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Agricultural value chains and structural transformation in Senegal: A product space approach

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Abstract

Using the product-space approach and BACI dataset for the period 1995-2014, we analyze the role of agricultural value chains selected under Agricultural Policy Support Project (PAPA) in Senegal's structural transformation process. Overall, our findings suggest that the dynamics of economic complexity index (ECI) has been rather volatile throughout the period. Simulations results suggest that exporting only non-processed agricultural products, even with Revealed Comparative Advantage (RCA), is not enough to substantially boost the country structural transformation process. Exporting manufacturing products with RCA is by far the best option to fast-track structural transformation. However, a value chain approach like the one adopted by PAPA where the production and processing capability are promoted, has the potential to trigger an agriculture-driven structural transformation. We also found that diversity (increase of exported products with RCA) alone does not generate structural transformation which requires also sophistication (adding value to primary goods). It follows that to create a critical mass of agriculture-led transformational activities, the country must: i) modernize smallholders' agribusiness value chains; ii) integrate smallholder farmers into transforming value chains; iii) optimize the role of producer organizations in promoting the integration of smallholders into agricultural value chains; iv) improve market intermediation, financial services and technology innovation.

Keywords: economic complexity index, agriculture, structural transformation

1. Introduction

To analyze development and structural transformation, Hidalgo et al. (2007) developed the product space framework as a network representation of all the products exported in the world. The product space links products according to their similarity on capabilities necessary for their production; countries with abundant capabilities are more likely to add products that require many capabilities to their export basket (Hidalgo and Hausmann, 2009). The product space has a center-periphery structure where the center is dense and populated by advanced products; the periphery consists of the products only weakly connected to other products. According to Hidalgo et al. (2007), the likelihood that a country develops a product depends on how "near" is that product in the "product space" to the products that the country is already able to successfully export. Hence, structural properties of the global trade network can explain differences in economic development across countries (Caldarelli, 2012; Hausmann, 2014). One network measure, known as the Economic Complexity Index (ECI), uses countries' productive capabilities by making relative comparisons across their export baskets (Hausmann, 2014). The ECI has been successful in explaining cross-country differences in GDP/capita and in predicting economic growth (Mealy, 2018).

Since its introduction, Economic Complexity has emerged as a powerful framework to understand key issues in economics, geography, innovation studies, and other social sciences. It has helped to shed light on the variation in standards of living across nations (Hidalgo and Hausmann, 2009; Hartmann, 2017), differences in sophistication of technologies (Fleming and Sorenson, 2001), and the heterogeneous distribution of knowledge in space (Balland and Rigby, 2017).

In this paper, using the Method of Reflections, we apply the concept of economic complexity to assess the impact of agricultural value chains selected by PAPA[1] project on the Senegalese ambition to reach the status of emerging economy through structural transformation.

As in Mealy et al. (2018), we distinguish the ECI from diversity; simply put, diversity captures how many products countries are competitive in. In contrast, the ECI captures what type of products countries are competitive in; it sheds light on the type of production capabilities that separate high- and low-income countries and provides empirical validation of the long-standing theory of technological capabilities in development economics (Mealy et al., 2018).

In Senegal, agricultural sector accounted for an average of 18.8 percent of GDP over the period 1960-2017 with a minimum of 11.9 percent in 2007 and a maximum of 28.6 in 1976 (WDI, 2018). Although agriculture's share is rather small, the sector plays an important role in food security and household income generation. Indeed, 54.8 percent of the total population lives in rural areas (ANSD, 2014) and rely on agriculture for food and income. The sector also provides raw materials to manufacturing industry. Agriculture is also the main source of employment as it employs 40 percent of the population (World Bank, 2014).

Since the 2000s, Senegal put in place several programs to accelerate growth. The Accelerated Growth Strategy (SCA) was developed to achieve 7% growth rates through diversification of sources of wealth. Later in 2012, with its new development plan PSE[2], Senegal aims to accelerate the emergence of the country through structural transformation and sustainable growth.

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[1] The Agricultural Policy Support Project (PAPA) is an initiative of the Government of Senegal funded by Feed the Future USAID-Senegal and implemented for a period of 3 years (2015 - 2018) by the Ministry of Agriculture and Rural Equipment with the support of the International Food Policy Research Institute (IFPRI) and Michigan State University (MSU).

[2] "Plan Senegal Emergent" (PSE) describes the Senegalese strategies of development.

In agriculture and agri-food sector, the country's goal is to reduce by half the deficit of the trade balance on the cereal crops (millet, rice and maize) (PSE, 2014). In addition to the establishment of agro-processing poles for the development of a high value-added agribusiness in the field of fruit and vegetable processing, oils, dairy products, cereals, poultry farming, and the revival of national groundnut production are all key elements identified in the development plan.

The rest of the paper is organized as follows. In the second section, we generate a series of metrics to analyze structural transformation in section. In section 3, we present the main Senegalese agricultural value chains. In section 4 we apply the concept of economic complexity to understand the dynamics of structural transformation in Senegal. Section 5 concludes the paper.

2. Metrics for structural transformation

In this paper, following Mealy et al. (2018), Hartmann et al. (2017) and Kemp-Benedict (2014), we use the Method of Reflections to construct a series of metrics using a country-product matrix M with elements M_{cp} indexed by country c and product p. The matrix entries are equal to one if Balassa's (1965) index of revealed comparative advantage (RCA) is greater than or equal to one, and zero otherwise. RCA is defined as:

$$RCA_{cp} = \frac{X_{cp}}{\sum_p X_{cp}} \Big/ \frac{\sum_c X_{cp}}{\sum_{cp} X_{cp}} \tag{1}$$

Where X_{cp} is the value of exports of product p by country c.

From matrix M, the following initial metrics are derived:

$$k_{c,0} = \sum_p M_{cp} \,, \tag{2}$$

$$k_{p,0} = \sum_c M_{cp} \,, \tag{3}$$

The vector $k_{c,0}$, called "diversity", counts the number of products a country exports with RCA. The other vector $k_{p,0}$, called "ubiquity", represents the number of countries that exports a given product with RCA.

Additional higher-order elements are generated by iterative sequences,

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_p M_{cp}\, k_{p,N-1} \tag{4}$$

$$k_{p,N} = \frac{1}{k_{p,0}} \sum_p M_{cp}\, k_{c,N-1} \tag{5}$$

Substituting equation (5) into equation (4) to eliminate the expression for $k_{p,N}$, yields the following result

$$k_{c,N} = \sum_{c"} \left(\frac{1}{k_{c,0}} \sum_p M_{cp} \frac{1}{k_{p,0}} M_{c'p} \right) k_{c',N-2} \tag{6}$$

We can write this as a matrix equation,

$$\vec{k}_N = \boldsymbol{W}.\vec{k}_{N-2}, \tag{7}$$

where the matrix W has elements

$$W_{cc'} = \frac{1}{k_{c,0}} \sum_{p} M_{cp} \frac{1}{k_{p,0}} M_{c'p} \quad (8)$$

and the vector $\vec{k}_N$ represents the set of country values $k_{c,N}$.

Finally, the Economic Complexity Index (ECI) is given by:

$$ECI_c = \frac{K_c - \bar{K}}{std(K)} \quad (9)$$

K_c is the eigenvector of $W_{c\acute{c}}$ associated with the second largest eigenvalue.

