models



Analyzing the equilibria, Equation (8) in Appendix 2 shows that with a view to optimizing the exploitation of raw materials, the technology appears as a very crucial factor. However, under social sustainable consideration, there is a trade-off between the level of technology and the volume of human employment in endogenous growth models that is not exactly the message send by Equation (7). The future challenge is to find specification which reflects this trade-off. As illustrated in Figure 1, a hyper sophistication of the economy by an advanced or an abundance of technology (robotics) evicts some potential jobs that would result from an economic boom. The employment level ousted by robotics is estimated at 30% of total employment in 2030. The research's challenge is to determine the optimal level of technology A_{opt} (see Figure 1) required to make effective the production of both goods and then, to be also consistent with the optimal volume of employment E_{opt}.

Equation (15) in Appendix 3 shows the cumulative positive effects reached by an endogenous technology. The factors of production yields are amplified when the values chain is extended in Africa. These are the cumulative effects of the efficiency in the production of manufactured goods that are at the origin of the creation of value added and explain differences in levels of economic development between industrialized countries and exclusive exporters of raw materials.

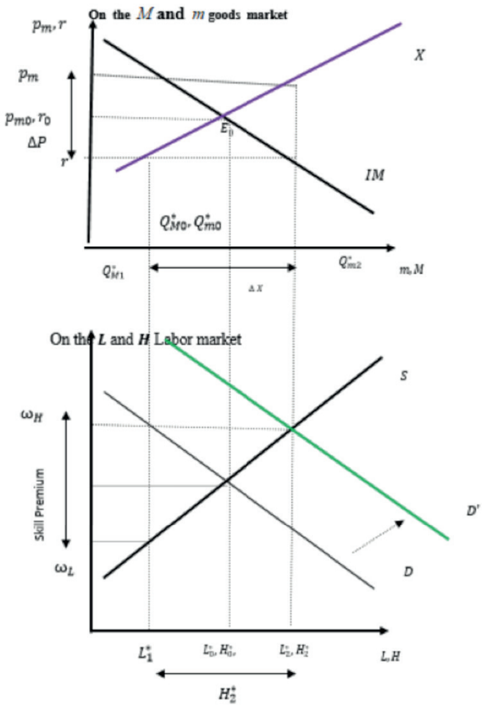
As the equilibria are determined sequentially, they are unstable, making some of them under optimal. Because, this can be interpreted as a weakness of the findings of the model, the challenge is to find mathematical technique which allows determining these equilibria jointly.

3.3. The impacts of the model equilibria on SD goals

The model distinguishes two phases of specialization (T1 and T2) in Africa's international trade. At T1, Africa, due to its disadvantage in technology and skilled labor shortage, specializes in the production and export of raw materials M . Levels of employment and pollution at T1 are low due to low diversification in production in the continent as shown by Figure 2. Stylized facts show that given an optimal level of exported raw materials Q^*_M, trade revenues[13] do not cover the needs of the continent imports because Africa's TGI < 1 (TABLE 1). The depletion of NR does not follow by other types of wealth accumulation as suggested in Hartwick (1977).

At T2, Africa exports only good m. This new configuration changes the trade equilibria of Africa as shown in Figure 2. These equilibria can be analyzed in terms of SD goals.

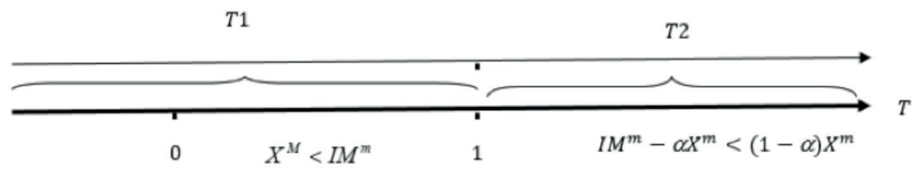
FIGURE 2: TRADE EQUILIBRIUM AND EMPLOYMENT IN AFRICA BEFORE AND AFTER NEO-FACTORIAL SPECIALIZATION



[13] According to the WTO definition, exports are valued on the basis of the transaction value, including the cost of transportation and insurance for the delivery of goods to the border of the exporting country or territory (value "FOB "). Imports are valued on the basis of the transaction value plus the cost of transportation and insurance to the frontier of the importing country or territory (value "cost, insurance and freight"), WTO Report, 2013, p.198.

