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An empirical analysis of the determinants of cocoa production in Cote d'Ivoire

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Abstract

Cote d'Ivoire has been at the helm of cocoa production for more than 3 decades. Despite being fraught by occasional challenges, she is still poised to steer the global cocoa production rudder. To keep the mantle of, we investigate and analyse some determinants that influence cocoa shortage in Cote d'Ivoire. Employing an ARDL using time series data for a 33-year period, we identify a long-run relationship between cocoa output and labour, land as well as fertilizer implements. We found a short-run relation among the same variables using an ECM. Additionally, political stability and carbon dioxide emissions had no statistically significant effect, indicating that Ivorian cocoa production is not impacted by these non-economic factors. Intuitively, policy makers can identify the causes of the shortages in the long and short terms and calibrate targeted decisions that will benefit the cocoa sector in particular and Ivorian agricultural activity in general.

1 Introduction

This article is based on a report published by global chocolate manufacturer Barry Callebaut (BC) which estimates a shortage of cocoa by 2022. In its capacity as largest chocolate manufacturer in the world, BC[1] has been producing chocolate and assorted confectionery products for more than 150 years. Their range of activities span from industrial food manufacturing, chocolatiers, and retail to a diverse clientele from across the globe. In 2013, the company dominated the global marketplace with an estimated market share of 40%.[2] Therefore, it can be said that the company has an extensive understanding of both the market and supply chain related to its products. Hence, any concerns the company may have about the sector can be accepted as sound. The likelihood of a severe cocoa shortage is bolstered by a newspaper article published by Bloomberg News on 2 December 2013. The article titled Global Cocoa Deficit Triples as Second Year of Shortages Loom[3] said the demand for cocoa butter which is used to make chocolate was increasing while the harvesting of cocoa beans declined.[4] In the same year, citing another report from the International Cocoa Organization (ICCO), the article also noted that "demand outstripped production by 160,000 metric tons".[5]

[1] The world's leading manufacturer of high-quality chocolate and cocoa products, http://www.barry-callebaut.com/1699.

[2] http://www.barry-callebaut.com/21.

[3] Bloomberg News.

[4] Ibid.

[5] ICCO.

Given that Cote d'Ivoire is the world leader in cocoa production, it is therefore vital that the country seeks to position itself to benefit from this shortage. Since 1960,[6] the cocoa sector has contributed a lot to the country's gross domestic product (GDP). It is a key component of the agricultural sector and accounts for more than 70% of the country's exports. Cocoa production further employs more than 1,000,000 farmers who go a long way in the reduction in the country's high unemployment rate. Hence, an increase in global cocoa prices would directly impact the country's earnings. According to an article published in Le Figaro,[7] the price of cocoa beans will multiply by 5 or 6 by 2030. Cocoa prices are determined on the international market hence exposing local producers to price fluctuations. In order to protect the farmers' produce, the country created a cocoa board to facilitate the development of the cocoa sector. One way was by fixing the price of cocoa for the farmers relative to that on the international market. The idea behind this was for the government to be able to ensure local farmers made a decent and stable income off their produce and for it to make a profit based on cocoa export taxes which was meant to be reinvested in the cocoa sector. This system of cocoa price fixing has had its adverse impact on the country's economy. In the event of a decline in the international price of cocoa below the anticipated price in Cote d'Ivoire, there has been a contraction in GDP. In 1979, cocoa was sold for $4800 per ton. Twenty years later, the same product sells for $1050 per ton 70% less than its 1979 price. Cote d'Ivoire has been the world's leader in cocoa production since 1978.[8] However, its market share has been decreasing as it faces competition from other cocoa-producing countries such as Ghana and Indonesia. Together Ghana and Cote d'Ivoire account for 58% of cocoa produced worldwide. This research posits that Cote d'Ivoire should reposition itself to take advantage of the projected cocoa shortage since a higher price due to scarcity will increase revenue which will and hence developments of industry supply chain and infrastructure.

According to demand–supply theory, and all other things being equal, the growth of a population will have repercussions on its consumption. In other words, an increase in the population will lead to a growth in consumption and subsequently growth in production. This, in an effort of satisfying rising demand by an equivalent quantity supplied to reach the market equilibrium. The world population should reach 8.425 billion by 2030, according to data from the United Nations.[9] Based on our understanding of the economic equilibrium theory of supply and demand, the existing gap between rapidly increasing demand and stagnating supply will, therefore, have a significant and direct impact on the global consumption levels via price hikes. To assuage this shortage, Cote d'Ivoire has to step up its production capacity to meet up with this increasing global demand to benefit from more substantial revenues stream margins. Cocoa is the raw material for many consumer products such as chocolate, liquors and even cosmetics. Hence, it is reasonable to assume that as consumption of its by-products increase so

[6] Independence of Cote d'Ivoire, August 07.