As pointed by Mealy et al. (2018), while diversity (2) captures how many products countries are competitive in, the ECI (9) captures what type of products countries are competitive in.

To empirically implement the set of metrics developed in this section, we updated and recoded in MatLab the Scilab codes from Kemp-Benedict (2014).

3. Main Senegalese agricultural value chains

In Senegal, agriculture is practiced in six agro-ecological zones: the Senegal River Valley (SRF), the natural Casamance, the Groundnut Basin, the Niayes zone, Eastern Senegal and the sylvo-pastoral zone. Most of agricultural activities in these areas are rainfed except for the SRF where irrigated and rainfed agriculture coexist, and the Niayes where only irrigated agriculture is practiced in the dry season.

Cereals value chains

Senegal's cereal sectors have undergone significant changes since the beginning of the 2000s. Due to change in consumption patterns, rice, the most widely consumed cereal, has experienced significant increase. Maize has also been increasing in importance as a food crop and animal feed. Yields and production of rice and maize are increasing, but not enough to meet the growing demand, leading to sharp increases in imports of these two cereals. Although each cereal value chain faces different challenges, one factor common to rice and maize as well as millet and sorghum value chains is that each has significant potential for expansion, particularly if constraints along the value chain can be addressed and an enabling environment for private sector investment can be created. The millet and sorghum value chains experienced significant changes over the last eight to fifteen years, away from traditional forms of consumption to industrially processed foods.

In terms of area planted and production, millet has traditionally been the main crop in Senegal. However, following the 2007-2008 food crisis, the government has initiated explicit policies to significantly increase the production of rice. In 2008, the government launched the Great Offensive for Food and Abundance (GOANA) with the main objective of ensuring food sovereignty and eliminating any risk of famine. In the rice sector, the National Rice Self-Sufficiency Program (PNAR) was established under the National Strategy for Rice Development (SNDR), whose objective was to increase, over a period of 4 years (2008-2012), the national production of clean rice to 1 million tons, the equivalent of 1.5 million tons of paddy (Republic of Senegal, PNAR, 2009). Because of these new policies, rice increasingly became the most important cereal crop, with a share of 38.7 percent of total cereal production over 2010-2016, followed by millet with 38.5 percent. The year to year variation in individual cereals production is depicted in figure 2.

Figure 1: Cereals production over the period 2010-2016

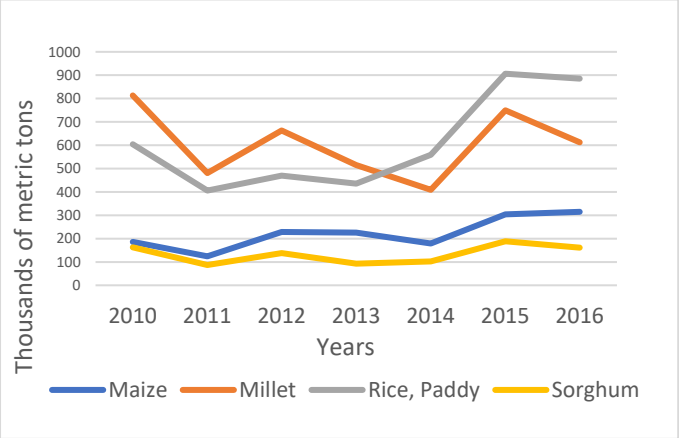
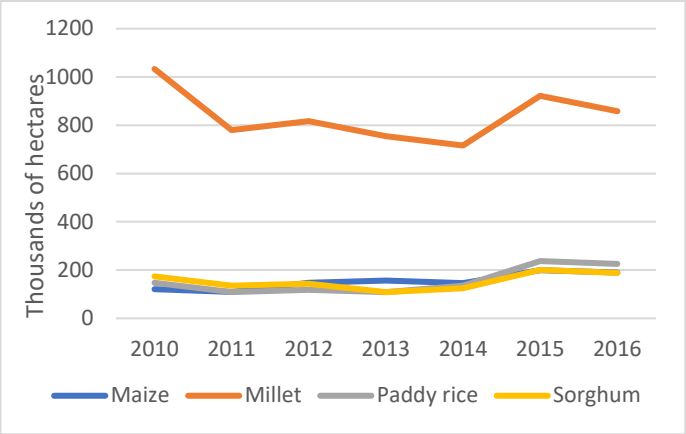


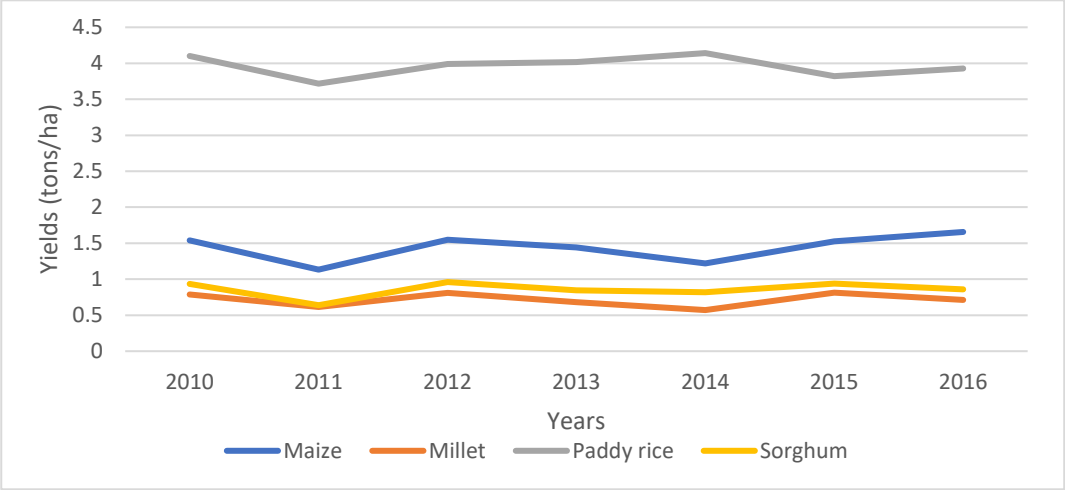
Figure 2: Harvested area



Data source fig. 1 and 2: FAOSTAT

However, although rice is dominant in terms of production, millet remains largely the major crop in terms of area cultivated as shown in the figure 3. The dominance of rice in physical production is due to the significant yield differential between rice and other crops. While millet yield averaged 0.7 ton per ha over 2010-16, average rice yield was nearly 4 tons; and in some of the highest potential areas such as the SRF, average rice yield was 7 tons per ha. Figure 3shows the annual change of cereals yields between 2010 and 2016.