The model predicts that for equal quantities of raw materials Q^*_M produced in periods 1 and 2, Africa realizes preferential benefits to the international exchange by exporting manufactured goods. This advantageous situation leads in improved TGI (see Figure 3). Proof of this TGI's evolution is showed in Appendix 4.

FIGURE 3: EVOLUTION OF AFRICA'S TRADE GAIN INDEX



In Figure 2, the trade surplus is represented by p_m - r, where p_m is the international prices of manufactured goods and r, the price of commodity. In volume terms, the trade surplus is $\Delta X = Q_m - Q_M$.

However, how this advantage could be maintained when one integrates the production costs of manufactured goods, including costs of technology and engineering education? To answer that, we calculate the overall profit of the production chain of goods *m* at T2. Table 1 gives the conditions for which Africa wins in manufactured goods exports. Proof of Table 1 is given in Appendix 5.

Most interesting result is that Africa is competitive even integrating environmental costs. That differs from traditional business maximization input-output model. $p_m - \tau e_m$ is called "green unit price" of *m* i.e. the price of the manufactured good after deducting the cost of pollution that its production induces. $p_m - \tau e_m$ is necessarily positive, if not, it is not rational to produce the good *m*. As the price p_m is set on the world market, equation (20) in Appendix 5 indicates the arbitration must do African regulator to encourage individual firms to produce the good *m* in Africa while preserving the Environment. Equation (21) and Table 1 show that the overall profit is positive when the green unit price covers the average cost of producing the good *m* i.e. the remuneration of workers *L* and *H* taking into account the cost remediation of the Environment caused by the exploitation of raw materials and pollutants discharged.

How do the model results affect the social dimension of SD? Social variable is labor. As shown by Figure 2, the specialization of Africa in period 2 is not only enriching economically; it has positive effects on the social dimension.

Starting from the equilibrium point E_0 (see Figure 2), we analyze the overall level of employment in Africa at T1 and T2. At the point E_0, the equilibrium is established between imports *IM* and exports *X*. L^*_0 and H^*_0 are determined on the labor market. Assuming that labor supply is always satisfied, that is the case in African economies because imports exceed exports.

At T2, Africa realizes a trade surplus of a unit amount equivalent to p_m - r and in terms of volume this trade surplus is $\Delta X = Q_m - Q_M$. This induces an additional demand for labor especially in skilled labor *H*. The level of employment increases from L^*_1 to L^*_1+ o H^*_1 with $L^*_1 < L^*_0 + H^*_0 < L^*_2 + H^*_2 \leq L + H$; $L + H$ being the total workforce. The $H^*_2 = L^*_2 + H^*_2 - L^*_1$ gap is called structural unemployment. This level of underemployment in period 1 is endogenous to the choice of specialization that Africa suffers at T1, highlighted the wage differential between skilled and unskilled workers as pointed out in Hellier (2012). The skill premium is much higher in Africa than that expected in the international equilibrium, i.e. at the point E_0.

At T3, we will attend a coexistence of two economic models of production. Countries that have built up reserves in NR, will continue producing manufactured goods *m*, as at T2. However, they use more efficient production technologies due to the gradual depletion of the stock of certain resources. Countries that have exhausted their stocks factors *M* during period 2 or those that have none, adopt the circular economy model. They therefore invest more in sustainable production patterns such as renewable sources. In the long term, the scarcity of factor *M* will lead to a more stable equilibrium of factors of production than its level at T2.