[7] http://www.lefigaro.fr/matieres-premieres/2012/01/02/04012-20120102ARTFIG00289-le-risque-de-penurie-s-accentue-sur-le-cacao.php.

[8] OECD 11/07/2008, évolution de la production oust-africaine 1960–2005.

[9] UN division of the population (World population prospects: the 2012 Revision), http://esa.un.org/wpp/unpp/panel_population.htm.

too world cocoa consumption. Benjamin Louvet[10] manager at Prim'finance provides a possible reason for this increase. According to the 1 January 2013 article published in the French newspaper Le Figaro, titled "Economies des Matieres Premieres", Louvet said world consumption would increase as the economies of emerging countries develop.

This assessment is not far off the mark as an examination of emerging economies such as Brazil and China reveal that as their GDP increases so too do their consumption levels. With a GDP of US $8.227 trillion,[11] China's annual productivity ranks number two after the United States of America (USA) in the world. It is the largest market for confection items in Asia.[12] China alone consumes approximately 100 g of chocolate per capita (World Cocoa Foundation). A member of the emerging economies bloc, Russia, India, China and South Africa (BRICS), Brazil has the largest GDP[13] in Latin America. It has a GDP of US $2.253 trillion.[14] In 2011, Brazil consumed 2.9 kg of chocolate per capita.[15] The increase in consumption can be seen even more clearly at the regional level wherein Asia-Pacific the annual chocolate consumption has grown by 2.5% points over the last 3 years from 3% of the region's annual consumption. This trend is also seen in other markets such as Eastern Europe and South America whose consumption levels have increased. According to Richard Truscott study, World Cocoa and CBE Markets are showing the fastest consumption growth in chocolate. The main products from cocoa are growing at around 2% per annum because of two trends: the mature market and the emerging market. It further shows that even though the mature market consumption fell between 2011 and 2012, demand continued to rise sharply in the emerging markets. The growth of consumption comes from diverse reasons, but the primary cause is the growing middle class which has a higher disposable income to spend on confectionery and luxury items. The challenge for Cote d'Ivoire is that in order to optimize its cocoa production and it needs to create an efficient production function. As has been mentioned above, there are many factors which are negatively influencing the growth and development of Cote d'Ivoire's cocoa sector; but if one were to create a production function that seeks to maximize the use of land, technology, labour and capital within the sector, the impact of these factors could be reduced or even removed. This becomes even more important when viewed within the context of the projected cocoa shortage if Cote d'Ivoire could successfully address these on mitigating factors it would increase production and therefore benefit from the impending shortage.

One of the key raw materials in Cote d'Ivoire's agricultural sector, cocoa, originated in Central America. Then known as 'xocolatl', cocoa was consumed by the Mayans in the sixteenth century. One of the first documentation of cocoa occurred in 1520 when Aztec emperor Montezuma, reportedly offered Fernand Cortez a drink called 'xocolatl'. Apparently well received, the cocoa plant made its way to Spain under the appellation 'cacao'. The cocoa drink became popular in Europe, and subsequently, the plant was transported

[10] http://www.lefigaro.fr/matieres-premieres/2012/01/02/04012-20120102ARTFIG00289-le-risque-de-penurie-s-accentue-sur-le-cacao.php.

[11] http://data.worldbank.org/country/china.

[12] International market bureau P2.

[13] http://data.worldbank.org/region/LAC.

[14] http://data.worldbank.org/country/brazil.

[15] International Markets Bureau P.2.