Figure 3: Cereals yield 2010-2016



Data source: FAOSTAT (2018)

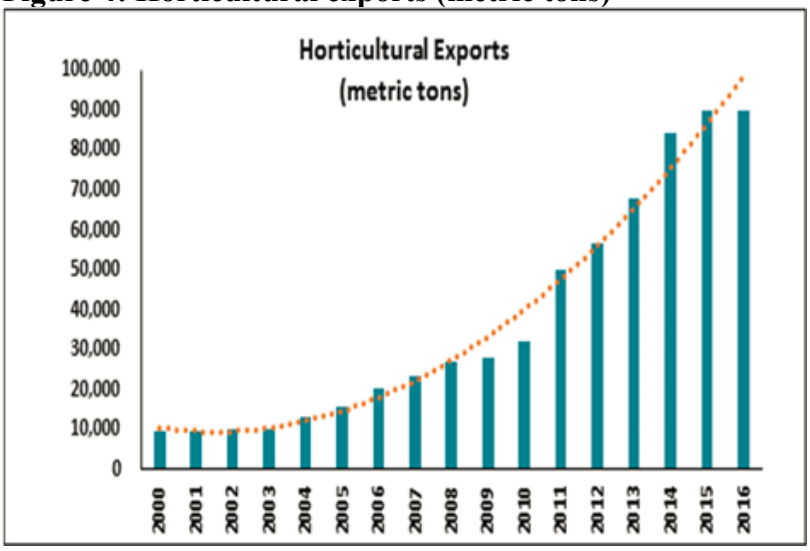
In terms of cereals consumption, rice is the main cereal consumed with a national average per capita consumption of 78.1 kg per year, 76.6 kg per head in urban areas and 80.9 kg in rural areas (Feed the Future, 2017). Local rice is consumed by 55 percent of urban households and 62 percent of households in rural areas. Rice is followed by millet with an annual national average per capita consumption of 30.2 kg/head/year (varying from 23.1 kg in urban areas to 53.3 kg in rural areas). As for maize, annual average national per capita consumption is 9.2 kg, with variations between urban (6 kg) and rural (19.5 kg). Finally, sorghum is only marginally consumed, with a national average per capita consumption of less than 1 kg.

The general framework that guides current agricultural policy is the *Programme d'Accélération de la Cadence de l'Agriculture sénégalaise* (PRACAS) which is the agriculture component of PSE. PRACAS's two main objectives are to attain rice self-sufficiency, as well as self-sufficiency of other widely consumed products including onion, and to develop the fruits and vegetables sector.

Horticulture value chain

Horticulture has emerged as the "*fer de lance"* of the Senegal agricultural sector since the early 2000s. Exports rose from merely 20,000 metric tons in 2006 to almost 90,000 in 2016, while the value of horticultural exports has more than quadrupled over a period of 15 years – from 25.8 million USD in 2000 to 123.6 million USD in 2015 (World Bank, 2018). Production in the sector grew nearly sevenfold since the middle of the 2000s. This strong and impressive performance has been mainly driven by the private sector. Indeed, horticulture has not been the beneficiary of massive subsidies or other major pricing or institutional support. The horticultural sector is also benefiting from rapidly expanding demand globally as well as domestically. It is therefore positioned to become a major growth engine for the Senegalese economy for decades to come if its performance can be sustained. Indeed, horticulture is the driving force of the Senegalese economy on the international market. Over the last decade horticulture export has increased at an increasing rate (See Fig. 4 below, borrowed from the World Bank 2018). In volume, annual exports soared from only 10,000 metric tons in the early 2000s to 90,000 metric tons in 2016.

Figure 4: Horticultural exports (metric tons)



Source: World Bank (2018)

Over the period 2010-2016, mango and melon ranked first and second in volumes exported with respectively 17.2 percent and 17.14 percent of the total. Four other crops (cherry tomatoes, sweet corn, green beans and watermelon) were almost equally important with 11-14 percent of total exports in volume. Europe is the destination of the bulk of the exports, while the African market accounts for rather a very small share (1.5 percent). The export sector is dominated by integrated multinational companies that handle production, processing and exporting. Smallholders remain however significant in the case of mangoes and green beans (English, 2016).

According to the World Bank (2017), Senegal has a comparative advantage in the production of several of the horticulture products listed above. A set of seven factors appear to give advantage to Senegal compared to competitors: (i) land and water resources are available; (ii) agro-ecological and climatic conditions are generally favorable; (iii) the country is physically closer to European markets, either by see or air; (iv) labor cost is low; (v) the government has successfully privatized the input markets, thus improving farmers' access to quality inputs; (vi) recently, competitive players have emerged along the horticulture value chains; and (vii) the sector enjoys a better regulatory environment.

For Senegal to reap greater benefits from the horticulture sector, previous studies have shown that there is a need in creating stronger linkages between the various segments of the horticulture value chain. For example, only an estimated 5 percent of all fruit produced is locally processed. Another

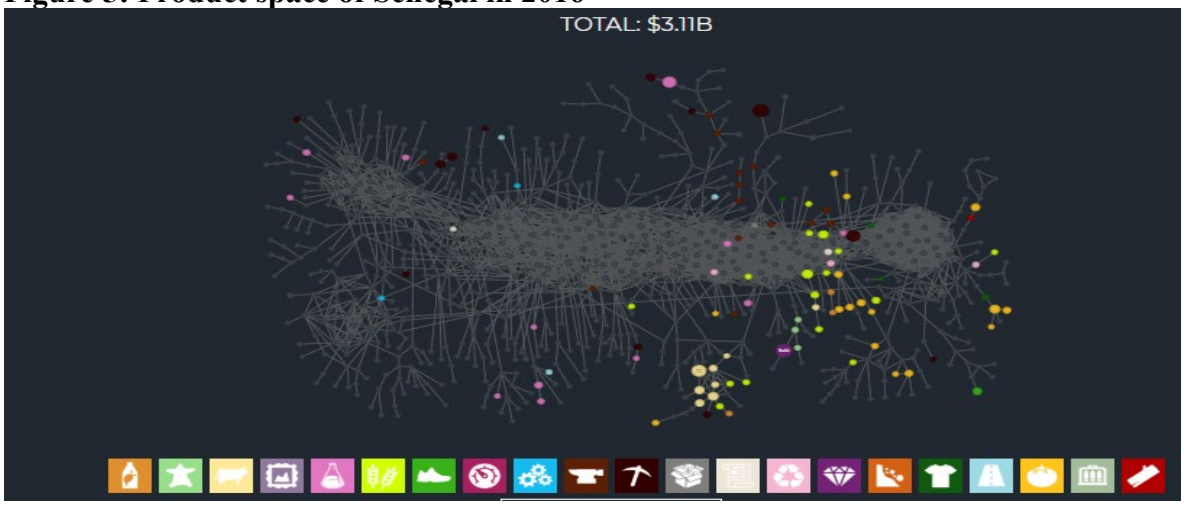
looming potentially significant constraint is the increasing salinization of the coastal areas, threatening production in the Niayes area.

4. Agriculture and structural transformation in Senegal

As stated in the introduction, the product space is a network connecting all products exported in the world. The proximity between two goods measures the similarities of the capacities required for the production of the two goods. Products that are likely to be co-exported can be used to predict the evolution of a country's export structure.

It follows that a country that is in a dense area of the space product introduces more easily new products into its export basket than a country located in a sparse part of this space. In 2016, Senegal exported 137 products with revealed comparative advantage. However, most export opportunities in 2016 are located in the periphery of the product space as evidenced in Figure 5**,** which highlights the degree of sophistication in Senegalese exports basket.