TABLE 1: RESULTS OF NEO-FACTORIAL SPECIALIZATION MODEL AND THEIR IMPACTS ON THE SD OBJECTIVES

Pillars	**Goals**	**Indicators**	**Effects of the model**	
			Period T1	**Period T2**
Economy	Performance	Terms of trade	$(X^M) / (IM^m) < 1$ $\Rightarrow$ (-)	$((1-\alpha)X^m) / (IM^m - \alpha X^m) > 1$ $\Rightarrow$ (+)
		Profit	$if\ r > (\omega_L \mathrm{L}) / (Q_M) + (c(A_M) / (Q_M A_M)$ $\Rightarrow$ (+)	$if\ p_m - \tau e_m > ([\omega_L L + \tau e_M Q_M + \omega_H H]) / Q_m$ $\Rightarrow$ (+)
			$if\ r < (\omega_L \mathrm{L}) / (Q_M) + (c(A_M)) / (Q_M A_M)$ $\Rightarrow$ (-)	$if\ p_m - \tau e_m < ([\omega_L L + \tau e_M Q_M + \omega_H H]) / Q_m$ $\Rightarrow$ (-)
Social	Dynamism	Employment	$L^*_1 < L^*_0 + H^*_0$ $\Rightarrow$ (+)	$L^*_1 < L^*_0 + H^*_0 < L^*_2 + H^*_2 \leq L + H$ $\Rightarrow$ (++)
Environment	Equilibrium	Pollution	$e_M Q_M \leq \bar{E}$ $\Rightarrow$ (-)	$e_M Q_M + e_m Q_m \leq \bar{E}$ $\Rightarrow$ (--)
		Pollution treatment	$\tau e_M Q_M$ $\Rightarrow$ (+)	$\tau e_m Q_m + \tau e_M Q_M$ $\Rightarrow$ (+)
		NR Depletion	$S_0 - NR_1 < S_0 (1 + \alpha)$ $\Rightarrow$ (-)	$S_0 - (Q_M + RN_1) < S_0 (1 + \alpha)$ $\Rightarrow$ (--)

Notes: (+) ; (-) indicate a positive effect and a negative effect of the model's results on the SD goals; (++) ; (--) indicate a positive greater impact and greater negative effects respectively; S_0 is the stock of NR. a denotes the renewal rate of the raw material.

3.4. Model simulation

In this section, we simulate the model using data on NR endowment in Africa. We approximate technology costs to R&D expenses. Based on OECD data covering the period 2002-2012, the total annual cost of the technology is $c(A)$=920, 955 million dollars (PPP 2005) and the average cost of a discovery $CM(A)$ is estimated at 3% of the total cost. When fixed costs are zero, the average cost is equal to marginal cost $c'(A)$. We define tolerable thresholds of harmful particulate emissions in tons of CO_2 equivalent. From Health Standards of 20µg/m^3 per year of harmful particles tolerable recommended by WHO[14], we calculate the share of particulate matter standard $\bar{E}$ to 1,299,984 tons / year of CO_2 in Africa. The price τ of a ton of CO_2 set by the France's Parliament is € 32 / ton of carbon. The commodity prices and average prices of manufactured goods are approximated to the harmonized index of prices and provided by the National Institute of Statistics and Economic Studies. The rates of skilled workers' wages are based on the experiences of developed countries. However, the wage rate of unskilled workers is approximated to decent minimum income. Knowing the annual cost of technology and the average expenditure on R&D per year, we determine the volume of technology needed by year. The pollution coefficients are calculated from the relative contributions of the activities' sectors to overall pollution. Raw materials production and treatment of waste inherent contribute up to 49.5% against 50.4 in manufacturing and services sector. Finally, the model parameters are calibrated according to the experiences learnt. The results summarized in Table 2 and Table 3 are an illustration of a representative firm in both *M* and *m* goods production.

Table 2 and Table 3's results show rather optimistic results as a whole. Indeed, the industrialization of Africa in phase 2 of the model allows expecting on average 462 employees, including 224 in manufacturing per firm per year. The TGI is improving with a net gain of + 18.87% of wealth from trade against a net loss of 30% at T1. The adoption of technology will cost to Africa of € 9,209.55 billion over a period of ten years. This requires a depletion of its NR of 3,026,332 tons sold during period 1 in the global raw materials' prices. Moreover, without clean technology, industrialization of the continent generates higher pollution to tolerable standards recommended by WHO; either 3,962,695t CO_2 equivalent/year against a tolerable threshold of 1299984t / year in Africa.

[14] http://www.who.int/mediacentre/factsheets/fs313/en/

Table 2: Model Parameters and Optimal Values

Variables and model parameters	Values	Units of measure
α_M	0.67	
α_m	0.34	
β_M	0.33	
β_m	0.33	
η_m	0.33	
$c^{'}(A_M)$	511,641	€/year
$c^{'}(A_m)$	511,641	€/year
e_M	0.496	
p_m	102	
r	3, 043	
e_m	0.504	
ω_L	1,424	€
ω_H	3,173	€
τ	32	€/ton
A_M	16	units
A_m	17	units
L^*	238	persons
H^*	224	persons
Q^*_M	6.068	tons
Q^*_m	139.630	Millers of units
$\bar{E}$	1,299,984	tons/year