across Europe and into the colonies. It then made its way to Asia by way of the Spanish. It was documented in the Philippines in 1614. From there it travelled to Africa's Sao Tome and Principe in 1822. It arrived in Ghana in 1871 and Cote d'Ivoire in 1890. Therefore, history tells us the plant migrated across different continents before finally reaching Africa (especially West Africa). By trying to understand this movement, we are going to identify the historical causes related to this shift. The fundamental reason why cocoa got deeply implanted in Cote d'Ivoire and Ghana as compared to other areas across the African continent, as is reported in the existing literature, comes from the relationship between the colonizer and their colonial office which proffered them significant advantages. Before we expound on these advantages, it is important to note that cocoa beans got to Ghana and Nigeria via the British meanwhile in Cote d'Ivoire it was the French who introduced it. Management in the colonies at all levels, including and not limited to the cocoa industry was monitored and evaluated by duly appointed colonists for the metropolis. Meredith (1988) argued for the business interests and the reform of cocoa marketing in West Africa. He talked about how post world war one and two reforms were important to limit cartels or competition which slows down their interests. Thus, we come to realize that certain advantages existed which incited the colonizer's interest from the beginning. Also, Acquaah (2000) emphasized that the development of cocoa in West Africa be in the context of western markets. Besides their interests, the culture of subsistence farming and for local trade was already well established in West Africa which made it suitable to grow cocoa. Urquhart (1955) specified the main requirements to produce and satisfy world demand for a tropical crop, geography, climate and soil fertility are fundamental. Adding more factors to the ones mentioned by Clarence-Smith (2001) attributes the shift of this tropical crop production from Central and South America to the Caribbean and Africa to certain crucial factors which influence production such as government policy, access to land, odes of cultivation and labour. The ultimate reason according to him that encouraged this movement was the shift from coerced to free labour. An important study conducted by de Planhol (1947) on the causes of shifting cocoa production to West Africa (Cote d'Ivoire) drives the point as mentioned earlier home. He described the crop as a tropical plant which needed to be planted in the forest area. Tropical evergreen vegetation is found in the southern part of Cote d'Ivoire. In addition to this, cocoa cultivation necessitates a relatively stable temperature of at least 20 °C in a mildly windy area. On the other hand, soil composition is an important requirement (loose surface soil in areas with fewer rocks) in order to expect the cocoa roots to spread out farther and deeper to expect a considerable yield. Seeing the favourable conditions in Cote d'Ivoire for cocoa cultivation, the governor of the colony at the time made the cultivation of cocoa compulsory and later on utilized coerced labour. De Planhol in his paper said, the technique to compensate for the deficient labour force was based on conscription for coerced work and using indigenous workers for compulsory free labour on the cocoa plantations before they could retire to any work related to their plantations. It was accepted that labourers should get one-third of the crop they produced. It should be noted that during the introduction of cocoa cultivation in the colonies, it was not a success story because the population was hostile and did not see any interest in producing a product which had to serve another country, which was the main objective of the colonizer. Cocoa production was initially meant to satisfy the European

demand. This being the prime motivation for initiating its production was at the centre of the conflict that emerged and developed at the early stages of cocoa cultivation and consumption. Nowadays, the cultivation of cocoa contributes significantly to the agricultural business and the economy of Cote d'Ivoire in general. Also, many farmers without any coercive requirement specialize themselves in the cultivation of cocoa to make a profit. The post-independence era has recorded a steady increase in the number of farmers which attained approximately 600,000 farmers by 2006. Due to their relentless effort, the country is reputed as the greatest supplier of cocoa beans worldwide. This boosts the government's coffers given that the crop is a key contributor to the economy through taxes collected from exports.

Côte d'Ivoire became a French colony in 1889, and with the building of a railway system, it became the wealthiest colony in Francophone Africa by the 1940s.[16] It achieved long-term growth and prosperity after independence in 1960 until the early 1990s. Côte d'Ivoire has been for a long time the leader of the West African sub-region. The economy of Côte d'Ivoire is primarily dependent on its agriculture: important export products such as cocoa and coffee, other export crops such as sugar cane, cotton, palm oil, hevea (rubber tree), pineapple and bananas and food crops such as plantains, cassava and yams, among others. Located in West Africa, with an area of 322,462 km^2 and a population estimated at 23 million according to the 2014 Ivorian census, Côte d'Ivoire has certain natural advantages favourable to economic development. It has a tropical climate and vegetation suitable for agriculture, the backbone of this economy. A seacoast 520 km long ensures its exports and imports of goods via its two autonomous seaports of Abidjan and San Pedro. Côte d'Ivoire is a member of the West African Economic and Monetary Union (WAEMU). This union adopted convergence criteria aiming at specific targets such as limiting inflation, public debt and deficits to monitor the fiscal situation of the member countries in 1994 (World Bank Structural Adjustment Program). In 2003 and 2004, Côte d'Ivoire recorded negative economic growth rate of -1.6 and -1.7%, respectively, due to the political unrest that began in September 2002. In 2013, the primary sector grew sluggishly at 3.7%, with food crop production rising at 4% and the recovery of export crops such as rubber at a rate of 7.8%, cashews 6.7%, palm oil 5.8% and cocoa increasing at 1.1%. Despite a 13.6% drop in petroleum output because of natural depletion, the extractive sector grew 1.3%, after declining in 2012. This was due to higher natural gas production ($+9.3\%$) because of investment in fields CI-26 and CI-27), a 15.1% rise in gold output thanks to a rise in production at the Tongon and Bonikro mines, and a massive 121.5% leap in the production of manganese.[17] The Ivorian primary sector employs over 60% of the total population and contributes 23% to GDP. Primary sector is designated as all production activities of unprocessed material. This sector is composed of agriculture, animal resources and forestry. Coffee, cotton and cocoa sectors, which are the main export products of the country, feed about 9 million people. Government spending on the poor rose

[16] Sean Morris, "Deforestation in Cote d'Ivoire," in Case Study 318 (Washington, DC: American University Press May, 1996). http://www.american.edu/TED/ivorywd.htm.