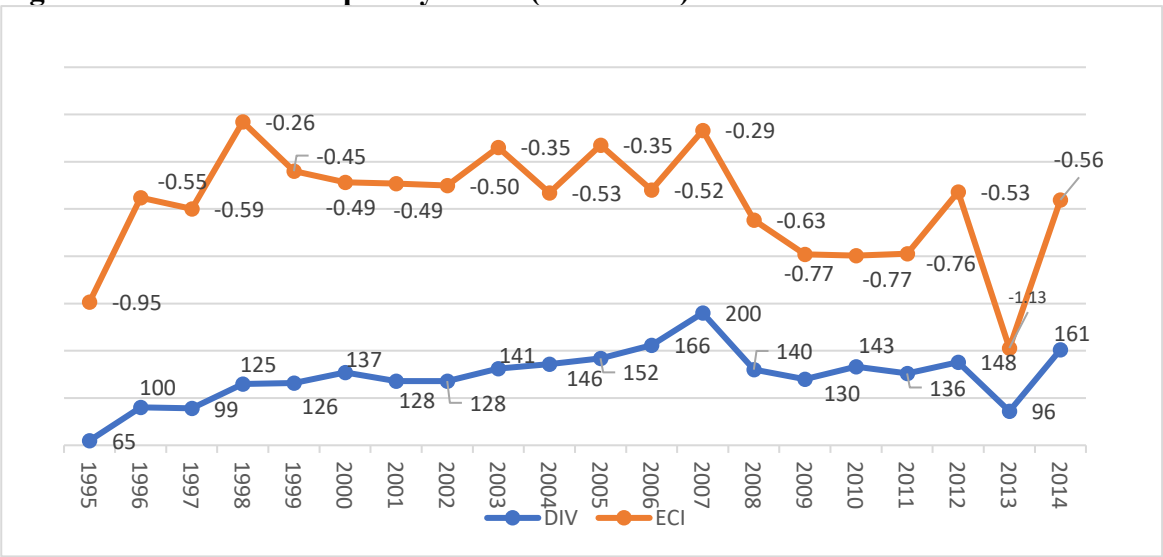
Figure 5: Product space of Senegal in 2016



Source: The Observatory of Economic Complexity (2018); https://atlas.media.mit.edu/en/profile/country/sen/

Using the BACI dataset for the period 1995-2014, Figure 6 below shows the dynamics of structural transformation for Senegal. Indeed, the ECI has been rather instable throughout the period under consideration. It went from -0.95 in 1995 to -0.29 in 2007, just to fall again to -0.77 in 2009-2010, probably because of the 2008-2009 financial crisis, However, the index recovered to reach -0.56 in 2014 hinting to a significant push towards structural transformation.

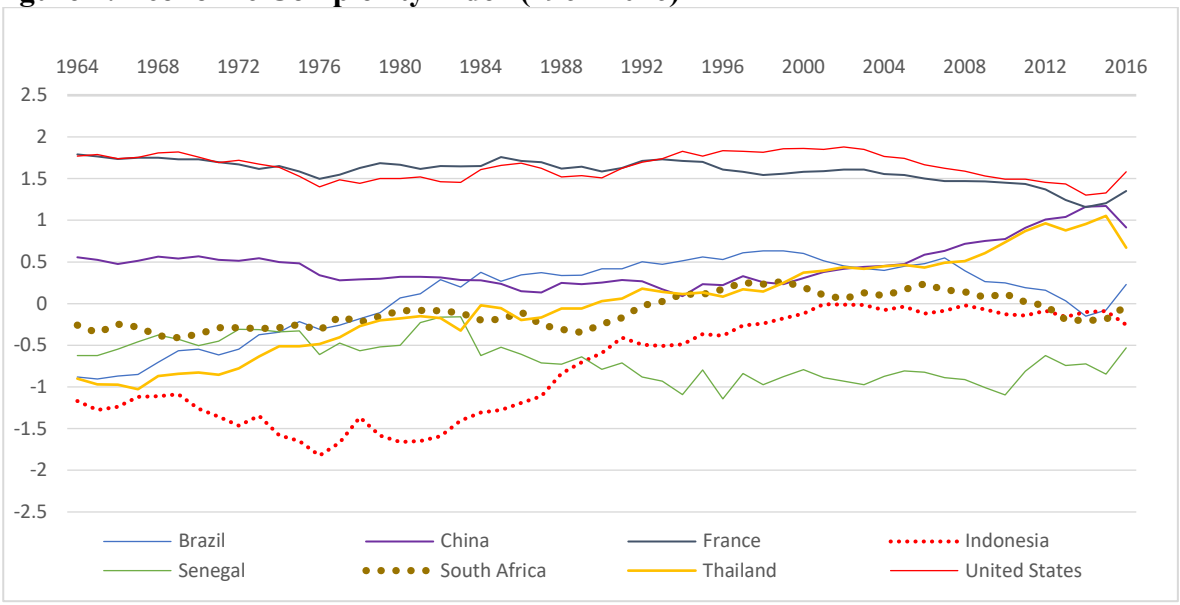
Figure 6: Economic Complexity Index (1995-2014)



Source: Authors calculations, BACI (1995-2014)

As reported in Figure (7), the productive structure of some emerging countries like Indonesia, Thailand, Brazil and South Africa was similar or less complex than the Senegalese economy in the early 1960s. From the 1980s, the accumulation of capabilities allowed emerging countries to experience higher degree of sophistication. Those countries which have completed the process of structural transformation have a growing ECI closer to the complexity of developed countries such as the United States and France. Meanwhile, in the same period, Senegal experienced a decline in terms of sophistication until 2010 before rebounding by 51 percent from 2010 to 2016. The overall trends of the economic complexity index of emerging countries confirms the positive correlation between ECI and structural transformation.

Figure 7: Economic Complexity Index (1964-2016)



Source: The Observatory of Economic Complexity (2018)
Note: Data here comes from the Economic Complexity Index scores published by the MIT Observatory of Economic Complexity.

To assess the importance of value chains development in the process of structural transformation, we present different scenarios to see how agriculture can boost structural transformation in Senegal. For simplicity, our simulations are driven by allowing products which were not previously exported with RCA to be exported with RCA. Below, we describe how the new level of exports for targeted products are estimated.

Following Balassa's formula (see equation 1) a country c_s exports a set of products $P_\alpha = \{p_{\alpha_1}, p_{\alpha_2}, \dots, p_{\alpha_k}\}$ with RCA if the following conditions are satisfied.

$$X_{c_s p_{\alpha_i}} * \frac{\sum_{c \in C \setminus \{c_s\},\ p \in P \setminus \{p_{\alpha_i}\}} X_{cp}}{\sum_{c \in C \setminus \{c_s\}} X_{c p_{\alpha_i}}} - \sum_{p_\alpha \in P_\alpha \setminus P_{\alpha_i}} X_{c_s p_\alpha} \geq \sum_{p \in P \setminus P_\alpha} X_{c_s p} \qquad (10)$$

where

C is the set of countries;

$P = \{p_1, p_2, \dots, p_n\}$ is the set of products exported for all countries;

$P_\alpha = \{p_{\alpha_1}, p_{\alpha_2}, \dots, p_{\alpha_k}\}$ is a subset of products that are exported with RCA;