TABLE 3: EFFECTS OF MODEL RESULTS ON SD GOALS DURING T2: PREDICTIONS AND VALIDATIONS

Equations	**Predictions (effects in ())**	**values**	**Conclusions**
$((1-\alpha)X^m) / (IM^m - \alpha X^m) > 1$	(+)	1.1887	Hypotheses confirmed
$if\ p_m - \tau e_m > ([\omega_L L + \tau e_M Q_M + \omega_H H]) / Q_m$	(+)	85.872>34.218	Hypotheses confirmed
$if\ p_m - \tau e_m < ([\omega_L L + \tau e_M Q_M + \omega_H H]) / Q_m$	(-)	85.872>34.218	Hypotheses rejected
$L^*_1 < L^*_0 + H^*_0 < L^*_2 + H^*_2 \leq L + H \Rightarrow$ (++)	(++)	+462 employees / year / enterprise	Hypotheses confirmed
$e_M Q_M + e_m Q_m \leq \bar{E} \quad \Rightarrow$ (-)	(-)	3962695.39t eq.CO2/year	Hypotheses rejected
$e_M Q_M + e_m Q_m > \bar{E} \quad \Rightarrow$(--)	(--)	3962695.39t eq.CO2/year	Hypotheses confirmed
$S_0 - (Q_M + RN_1) < S_0 (1+ \alpha)$	(--)	3026338.22t the first year of T2, then, 6.068 t/year	S_0 not available

4. Conclusion

This paper aimed to show, through the stylized facts, that the current specialization of Africa in world merchandise trade is an impoverishing one. We then developed a model of neo-factorial specialization that highlights the crippling factors industrialization of the continent. This low industrialization of Africa explains its weak gains in world merchandise trade relative to its trading partners. From the theoretical point of view, the model brings added value to the traditional models of international trade by introducing a new factor (commodities M) of specialization in the function of production of manufactured goods. The model also makes the technology factor endogenous and internalized environmental constraints. The integration of the two factors helps explaining why Africa does not produce manufactured goods in Period 1. By leveraging its advantage in NR, the model shows that Africa, by staggering the exploitation of its NR, can constitute an annuity in the second period that allows importing technology from outside and trains the skilled workforce (engineers) essential to the production of manufactured goods. In Period 2, by extending its value chain by processing raw materials, Africa moves from a situation of impoverishing specialization (period 1) to a new specialization which is rewarding. The model also shows that the neo-factorial specialization of Africa is consistent with the main SD goals that a supranational regulator (African Union) regulates the exploitation of raw materials and the inherent pollution. In the long term, we expected the coexistence of two economic models namely the traditional and the dominant model and the circular economy. The future research's challenges are: Mathematical formulations which respect the trade-off between endogenous technology level and employment, the determination of equilibria jointly and to test the empirical validity of the model by robust econometric tools and more disaggregated data of African economies.

Biographical notes

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Appendix 1: Optimization program over T1-T3

Following the hypotheses made in section 3.2, the optimization program of production of both tradable goods on all three periods T1, T2 and T3 can be formalized as follows:

$$\begin{cases} At\ \text{T1: } Max\sum_i \left[F_M(A_M, L) = A^{\alpha_M} L^{\beta_M} = (1+e_M)Q_M\right] i = 1,2,\ldots,N \\ \qquad\qquad S.t \\ rQ_M = c(A_M) + w_L L + \tau e_M Q_M \\ e_M Q_M \leq \overline{E} \\ At\ T2;T3: Max\sum_i \left[F_M(A_M, L) = A^{\alpha_M} L^{\beta_M} = (1+e_M)Q_M\right] + Max\sum_i \left[F_m(A_m, H, M) = A^{\alpha_m} H^{\beta_m} M^{\eta_m} = (1+e_m)Q_m\right] i = 1,2,\ldots,N\ (3) \\ \qquad\qquad S.t \\ p_m Q_m = c(A_m) + w_H H + rM + \tau e_m Q_m; \\ rQ_M = c(A_M) + w_L L + \tau e_M Q_M; \\ e_M Q_M + e_m Q_m \prec \overline{E} \end{cases} \tag{3}$$

With $c(A_M) + \omega_L L + \tau\, e_M\, Q_M$ and $c(A_m) + \omega_H H + rM + \tau\, e_m\, Q_m$ the total cost of producing the good *M* and *m* respectively. ω_L and ω_H are the respective wage rate of unskilled and skilled workers; τ, the unit tax per ton of carbon; p_m the price of manufactured goods.