[17] Africa Economic Outlook Côte d'Ivoire (2014).

to 9.3% of GDP in 2013 (from 8.6% in 2012), but the 2013 National Human Development Report mentions the multidimensional poverty rate increased from 31.8% in 2008 to 34.4% in 2011, while income poverty increased from 48.9 to 51.3% over the same period.

Researching cocoa production in Cote d'Ivoire is essential due to the role this sector plays in the economy. As mentioned in the previous section, cocoa production plays a significant role in the social and economic development of Cote d'Ivoire. It is one of the key GDP components, and it is the engine of the Ivorian agricultural economy. Also, this crop production is the first source of income in the rural area. Moreover, Cote d'Ivoire has not been able to stabilize throughout the year and consequently the prediction of insufficient world production in the near future is imminent. For now, varying results based on analyses and research from independent sources have been found to concur with this observation. Most of the research done takes into consideration the current conditions of farmers in the plantation such as agricultural technique and social development. Therefore, the motivation for the research emerged from a genuinely different viewpoints in the economic analysis. That is, analysing the impact of cocoa production in the short and long run by investigating the historical, current and forecasting future supply trends which could enable Cote d'Ivoire to reposition itself at the helm of competitive global cocoa production. Implying a pedantic study of the cocoa sector, focusing on the evolution of the industry, to enhance understanding and provide effective proposals. Due to that, the determinants of a probable insufficient production based on a novel approach will significantly improve our understanding of how to salvage the Ivorian cocoa sector.

The primary objectives of the study are to identify, analyse, evaluate and interpret the determining factors of cocoa production in Cote d'Ivoire so as to achieve a sustainable output in the cocoa industry by 2020 and beyond. To do this, we utilize production factors like labour force, land use, fertilizers and some controlled variables such as political instability and carbon dioxide. The study's objectives take into account the following assessment:

1. To estimate the quantitative effect of the production factors that lead to insufficient production.
2. To use a robust econometric model to test the procedures and identify the significance of each variable.
3. To recommend strong action to all relevant departments in charge of this sector to implement a dynamic system of production in Cote d'Ivoire.

This research is a contribution to the economic literature on the merits of cocoa production. It specifically targets the case study of the cocoa economy of Cote d'Ivoire, the leading world producer of cocoa. The study will augment existing knowledge on the determinants of insufficient production of the cocoa industry in Cote d'Ivoire. Given the ongoing discussion on the factors which decrease production globally, this conducted research aims at bridging the existing global supply gap, so as to enable Cote d'Ivoire to take advantage of future price hikes to increase its revenue. It looks forward to giving a broader perspective on the advantage of such research.

2 Methodology and data analysis

The mechanisms used in this paper focus on two well-known techniques. Essentially we link our dependent variable and the independent variables. Annual cocoa production is the result of many selected factor inputs from which we will choose to explain the yearly change in cocoa production. First of all, we use the simplified method applied in the field by previous researchers to link dependent and independent variables and then expand to the current reality case study associated with Cote d'Ivoire's cocoa production model. The basic form of the Cobb–Douglas formula is:

$$\boldsymbol{Y_t = At(K, L)} \tag{1}$$

where (1) is a linear function of Y annual cocoa production depending on A denoted as technology used in the process of producing annual production, K is the capital invested in order to produce more goods and finally L stands for labour used and t refers to time. Function (1) can be written in the Cobb–Douglas form as:

$$\mathbf{Y = AL^{\alpha}K^{\beta}} \tag{2}$$

Equation (2) is the basic form of Cobb–Douglas where Y is the output aggregate of cocoa production, L stands in this case for labour input, K measures capital equipment input, A denotes technology and α and β are the output elasticity of labour and capital, respectively.

Equation (3) is an augmented Cobb–Douglas function where Y is the output aggregate of cocoa production, L stands in this case for labour input, K measures capital equipment input, N stands for L and measured in hectares, A denotes technology and α, β and δ are the output elasticity of labour, land and capital, respectively.

$$\mathbf{Y = A.L^{\alpha}K^{\beta}N^{\delta}} \tag{3}$$

$$\mathbf{Y = A.L^{\alpha}K^{\beta}N^{\delta}C^{\Omega}} \tag{4}$$

$$\mathbf{Y = A.L^{\alpha}K^{\beta}N^{\delta}C^{\Omega}PS^{p}} \tag{5}$$

The theoretical framework uses a logarithm form; the transformation is obtained from the basic Cobb–Douglas function. Taking natural logs of both sides of Eq. (5) with ln (…) denoted as logarithm of the variables, we have Eq. (6).