The solution to the system (10) is given by:

$$X_{c_s p_{\alpha_1}} = \frac{\sum_{p \in P \setminus P_\alpha} X_{c_s p}}{\gamma_{\alpha_1} - \sum_{\alpha_i \neq \alpha_1} \frac{(\gamma_{\alpha_1} + 1)}{(\gamma_{\alpha_i} + 1)}} \qquad (11)$$

$$X_{c_s p_{\alpha_i}} = X_{c_s p_{\alpha_1}} \frac{(\gamma_{\alpha_1} + 1)}{(\gamma_{\alpha_i} + 1)} \qquad \text{for all } \alpha_i \neq \alpha_1 \qquad (12)$$

where

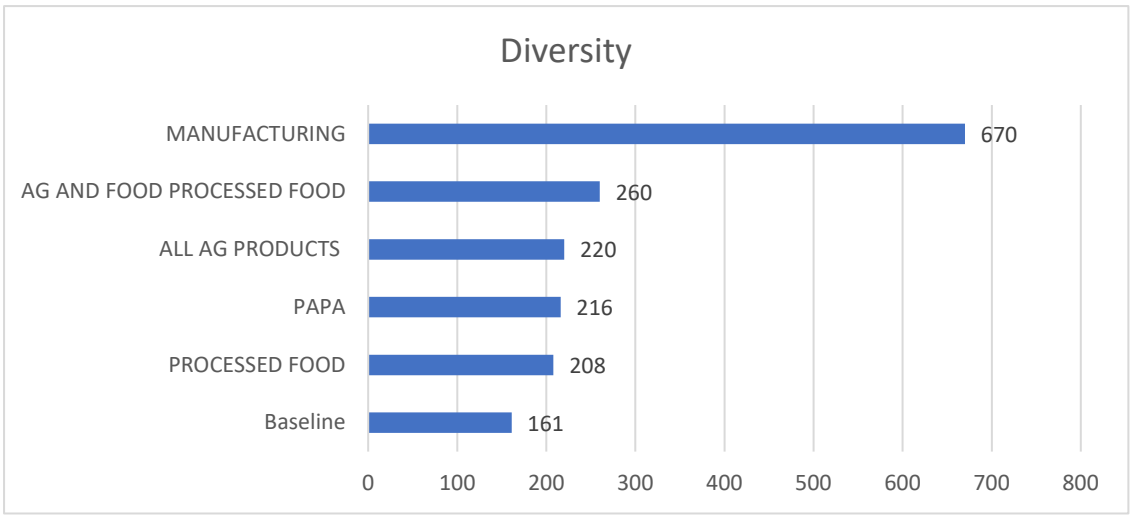
$$\gamma_{\alpha_i} = \frac{\sum_{c \in C \setminus \{c_s\},\ p \in P \setminus \{p_{\alpha_i}\}} X_{cp}}{\sum_{c \in C \setminus \{c_s\}} X_{c p_{\alpha_i}}} \qquad (13)$$

Data used are the bilateral values of exports from BACI database at the HS 4-digit product disaggregation for 205 countries and 1219 products in 2014. We define 5 scenarios to consider the different stage of structural transformation. In each scenario we define a subset of products exported with RCA for Senegal. The first scenario "PAPA" promotes a value chain approach which combines agricultural products targeted by the project and its processed food. In the second scenario, "all agricultural products," Senegal is expected to export all its agricultural products with RCA. In the third scenario "processed food", only processed food is exported with RCA.
The fourth scenario combines all agricultural products and processed foods. In the last scenario, we focus on manufacturing products only.

Figure 8 presents the diversity index while figure 9 shows ECI for different scenarios. Overall, exporting only non-processed agricultural products, even with RCA, is not enough to substantially boost the country structural transformation process. As expected, exporting manufacturing products with RCA is by far the best option to fast-track structural transformation. However, a value chain approach like the one adopted by PAPA where promotion of increased production is combined with processing capability, has the potential to trigger an agriculture-driven structural transformation.

Figure 8: Diversity index

Source:



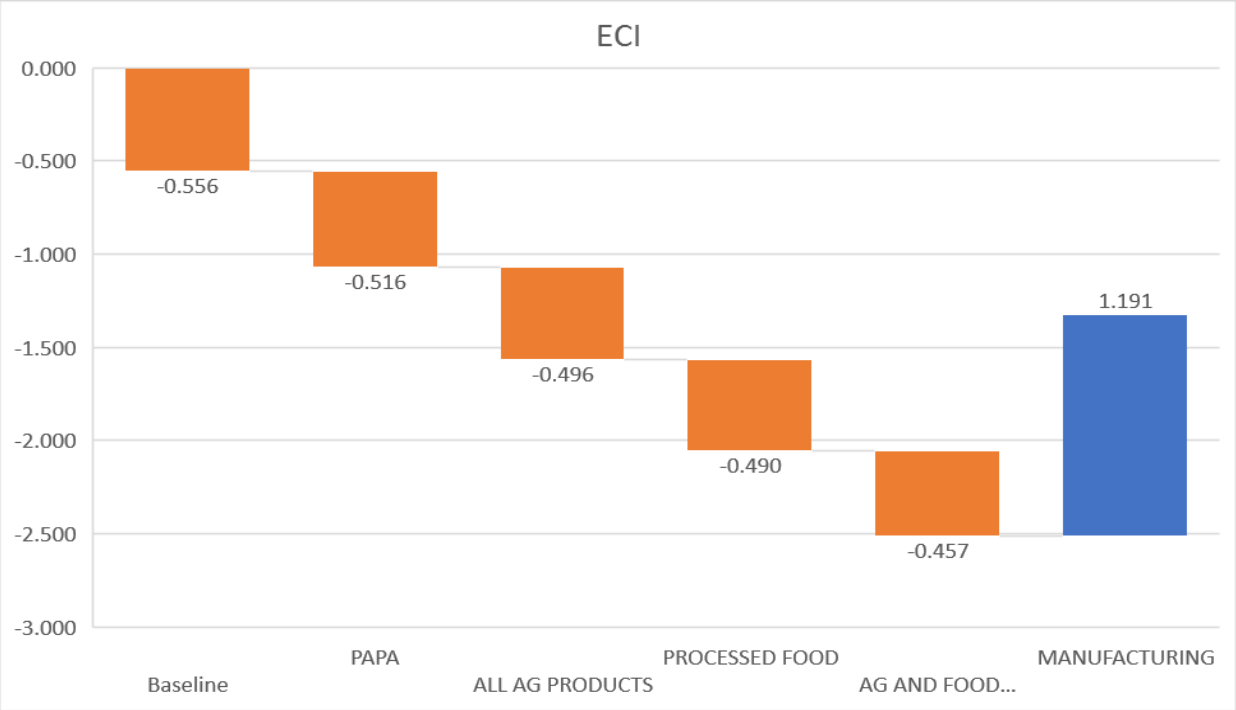
Authors' calculations, BACI (1995-2014)

Our findings suggest that agricultural value chains under PAPA, have the potential to speed up structural transformation in Senegal. Indeed, in the baseline 161 products are exported with RCA while with PAPA scenario, Senegal will be competitive in 216 products with an ECI of -0.516 which is 7 percent higher than the baseline.
Under the "All agricultural products" scenario, 220 products are exported with RCA [Figure 8] and the complexity index increase by 11% compared to the baseline. However, the processed food scenario has a greater impact on the sophistication of Senegal's economy than the agriculture and PAPA scenarios; although it generates less products exported with RCA (208) than PAPA (216), because of the increased value of exports, the ECI (-0.490) is much higher compared to agriculture (-0.496) and PAPA (-0.516). This shows that diversity alone does not generate structural transformation which requires also sophistication.