Appendix 2: Determination of M and L

As in Weber (1929), the optimal equilibria in this model are determined sequentially. From equation (3), the Lagrangian goods-producing program of *M* and *m* is:

$$L_M(A_M, L, \lambda) = F_M(A_M, L) + \lambda\,(C(Q_M, E_M) - c(A_M) - \omega_L L - \tau e_M Q_M)$$

Using the first order conditions (FOC) :

$$\frac{\partial L_M(A_M, L, \lambda)}{\partial A_M} = 0 \Leftrightarrow F'_M(A_M) - \lambda c'(A_M) = 0 \Rightarrow F'_M(A_M) = c'(A_M) \quad (4)$$

$$\frac{\partial L_M(A_M, L, \lambda)}{\partial L} = 0 \Leftrightarrow F'_M(L) - \lambda w_L = 0 \Rightarrow F'_M(L) = \lambda w_L \quad (5)$$

$$\frac{\partial L_M(A_M, L, \lambda)}{\partial \lambda} = 0 \Leftrightarrow rQ_M = c(A_M) + w_L L + \tau e_M Q_M$$

By $\frac{(4)}{(5)}$, one obtains $F'_M(A_M) \Big/ F'_M(L) = \frac{c(A_M)}{w_L}$ (6)

Equation (6) indicates that at the optimum, production factors *A* and *L* are paid up to their respective marginal productivities.
From equation (6), optimal function of each input is determined

We have: $F_M(A_M) = \alpha_M A^{\alpha_{M\text{-}1}} L^{\beta_M}$ and $F_M(L) = \beta_M A^{\alpha_{M\text{-}1}} L^{\beta_{M\text{-}1}}$
Hence,

$$F'_M(A_M) \Big/ F'_M(L) = \alpha_M L \Big/ \beta_M A = \frac{c'(A_M)}{w_L} \Rightarrow L^* = \frac{\beta_M c'(A_M)}{\alpha_M w_L} A \quad (7)$$

Equation (7) shows that the number of low-skilled labor depends on the technology employed, respective yields of the two factors of production and of course the wage rate of unskilled labor. The optimal output Q^*_M is given by:

$$F_M(A_M, L) = A^{\alpha_M}\left(\frac{\beta_M c'(A_M)}{\alpha_M w_L} A\right)^{\beta_M} = A^{\alpha_M + \beta_M}\left(\frac{\beta_M c'(A_M)}{\alpha_M w_L} A\right)^{\beta_M}$$

As returns to scale are assumed constant, then $\alpha_M + \beta_M$; hence

$$F_M(A_M, L) = Q^*_M = A\left(\frac{\beta_M c'(A_M)}{\alpha_M w_L}\right)^{\beta_M} \quad (8)$$

Appendix 3: Determination of factors A_m and H

Similarly, we determine the optimal amounts of factors A_m and *H* used in the production of manufactured goods at T2.
At each period (see equation (3)), the Lagrangian is written:
$L_m(A_m, H, M, \lambda) = F_m(A_m, H, M) + \lambda\,(C(Q_m, E_m) - c(A_m) - \omega_H H - r_M - \tau\, e_m\, Q_m)$
The FOC imply that:

$$\frac{L_m(A_m, H, M, \lambda)}{\partial A_m} = 0 \Leftrightarrow F'_m(A_m) - \lambda c'(A_m) = 0 \Rightarrow F'_m(A_m) = \lambda c'(A_m) \quad (9)$$

$$\frac{L_m(A_m, H, M, \lambda)}{\partial H} = 0 \Leftrightarrow F'_m(H) - \lambda w_H = 0 \Rightarrow F'_m(H) = \lambda w_H \tag{10}$$

$$\frac{L_m(A_m, H, M, \lambda)}{\partial M} = 0 \Leftrightarrow F'_m(M) - \lambda r = 0 \Rightarrow F'_m(H) = \lambda r \tag{11}$$

$$\frac{L_m(A_m, H, M, \lambda)}{\partial \lambda} = 0 \Leftrightarrow p_m Q_m = c(A_m) + w_H H + rM + \tau e_m Q_m \tag{12}$$

By $\frac{(9)}{10}$, one obtains :

$$F_{'m}(A_m) \Big/ F'_m(H) = \frac{c'(A_m)}{w_H} \tag{13}$$

Equation (13) indicates that at the optimum, production A_m and H are paid up to their respective marginal productivities.
From equation (13), optimal function of each input is determined.