$$\boldsymbol{Ln(Y) = ln(A) + \alpha ln(L) + \beta ln(K) + \delta ln(N) + \Omega ln(C) + p(PS) + \varepsilon} \tag{6}$$

In the equation, we use PS as a dummy variable and can be defined as:

$\mathrm{PS}_t = 1$ denote Political instability

$\mathrm{PS}_t = 0$ denote Political Stability

where ε is an error term, with the log linear specification meaning that the estimates of $\alpha, \beta, \Omega,, p$ are elasticity. To estimate the factor share of Eq. (6), we employ an autoregressive distributed lag with Y which is annual production in cocoa for the dependent variable, all other variables on the right side are considered as independent variables. We note that we assume fertilizers to be capital input in the equation. Therefore, the translog form of the function can be rewritten as:

$$\boldsymbol{Ln(Y) = ln(A) + \alpha ln(L) + \beta 1 ln(Nitr) + \beta 2 ln(PHOS) + \delta ln(N) + \Omega ln(C) + p(PS) + \varepsilon} \tag{7}$$

Table 1 Variables definitions

Dependent variable	Definition
Prod	Annual production of cocoa beans in tons
Independent variable	Definition
L	Labour, active population
Nitro	Nitrogen imported in tons
Phosp	Phosphate imported in tons
Land	Land is the total area harvested in hectares
CO_2	Carbon dioxide in Kt
PS	Political stability as a dummy variable

We denote N as nitrogen used in the cocoa industry and Phos as phosphate used in the cocoa sector.

To achieve the main objectives of this study with the relevant results, annual time series data of the variables were used. The data were sourced from FAOSTAT (2012), SYSTEMIC PEACE and the World Bank's World Bank Development Indicators (WDI) (2013). The period covered by the study is 1980–2012. The choice of this period is subjected to the period before and after the decline in Cote d'Ivoire's economy and the beginning of the financial crisis due to price fluctuations of raw material and also the availability of the data. All data used for a robust regression are transformed in logarithmic form except political instability which is expressed as a dummy variable. The advantage of this transformation is that the Cobb–Douglas production function can be linearized and the direct effect of independent variables on dependent variables. Secondly, according to Wicklin (2011), the transformation into the log is one of the most useful transformations in data analysis. It adds a constant value to the variables which can be maximized or minimized. These constants are called constant elasticity. Furthermore, Osborne (2010) conducted a research study on how data transformation improved normality of data from normality distributed data and the more the transformation in the log can correct the significant violation.

Here the descriptive statistics analysis gives us a brief idea after computing the quantitative data. This will give the characteristics of a group of variables. The mean is used as our central tendency for describing the ratio data, and standard deviation measures the variability of interval data, because it is the most stable measure of variability and includes every score in its calculations. The dependent variable, annual production of cocoa is measured in tons. This quantifies the level of production made in Cote d'Ivoire by using inputs to grow cocoa. The inputs selection which has been done in this paper follows the quantitative data.

According to production theories, it is allowed to add production factors in order to capture a better estimation of the regression. These production factors will be represented through the elasticity coefficients that will bring out the contribution of each factor. By this practice, it led us to understand the determinants of insufficient production of cocoa in Cote d'Ivoire. Table 1 defines the variables, and Table 2 summarizes the statistics of data mentioned.

Table 2 General descriptive statistics

	Prod	*L*	Nitro	Phosp	Land	CO_2	PS
Mean	1,007,841	2,606,061	31,636.55	19,808.52	1,701,321	6610.773	0.242,424
Std. dev.	374,596.9	263,319.4	20,664.89	11,872.95	498,741.1	1196.411	0.435,194
Maximum	1,700,000	2,900,000	92,100.00	51,633.00	2,500,000	9160.170	1.000,000
Minimum	360,445.0	2,000,000	5700.000	5800.000	836,700.0	4466.410	0.000000
Observations	33	33	33	33	33	31	33

3 Results estimation

Over the last 2–3 decades, econometric methods have brought clear and comprehensive solutions to economic problems, especially modelling an assumption using time series data. This innovation allows researchers to investigate long-run and short-run relationships. Autoregressive distributed lag (ARDL) approach uses time series data to regress a dynamic regression. It also requires stationary variables with an integration order which is denoted by I(1). In order to follow all the requirements for estimating a dynamic and meaningful regression, a researcher must have a linear dynamic regression model, Greene (2000) and Elhorst (2001). ARDL is an econometric model developed and modified by scholars in order to apply a time series data. The model was created in 1981 by the eminent economist Granger (1981) and later improved upon by Weiss (1983) and Engle (1982). It shows the complexity of using time series data. This model has proved indispensable to the development of econometric theory over the years. A fact which is further concretized by its being referenced by several respected researchers in the field (Stock and Watson 1999; Engle and Yoo 1987; Engle and Granger 1987; Weisz et al. 1995; Awokuse 2009; Baek and Koo 2007; Ferreira and Harrison 2012; Shahbaz et al. 2011). The ARDL model is both useful and highly relevant to the estimation of modern econometric trends. From the perspective of an economist, two different and essential periods must be measured, namely the short term and the long term. Therefore, it is meaningful to know and understand the real impact of a phenomenon over periods varying between 10 and 50 years. With the ARDL approach, it is possible to gain a clear understanding of changes over time and to predict the most likely outcome.