The combination of more agricultural products (beyond those selected by PAPA) and their processed food is expected to generate 260 competitive products and increase the complexity by 18 percent compared to the baseline.

As highlighted above, manufacturing is the golden sector when it comes to structural transformation. With respect to Senegal, manufacturing scenario produces 670 products with RCA and a complexity index of 1.19 which could propel Senegal to the path of an emerging economy. There is a growing body of literature that puts manufacturing—particularly specialization in high-end manufactured products—as one of the main driving forces behind economic development. The main argument being that manufacturers play a key role in driving growth-enhancing structural change. Rodrik (2007) highlights manufacturing's role in economic development by pointing out that not only do countries with a relatively large manufacturing sector grow faster than those with a relatively small one, but also that instances where the structure of the economy has moved toward manufacturing are associated with faster growth. Fagerberg (2000) argues that countries that have been able to move into production of the most technologically advanced manufactured products such as electronics, have had higher-than--average aggregate productivity growth. Similarly, Duarte and Restuccia (2010) show that, while catch-up in labor productivity in agriculture helps reduce the differential in aggregate productivity between developed and developing countries, catch-up in manufacturing does so by a much higher proportion.

Figure 9: Economic Complexity Index Simulations



Source: Authors' calculations, BACI (1995-2014)

Senegal must sustain its pursuit of emerging economy status through structural transformation. However, the cost of achieving agriculture-led structural transformation is quite high as shown by the difference between the actual exports (2014) and required minimum exports for selected products to be competitive (Table A in Appendix).

The main priority products targeted by PAPA but without a revealed comparative advantage include cereals, potatoes, maize, cabbages and banana. Other products such as millet, onion, cassava and sweet potatoes, melons and tomatoes were exported with RCA. To improve Senegal's diversity index, exports of grain sorghum must be multiplied by 227 while those of maize by 37. Other selected products should increase significantly: banana (25 times), cereals by-products (11 times), potatoes (8 times) and cabbages (6 times).

In the second scenario based on all agriculture products, the country must increase meat exports competitiveness. Table A in Appendix shows export ratios[3] of 3685 for swine, 3378 for beef, 252 for poultry. Moreover, in addition to the selected value chains by PAPA, increased exports of birds' eggs, coffee, fresh or dried citrus fruits, fruits and nuts, milk and cream, grapes, fish, tea, and legumes would increase the degree of sophistication of Senegalese exports basket. In the food processing scenario, strategic commodities with a huge gap in exports ratio values are ice creams (603 times), sunflower seeds (229 times), food preparations based on meat[4] (72 times), cereals grains otherwise worked (11times).

The general finding is that structural transformation of the economy requires reallocation of resources from low productivity sectors such as agriculture to sectors with high productivity such as manufacturing. The analysis of export baskets of selected emerging and developed countries [Table 1] reinforces this point and reveals that these countries are more competitive in manufacturing and processed food. Japan, ranked first place in terms of economic complexity, exports only 3 agricultural products and 2 processed products with revealed comparative advantage. On the other hand, agriculture sector accounts for only 6 percent of The United States exports basket and 8 percent of France basket of all products exported with RCA. The same pattern is observed for emerging

[3] Exports ratio of a given product refers to $\frac{Minimum\ Export\ value}{Exports\ value\ in\ the\ baseline}$ which is the ratio of the minimum value of exports that the country need to be competitive to the real exports value in the baseline

[4] Sausages and similar products, of meat, meat offal or blood;

countries; agriculture and food processing account for less than 20 percent of competitive products. Structural transformation can be triggered with the agriculture sector, but it needs to be accelerated by investing in processing and manufacturing.

Table 1: Diversification and ECI of some emerging and developed countries

Country	Diversification (2014)			ECI Ranking in 2014
	Ag Product	Processed Food	All Product	
Senegal	27	25	161	148
Brazil	25	24	202	95
China	16	13	548	27
Hongkong	17	6	263	34
India	32	27	392	75
Indonesia	22	30	254	114
Mexico	21	15	207	32
Russia	7	8	131	71
South Africa	22	24	228	93
Thailand	16	33	321	35
Vietnam	22	20	257	112
France	38	58	490	15
Japan	3	2	352	1
United States	28	25	442	12

Source: Authors calculations, BACI (1995-2014)

5. Concluding remarks

In this paper, using the product space approach, we simulated the role of agricultural value chains in Senegal's structural transformation process. The findings show that Senegal's ECI has been rather unstable throughout the period under consideration; it went from -0.95 in 1995 to -0.29 in 2007 before falling to -0.77 in 2009-2010. However, the index bounced back to reach -0.56 in 2014. Overall, our results suggest that an increase in number of products exported with RCA alone is not enough to boost structural transformation; indeed, exporting only non-processed agricultural products, even with RCA, is not enough to boost the country structural transformation process. However, the value chain approach adopted by PAPA has the potential to trigger an agriculture-driven structural transformation with the promotion of both production and processing capabilities. Still, as expected, exporting manufacturing products is the best option to fast-track structural transformation.

Given where the country stands, the cost of achieving agriculture-led structural transformation in terms of bridging the gap between the actual exports (2014) and the required minimum exports to be competitive, is very high. If PAPA is the main strategy, exports of grain sorghum must be multiplied by 227 while those of maize by 37 to improve the Senegalese diversity index. Other selected products should increase significantly as well: banana (25 times), cereals by-products (11 times), potatoes (8 times) and cabbages (6 times). Similarly, increased exports of birds' eggs, coffee, fresh or dried citrus fruits, fruits and nuts, milk and cream, grapes, fish, tea, and legumes would increase the degree of sophistication of Senegalese exports basket. With respect to food processing, strategic commodities with a huge gap in exports ratio values are ice creams sunflower seeds, food preparations based on meat and cereals grains otherwise worked.

Overall, our findings highlight the fact that agricultural value chains have the potential to become a core segment of renewed industrialization strategies across Africa, especially in Senegal. Indeed, from processing to packaging, transport, distribution, sales and advertising, and safety and certification services providers, agribusiness value chains have the potential to substantially contribute to the diversification and sophistication of the production structure.

In Senegal, under PAPA, value chains development is driven by thousands of small and medium sized, often women-led enterprises employing a handful of workers concentrated in the main production areas or around the large urban centers. To move to the next level, Senegal must adopt comprehensive and integrated approach that includes sustainable investments in both fundamentals and innovation along agricultural value chains to generate effective agriculture-driven structural transformation required to achieve the status of emerging economy. Fundamentals refer to human capital, institutions, infrastructure, and knowledge. Human capital represents the stock of educated and healthy population who positively contribute to the workforce along agricultural value chain. Institutional capacity represents norms and rules regulating key areas of agricultural value chains such as land management, markets access, access to financing and agricultural trade. Infrastructural capacity includes transportation networks (roads, railways and waterways), energy, communication and information technology. Knowledge encompasses the stock of available evidence-based information to improve agricultural productivity along the value chains.