$F'_m(A_m) = \alpha_m A^{\alpha_{m-1}} H^{\beta_m} M^{\eta_m}$ et $F'_m(H) = \beta_m A^{\alpha_m} H^{\beta_{m-1}} M^{\eta_m}$

Equation (13) indicates that at the optimum, production A_m and H are paid up
Hence,

$F'_m(A_m) = \alpha_m A^{\alpha_m - 1} H^{\beta_m} M^{\eta_m}$ et $F'_m(H) = \beta_m A^{\alpha_m} H^{\beta_m - 1} M^{\eta_m}$

Hence,

$$F'_m(A_m) \Big/ F'_m(H) = \alpha_m H \Big/ \beta_m A_m = \frac{c'(A_m)}{w_H} \Rightarrow H^* = \frac{\beta_m c'(A_m)}{\alpha_m w H} A_m \tag{14}$$

Equation (14) indicates that the number of skilled workers to be employed also depends on the technology used, respective yields of the two factors of production and the wage rate of skilled workers. The optimal output Q^*_m is given by

$$F_m(A_m, H, M) = A_m^{\alpha_m} \left(\frac{\beta_m c'(A_m)}{\alpha_m w_H} A_m \right)^{\beta_m} M^{\eta_m}$$

By replacing factor M by its optimum value previously determined in equation (8), the maximum output obtained is given by:

$$F_m(A_m, H, M) = Q^*_m = A_m^{\alpha_m + \beta_m} \left(\frac{\beta_m c'(A_m)}{\alpha_m w_H} A_m \right)^{\beta_m} \left[A \left(\frac{\beta_M c'(A_M)}{\alpha_M w_L} \right)^{\beta_M} \right]^{\eta_m}$$

$$Q^*_m = A^{(\alpha_m + \beta_m + \eta_m)} \left(\frac{\beta_m c'(A_m)}{\alpha_m w_H} \right)^{\beta_m} \left[\left(\frac{\beta_M c'(A_M)}{\alpha_M w_L} \right)^{\beta_M} \right]^{\eta_m} \tag{15}$$

Appendix 4: The Africa's TGA improvement demonstration

We know that at T1, the Africa's TGI is < 1, because of its disadvantage in technology and skilled labor. At T2, technology and training of skilled labor make possible the production of manufactured goods *m*. A fraction of this production replaces one part IM^m of imports manufactured goods at T1. Let X^m, the amount of exportable manufactured goods produced by Africa. Imports IM^m in period 2 are reduced by an amount αX^m ($0 < \alpha < 1$). Africa thus exports the rest of its manufactured production for a volume $(1-\alpha)X^m$.

The Africa's TGI at T2 is thus written: $TTI = \frac{(1-\alpha)X^m}{IM - \alpha X^m}$

One has to demonstrate that

$$\frac{(1-\alpha)X^m}{IM - \alpha X^m} \succ \frac{X^M}{IM^m}$$

Let's suppose that

$$\frac{(1-\alpha)X^m}{IM - \alpha X^m} \succ \frac{X^M}{IM^m} \tag{16}$$

As $(1-\alpha) \succ 0$ and $IM^m - \alpha X^m \geq 0$, thus

$$\frac{(1-\alpha)X^m}{IM - \alpha X^m} \succ \frac{X^M}{IM^m} \Leftrightarrow \frac{(1-\alpha)X^m}{(IM^m - \alpha X^m)X^M} \succ \frac{X^M}{X^M IM^m}$$

$$\Leftrightarrow \frac{(1-\alpha)X^m}{(IM^m - \alpha X^m)X^M} \succ \frac{1}{IM^m}$$

$$\Leftrightarrow \frac{(1-\alpha)X^m}{(IM^m - \alpha X^m)X^M(1-\alpha)} \succ \frac{1}{(1-\alpha)IM^m}$$

$$\Leftrightarrow \frac{X^m}{(IM^m - \alpha X^m)X^M} \succ \frac{1}{(1-\alpha)IM^m}$$

$$\Leftrightarrow \frac{(IM^m - \alpha X^m)X^m}{(IM^m - \alpha X^m)X^M} \succ \frac{(IM^m - \alpha X^m)}{(1-\alpha)IM^m}$$

$$\Leftrightarrow \frac{X^m}{X^M} \succ \frac{(IM^m - \alpha X^m)}{(1-\alpha)IM^m}$$

$$\Leftrightarrow \frac{X^m}{X^M} \succ \frac{\left(1 - \frac{\alpha X^m}{IM^m}\right)IM^m}{(1-\alpha)IM^m} \tag{17}$$