Stock and Watson (1999) highlights the function of the ARDL approach. He sees it as a broad and robust framework for studying both long-run and short-run relationships. Many agricultural economic papers have used the ARDL approach to investigate the sector because of the proficiency of the model. The ARDL approach, when correctly applied, can provide a significant contribution to and foster great innovation in Cote d'Ivoire's cocoa production. The model can help to plot how future production can fit population growth and how the production factors can affect national production. Muhammad Sabihuddin has done a useful study in this same area. He uses the Cobb–Douglas function to establish a production function in which the factors explain the relationship between the financial sector and agriculture. After that, he comes to the ARDL method which he uses to estimate the long-run effects between the factors used in the Cobb–Douglas function before using the causality test to check whether the factors can cause each other. In the end, he found that the factors demonstrate a long-run relationship and bidirectional causality between agriculture and the financial sector. Sabuhi-Sabouni and Piri (2008) explain how external

factors affect agricultural products, particularly export products. He found that price fluctuations and saffron exports have a long-run relationship and that the variables are significant. The dynamic relations between the US agricultural trade balance and the national macroeconomic aggregate are measured using the ARDL approach. The results show that the exchange rate is a key determinant of the long-run and short-run association and a significant relationship (Baek and Koo 2007). In contrast, Gustavo used the Herzerand Nowak–Lehnmann model to test the ARDL hypothesis on coffee beans exports, and he concluded that there is a long-run relationship between the diversification of export and economic growth. Awokuse (2009) used the ARDL model to find strong evidence between agriculture and economic growth. According to his research, agriculture is the central driving force for economic growth. Instead of the Cobb–Douglas function, Titus used the Solow–Swan production function to test the real contribution of agriculture and if it is an engine for development before applying the ARDL approach. He found that trade openness based on agricultural products had a positive impact on economic growth, further proving the usefulness of the ARDL approach in econometric research.

The literature mentioned above gives a pertinent reason for the use of the ARDL model in research. First, many agricultural raw materials functionalities were tested using this model, and second researchers use it because of its unique ability in measuring long-run relationships. Iran is a world leader in saffron exports in the same way that Cote d'Ivoire is a world leader in cocoa production. Therefore, if the ARDL can be successfully applied in Iran, it follows that the same approach would be useful in Cote d'Ivoire's cocoa production analysis. However, what is the ARDL approach mathematically speaking? ARDL is a regression model which was used by researchers Henry and Mizon (1990) to show the importance of using methods that assume the errors are generated by a first-order serial autoregressive process Elhorst (2001). It is autoregressive in the sense that it accounts for lagged values of the dependent and the explanatory variable. Minzon and Hendry called it a dynamic regression in which Y_t is regressed on $Y_{(t-1)}$ as X_t on $X_{(t-1)}$, and we have a Gaussian error term. J. Paul talks about ARDL quality of being specific by including lag selection in the equation comes to deal with immediate change and imperfect information on the data collected from different sources and frequencies. Also, Patterson and Ryding (1984) found that the distributed lag effects were pervasive and that distributed lag affects short-run dynamics. One of the valuable tools of the ARDL model is its ability to test cointegrating equations in the analysis of time series data. Then, it gives valuable predictions for the presence of long-run and short-run dynamics. It is known that the long run builds strong confidence and stability to avoid pitfalls. As far as it concerns this paper, it may be meaningful to know how the ARDL model reveals the long-run equilibrium and short-run relationship between Cote d'Ivoire's cocoa production project and the determinants production factors. Therefore, we based our model on Greene (2003) to specify the ARDL equation so the model can be written as:

We suppose the variables are cointegrated of order 1 denoted I(1).

$$\mathbf{Y}_t = \boldsymbol{\mu} + \sum_{i=1}^{p} \mathbf{Y}_i \mathbf{Y}_i - 1 + \sum_{j=1}^{r} \boldsymbol{\beta}_j \mathbf{X}_{t-j} + \delta \mathbf{W}_t + \boldsymbol{\varepsilon}_t \tag{8}$$