Innovation in inputs and farming techniques are also essentials. Other areas where innovation is critical include irrigation, harvesting, processing, marketing, packaging, warehousing and reduction of post-harvest losses, energy (electrical, solar, wind), organizations (cooperatives, associations), social development (health, education), access to credit/finance, level of involvement (community as beneficiaries or as participants), gender mainstreaming, research and extension. To complement the proposed hard and soft investments outlined above, following Badiane and Ulimwengu (2017), we recommend: i) modernizing smallholders' agribusiness value chains; ii) integrating smallholder farmers into transforming value chains; iii) optimizing the role of producer organizations in promoting the integration of smallholders into agricultural value chains; iv) improving market intermediation, financial services and technology innovation.

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Appendix

Table A: Minimum Exports value to have RCA for Senegal (US$ 1000)

hs4	hs4name	Baseline	PAPA	Agriculture	Processed food	Agriculture and Processed food
106	Other live animals.	206.59766	206.5977	221.3435	206.5977	228.6451
102	Live bovine animals.	1.822	1.822	1680.76	1.822	1736.204
104	Live sheep and goats.	1.012	1.012	233.4907	1.012	241.1929
105	Live poultry	172.23303	172.233	553.1829	172.233	571.4309
201	Meat of bovine animals, fresh or chilled.	1.242	1.242	3826.196	1.242	3952.412
202	Meat of bovine animals, frozen.	1.116	1.116	3769.627	1.116	3893.977
203	Meat of swine, fresh, chilled or frozen.	1.43913	1.43913	5304.079	1.43913	5479.047
206	Edible offal of bovine animals, swine, sheep, goats, horses, asses, mules or hinnies, fresh, chilled or frozen.	1.859	1.859	1350.611	1.859	1395.164
207	Meat and edible offal, of the poultry of heading No. 01.05, fresh, chilled or frozen.	19.07492	19.07492	4807.961	19.07492	4966.563
210	Meat and edible meat offal, salted, in brine, dried or smoked; edible flours and meals of meat or meat offal.	42.441	42.441	873.8712	42.441	902.6979
301	Live fish.	243.74051	243.7405	316.6738	243.7405	327.12
401	Milk and cream not concentrated nor containing added sugar or other sweetening matter.	309.872	309.872	1638.458	309.872	1692.506
404	Whey, whether or not concentrated or containing added sugar or other sweetening matter; products consisting of natural milk constituents, whether or not containing added sugar or other sweetening matter, not elsewhere s	7.056	7.056	1056.497	7.056	1091.348
405	Butter and other fats and oils derived from milk; dairy spreads.	87.79684	87.79684	1486.217	87.79684	1535.244
406	Cheese and curd.	141.076	141.076	5620.914	141.076	5806.333
407	Birds' eggs, in shell, fresh, preserved or cooked.	85.2197	85.2197	760.8358	85.2197	785.9337
408	Birds' eggs, not in shell, and egg yolks, fresh, dried, cooked by steaming or by boiling in water, moulded, frozen or otherwise preserved, whether or not containing added sugar or other sweetening matter.	1.299	1.299	179.3214	1.299	185.2367
409	Natural honey.	8.79874	8.79874	391.8958	8.79874	404.8234
410	Edible products of animal origin not elsewhere specified or included.	3.802	3.802	64.4409	3.802	66.56663
510	Ambergris, castoreum, civet and musk; cantharides; bile, whether or not dried; glands and other animal products used in the preparation of pharmaceutical products, fresh, chilled, frozen or otherwise provisionally prese	6.79567	6.79567	39.03126	6.79567	40.3188
602	Other live plants (including their roots), cuttings and slips; mushroom spawn.	302.01196	302.012	1392.344	302.012	1438.274
601	Bulbs, tubers, tuberous roots, corms, crowns and rhizomes, dormant, in growth or in flower; chicory plants and roots other than roots of heading No. 12.12.	10.996	10.996	325.368	10.996	336.101
603	Cut flowers and flower buds of a kind suitable for bouquets or for ornamental purposes, fresh, dried, dyed, bleached, impregnated or otherwise prepared.	833.872	833.872	1507.393	833.872	1557.118
604	Foliage, branches and other parts of plants, without flowers or flower buds, and grasses, mosses and lichens, being goods of a kind suitable for bouquets or for ornamental purposes, fresh, dried, dyed, bleached, impregn	160.386	160.386	205.2168	160.386	211.9864
701	Potatoes, fresh or chilled.	87.76203	726.6298	724.9598	87.76203	748.8744
704	Cabbages, cauliflowers, kohlrabi, kale and similar edible brassicas, fresh or chilled.	81.70379	463.7277	462.6619	81.70379	477.9239

Table A: Continued

hs4	hs4name	Baseline	PAPA	Agriculture	Processed food	Agriculture and Processed food
705	Lettuce (Lactuca sativa) and chicory (Cichorium spp.), fresh or chilled.	3.029	3.029	444.5024	3.029	459.1654
711	Vegetables provisionally preserved (for example, by sulphur dioxide gas, in brine, in sulphur water or in other preservative solutions), but unsuitable in that state for immediate consumption.	12.265	12.265	129.7218	12.265	134.001
712	Dried vegetables, whole, cut, sliced, broken or in powder, but not further prepared.	155.32484	155.3248	494.3363	155.3248	510.6431
803	Bananas, including plantains, fresh or dried.	86.40465	2132.688	2127.786	86.40465	2197.977
805	Citrus fruit, fresh or dried.	64.25086	64.25086	2267.674	64.25086	2342.479
810	Other fruit, fresh.	31.3771	31.3771	1912.061	31.3771	1975.135
811	Fruit and nuts, uncooked or cooked by steaming or boiling in water, frozen,	19.84827	19.84827	751.7833	19.84827	776.5826
812	Fruit and nuts, provisionally preserved (for example, by sulphur dioxide gas, in brine, in sulphur water or in other preservative solutions), but unsuitable in that state for immediate consumption.	2.306	2.306	35.74403	2.306	36.92313
813	Fruit, dried, other than that of headings Nos. 08.01 to 08.06; mixtures of nuts or dried fruits of this Chapter.	22.97172	22.97172	411.8112	22.97172	425.3958
802	Other nuts, fresh or dried, whether or not shelled or peeled.	1026.0861	1026.086	2859.621	1026.086	2953.953
806	Grapes, fresh or dried.	114.81125	114.8112	1687.815	114.8112	1743.491
901	Coffee, whether or not roasted or decaffeinated; coffee husks and skins; coffee substitutes containing coffee in any proportion.	135.04317	135.0432	5294.255	135.0432	5468.899
910	Ginger, saffron, turmeric (curcuma), thyme, bay leaves, curry and other spices.	143.30059	143.3006	409.1474	143.3006	422.644
904	Pepper of the genus Piper; dried or crushed or ground fruits of the genus Capsicum or of the genus Pimenta.	669.22522	669.2252	741.4563	669.2252	765.915
1007	Grain sorghum.	1.725	391.509	390.6092	1.725	403.4943
1005	Maize (corn).	158.84922	5844.469	5831.037	158.8492	6023.387
1107	Malt, whether or not roasted.	15.952	702.382	15.952	697.4447	723.8842
1104	Cereal grains otherwise worked (for example, hulled, rolled, flaked, pearled, sliced or kibbled), except rice of heading No. 10.06; germ of cereals, whole, rolled, flaked or ground.	22.95093	243.3491	22.95093	241.6385	250.7988
1108	Starches; inulin.	76.35577	719.3747	76.35577	714.3179	741.3971
1109	Wheat gluten, whether or not dried.	174.22925	252.9472	174.2292	251.1691	260.6907
1206	Sunflower seeds	2.64644	609.0768	2.64644	604.7954	627.7227
1208	Flours and meals of oil seeds or oleaginous fruits, other than those of mustard.	2.24523	181.7557	2.24523	180.478	187.3198
1209	Seeds, fruit and spores, of a kind used for sowing.	179.86535	1218.097	179.8654	1209.535	1255.387
1302	Vegetable saps and extracts; pectic substances, pectinates and pectates; agar-agar and other mucilages and thickeners, whether or not modified, derived from vegetable products.	122.575	1217.976	122.575	1209.414	1255.262
1404	Vegetable products not elsewhere specified or included.	6.88987	150.8419	6.88987	149.7816	155.4596
1401	Vegetable materials of a kind used primarily for plaiting (for example, bamboos, rattans, reeds, rushes, osier, raffia, cleaned, bleached or dyed cereal straw, and lime bark).	12.09051	40.0456	12.09051	39.76411	41.27153
1509	Olive oil and its fractions, whether or not refined, but not chemically modified.	6.187	1212.523	6.187	1204	1249.642