One knows that $\frac{\alpha X^m}{IM^m} \prec 1$, because αX^m is a faction of Africa's total imports at T2. So,

$0 \prec \frac{\alpha X^m}{IM^m} \prec 1$. Moreover, $0 \prec \alpha \prec 1, \Rightarrow 0 \leq 1-\alpha \prec 1$. Thus, $\frac{\left(1 - \frac{\alpha X^m}{IM^m}\right)}{(1-\alpha)} \succ 1$. Hence,

$$\frac{X^m}{X^M} \succ \frac{\left(1 - \frac{\alpha X^m}{IM^m}\right)}{(1-\alpha)} \succ 1 \qquad \Rightarrow \frac{X^m}{X^M} \succ 1$$

$$\Rightarrow X^m \succ X^M \tag{18}$$

Equation (18) indicates that the export of manufactured goods is more rewarding for Africa than its commodity exports.

As we know that at T1 $TGI = \frac{X^M}{IM^m} \prec 1$ and that of period T2 equal $\frac{(1-\alpha)X^m}{IM - \alpha X^m} \succ 1$, that implies that $\frac{(1-\alpha)X^m}{IM - \alpha X^m} \succ 1 \succ \frac{X^M}{IM^m}$ we deduce that the situation in Africa in period 2 is much better than its specialization in period 1.

Appendix 5: Africa's manufactured goods trade advantage under technology and high skilled costs considerations

In the values chain, Africa is making two profits π_M and π_m linked to the production of good *M* sold locally as a factor of production and export of goods *m*. The overall profit is $\pi_G = \pi_M + \pi_m$.
Let $RT_M = rQ_M$, $RT_m = p_m Q_m$, $C(Q_m, E_M) = c(A_M) + \omega_L L + \tau e_M Q_m$, et $C(Q_m, E_m) = c(A_m) + \omega_H H + rQ_m + \tau e_m Q_m$ respective total revenues and total costs of goods *M* and *m*, it follows that

$$\pi_G = (RT_M + RT_m) - [C(Q_M, E_M) + C(Q_m, E_m)] \tag{19}$$
$$\Rightarrow \pi_G = [rQ_M + p_m Q_m] - [c(A_M) + w_L L + \tau e_M Q_M + c(A_m) + w_H H + rQ_M + \tau e_m Q_m]$$
$$\Rightarrow \pi_G = Q_m[p_m - \tau e_m] - [c(A_M) + c(A_m) + w_L L + \tau e_M Q_M + w_H H]$$

We know that technology costs $c(A_M)$ + c(A_m) are financed by the rent *arRN*1 constituted in period 1. In period 2, $c(A_M)$ + c(A_m) becomes a depreciable fixed cost on all periods T1 and T2. So, we can assume that the annual fixed cost is approximately zero. The overall benefit at T2 is then:

$$\Rightarrow \pi_G = Q_m[p_m - \tau e_m] - [w_L L + \tau e_M Q_M + w_H H] \tag{20}$$
$$\Leftrightarrow \frac{\pi_G}{Q_m} = [p_m - \tau e_m] - \frac{[w_L L + \tau e_M Q_M + w_H H]}{Q_m}$$
$$\frac{\pi_G}{Q_m} \geq 0 \Rightarrow [p_m - \tau e_m] \geq \frac{[w_L L + \tau e_M Q_M + w_H H]}{Q_m} \tag{21}$$

The unit maximized profit is:

$$\frac{\pi^*_G}{Q^*_m} = [p_m - \tau e_m] - \frac{[w_L L^*_2 + \tau e_M Q^*_M + w_H H^*_2]}{Q_m} \tag{22}$$

The conditions for a positive unit profit are given in Table 1.