Table 3 Results of unit root tests *Source*: Author's calculation

Variable	ADF		PP		Ord. of integ.
	Level	First diff.	Level	First diff.	(1)
lprod	2.51	−7.06***	−2.51	−8.15***	(1)
llabour	−1.99	−8.36***	−1.19	−8.57***	(1)
lland	3.18	−8.55***	−3.09	−17.58***	(1)
lnitr	−1.11	−8.76***	−2.12	−8.59***	(1)
lphos	−2.79	−5.14***	−2.79	−15.40***	(1)
llco2	−3.45	−7.30***	−3.47	−10.50***	(1)

The regressions at level and in first difference include trend and intercept

***Indicates rejection of null hypothesis of non-stationary of the variables at 1% level of significance

where ε is supposed to be uncorrelated and homoscedastic; Y_t is dependent variable and Y_{i-1} is auto-distributed lag of the dependent variables. X_{t-j} is a distributed lag variable of the independent variable X_t, W_t are called random walks.

From Eq. (8), we get the error correction model in which we have an equilibrium relationship between the variables so it can be specified as:

$$\boldsymbol{Y_t} = \boldsymbol{\mu} + \boldsymbol{Y}_1\boldsymbol{Y_t} - 1 + \boldsymbol{\beta}_0\boldsymbol{X_t} + \boldsymbol{\beta X_t} - 1 + \boldsymbol{\varepsilon_t} \tag{9}$$

If we suppose that Ω is called the error correction equation then we can write $\Delta Y_t = Y_t - Y_{t-1}$ so and $\Delta X_t = X_t - X_{t-1}$ from this assumption we obtain:

$$\Delta\boldsymbol{Y_t} = \boldsymbol{\mu} + \boldsymbol{\beta}0\Delta\boldsymbol{X_t} + (\boldsymbol{Y}_1 - 1)(\boldsymbol{Y_{t-1}} - \Omega\boldsymbol{X_{t-1}}) + \boldsymbol{\varepsilon_t} \tag{10}$$

$\Omega = -(\beta_0 + \beta_1)/(Y_1 - 1)$, ΔY_t stands for an equilibrium relationship and $(Y_t - 1 - \Omega X_t - 1)$ for the equilibrium error.

Those predictions mentioned can be done following ARDL model, so first of all we should regress the equation in order to have estimated results and then use the diagnostics test to check whether there is a common inaccurate dynamic.

Here we applied tests specification based on ARDL approach to cointegration (to deal with unit root problem). Before we use time series data to investigate the cocoa production sector, we first conducted unit roots tests. Secondly, we used Johansen cointegration tests to obtain long-run estimation, error correction model and causality test. Furthermore, the efficiency of the estimation was checked through diagnostics tests such as the presence of heteroskedasticity, serial correlation, normality test and ARCH test. After we conducted all these tests, we used the CUSUM test to check the stability of our equation. ADF and PP were used to detect whether the variables had unit root problems as well as the integration order of the variables. Here, the null hypothesis was that the data were stationary which meant the data did not have a unit root problem. An alternative hypothesis was the data were not stationary meaning that the variable had a unit root problem.

H_0: the data are stationary.
H_1: the data have a unit root.

It is evident that from Table 3 that all the variables were not stationary at level but stationary at first difference which means the variables do not have a unit root

Table 4 Johansen cointegration test result *Source*: Author's calculation

Rank	Trace statistics	Maximum eigenvalue
$r_0 = 0$	189.9017***	63.99001***
$r_0 \leq 1$	125.9117***	42.32292**
$r_0 \leq 2$	83.58880***	
$r_0 \leq 3$	49.89844**	

*** and ** indicate the rejection of null hypothesis at 1% and 5% significance levels, respectively

problem. In addition, both tests confirmed the results and gave the same order of integration that is I(1).

The integration order one, denoted by I(1), is one of the conditions to apply ARDL model so since we identified the variable order, we were able to examine whether there was a long-run relationship based on the Johansen cointegration test. Once we carried out the test, we were able to see whether there was a short-run relationship.

Here we assumed that all the variables were integrated in the same order meaning that all the variables were non-stationary at level (Table 3) but stationary at first difference. Johansen cointegration test, the most efficient Sjo (2008), was used to check whether the model had a meaningful association. The equation was written based on Hjlamarsson and Osterholm's (2007) equation:

$$\boldsymbol{Y_t} = \boldsymbol{\mu} + \boldsymbol{A_1 Y_{t-1}} + \cdots + \boldsymbol{A_p Y_{t-p}} + \boldsymbol{\varepsilon_t} \tag{11}$$

where Y_t is an n X_1 vector of variables that integrated I(1) and ε_t is called an n X_1 vector of innovations.

So we can then see there is at least one linear combination among the variables. According to Table 4, the cointegration ranks denoted as r in the time series have produced the results below using the trace test and the maximum likelihood method. Both methods found that rank is more than one and less than $M-1$. M is the total number of the variable. Therefore, all the variables are cointegrated, and there is a long-run relationship between them. Thus, we were able to run the VEC model.