Table A: Continued

hs4	hs4name	Baseline	PAPA	Agriculture	Processed food	Agriculture and Processed food
1514	Rape, colza or mustard oil and fractions thereof, whether or not refined, but not chemically modified.	8.901	1196.11	8.901	1187.702	1232.727
1513	Coconut (copra), palm kernel or babassu oil and fractions thereof	9.848	1082.12	9.848	1074.514	1115.247
1510	Other oils and their fractions obtained solely from olives	3.323	61.72005	3.323	61.2862	63.60951
1507	Soya-bean oil and its fractions, whether or not refined, but not chemically modified.	333.01055	1616.988	333.0106	1605.622	1666.489
1511	Palm oil and its fractions.	2062.4964	6097.879	2062.496	6055.015	6284.555
1515	Other fixed vegetable fats and oils (including jojoba oil) and their fractions	431.49141	669.3587	431.4914	664.6535	689.85
1521	Vegetable waxes (other than triglycerides), beeswax, other insect waxes and spermaceti	63.49032	72.96544	63.49032	72.45254	75.19915
1601	Sausages and similar products, of meat, meat offal or blood; food preparations based on these products.	11.73089	854.7433	11.73089	848.735	880.9098
1602	Other prepared or preserved meat, meat offal or blood.	76.832	2729.641	76.832	2710.453	2813.204
1702	Other sugars, including chemically pure lactose, maltose, glucose and fructose, in solid form; sugar syrups not containing added flavouring or colouring matter; artificial honey, whether or not mixed with natural honey;	46.17298	1216.276	46.17298	1207.726	1253.51
1701	Cane or beet sugar and chemically pure sucrose, in solid form.	1624.7471	4944.875	1624.747	4910.115	5096.253
1704	Sugar confectionery (including white chocolate), not containing cocoa.	1569.8804	1913.769	1569.88	1900.316	1972.355
1805	Cocoa powder, not containing added sugar or other sweetening matter.	110.374	368.9041	110.374	366.3109	380.1974
1903	Tapioca and substitutes therefor prepared from starch, in the form of flakes, grains, pearls, siftings or in similar forms.	5.57188	15.05244	5.57188	14.94663	15.51324
1905	Bread, pastry, cakes, biscuits and other bakers' wares, whether or not containing cocoa; communion wafers, empty cachets of a kind suitable for pharmaceutical use, sealing wafers, rice paper and similar products.	4623.0909	5403.828	4623.091	5365.842	5569.256
1904	Prepared foods obtained by the swelling or roasting of cereals or cereal products (for exam. corn flakes); cereals (other than maize (corn) in grain form or in the form of flakes or other worked grains (except flour and meal), pre-cooke	932.71116	1028.399	932.7112	1021.17	1059.882
2004	Other vegetables prepared or preserved otherwise than by vinegar or acetic acid, frozen, other than products of heading No. 20.06.	11.8314	1258.832	11.8314	1249.983	1297.369
2005	Other vegetables prepared or preserved otherwise than by vinegar or acetic acid, not frozen, other than products of heading No. 20.06.	94.02903	1780.287	94.02903	1767.772	1834.787
2008	Fruit, nuts and other edible parts of plants, otherwise prepared or preserved	203.2406	2415.057	203.2406	2398.081	2488.99
2003	Mushrooms and truffles prepared or preserved otherwise than by vinegar or acetic acid.	20.296	181.6977	20.296	180.4205	187.2601
2007	Jams, fruit jellies, marmalades, fruit or nut pure and fruit or nut pastes, being cooked preparations	247.45576	508.8823	247.4558	505.3051	524.4608
2001	Vegetables, fruit, nuts and other edible parts of plants, prepared or preserved by vinegar or acetic acid.	181.64773	359.8617	181.6477	357.3321	370.8782
2009	Fruit juices (including grape must) and vegetable juices, unfermented and not containing added spirit, whether or not containing added sugar or other sweetening matter.	2223.2449	2672.288	2223.245	2653.503	2754.095
2105	Ice cream and other edible ice, whether or not containing cocoa.	1.012	614.1513	1.012	609.8342	632.9525
2102	Yeasts (active or inactive); other single-cell micro-organisms,	40.214	419.5466	40.214	416.5974	432.3903
2106	Food preparations not elsewhere specified or included.	1749.0464	6266.232	1749.046	6222.185	6458.063

Table A: Continued

hs4	hs4name	Baseline	PAPA	Agriculture	Processed food	Agriculture and Processed food
2204	Wine of fresh grapes, including fortified wines; grape must other than that of heading No. 20.09.	346.765	6035.291	346.765	5992.866	6220.05
2201	Waters, including natural or artificial mineral waters and aerated waters,	41.701	610.1909	41.701	605.9016	628.8708
2203	Beer made from malt.	206.12125	2311.914	206.1212	2295.662	2382.689
2205	Vermouth and other wine of fresh grapes flavoured with plants or aromatic substances.	12.903	108.1797	12.903	107.4193	111.4914
2208	Undenatured ethyl alcohol of an alcoholic strength by volume of less than 80 % vol; spirits, liqueurs and other spirituous beverages.	651.323	5235.435	651.323	5198.633	5395.709
2202	Waters, including mineral waters and aerated waters, containing added sugar or other sweetening matter or flavoured, and other non-alcoholic beverages	1183.2249	2986.353	1183.225	2965.361	3077.775
2207	Undenatured ethyl alcohol of an alcoholic strength by volume of 80 % vol or higher; ethyl alcohol and other spirits, denatured, of any strength.	1255.1021	1309.239	1255.102	1300.036	1349.319