The relationship between cointegration and error correction was found by Granger (1981). According to Engle and Granger (1987), the error correction model can correct a proportion of disequilibrium from one period to the next. In the case of Cote d'Ivoire's cocoa sector, cocoa production in one period may depend on the surplus made by the production factors in the previous period.

Our short-run coefficients range from C (1) to C (9) as is indicated in Table 5. C (1) is equal to the speed of adjustment towards long-run equilibrium. The result was 52% which means that the speed of adjustment is not very fast. We found that the sign of C (1) is negative and was significant at 5%. Therefore, there is a long-run causality from the independent variables. It means that our independent variables influence the dependent variable in the long run.

Moreover, the study shows that there is a short-run relationship between the dependent variable and the independent variables. This was further confirmed through the application of the Wald test. It was likely that the ECM could have given a negative sign, but this was not the case. Our findings indicated that there was a

Table 5 Error correction model *Source*: Author's calculation

Depend. var		
Regressors	**Coefficients**	**t-statistics**
D(llabour(-1))	− 1.91	− 7.85**
D(lland(-1))	− 0.88	− 10.24**
D(lnitr(-1))	0.19	4.99**
D(lphos(-1))	− 0.30	− 7.83**
D(lco2(-1))	− 0.02	− 0.24
D(Ps(-1))	0.006	0.01
C	28.20	0.84
Ecm(-1)	− 0.52	− 2.55**

** Indicates significance of coefficients at 5% levels of significance

Table 6 Diagnostic tests *Source*: Author's calculations

Diagnostic test statistic	**Tests-stats**	**t-statistics**
Serial correlation	0.87	0.80
Normality	1.7	0.56
Heteroskedasticity	0.82	0.69
ARCH test	0.16	0.15

significant result with a speed of adjustment 52%. To further validate our findings, we also checked the stability of the model and ran diagnostic tests associated with the regression to avoid homogeneity problem. Lag selection is taken into account to make sure the model does not suffer from the diagnostic assumptions used. Serial correlation, normality, heteroskedasticity and ARCH test are carried out, and the lag selection follows the aim of this research paper. However, a small size of lag is advised to conduct an ARDL model.

After carrying out the ECM, we then checked whether the dependent variable had any statistical errors. Starting from heteroskedasticity, we can see from Table 6, the model is not suffering from heteroskedasticity which is a good illustration of the regression. Also, the result shows that our model is distributed normally with a 55% probability. This is more than the *p* value which is 5%. In the end, the estimation did not have any serial correlation problems, and consequently, we concluded that the model was well fitted and did not suffer from any statistical error. The stability of the model was checked using the CUSUM test and the CUSUM squares test. From Figs. 1 and 2, we can see that the curve is between the two straight lines which represent critical bounds at 5% level of significance. This demonstrates that the ECM model is quite stable.

After the long-run relationship is found and established (Table 7 shows more than one integrating equation), we interpreted the long-run results of the estimation. The model revealed that our explanatory variables were all significant and could explain the dependent variable at 67%.

$$\boldsymbol{Lprod} = \boldsymbol{Y} = -1.91\boldsymbol{L} - 0.88\boldsymbol{N} + 0.19\boldsymbol{C}1 - 0.30\boldsymbol{C}2 - 0.019\boldsymbol{lco}2 + 0.0067\boldsymbol{PS} + 267.75 \tag{12}$$

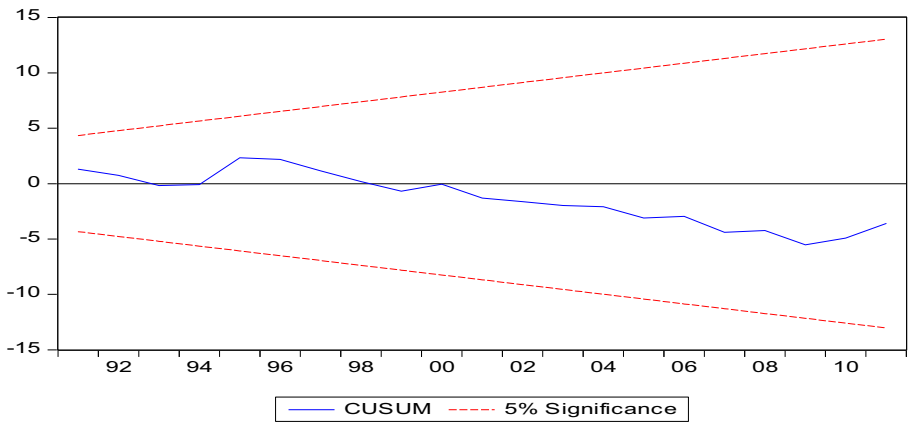

Fig. 1 CUSUM test

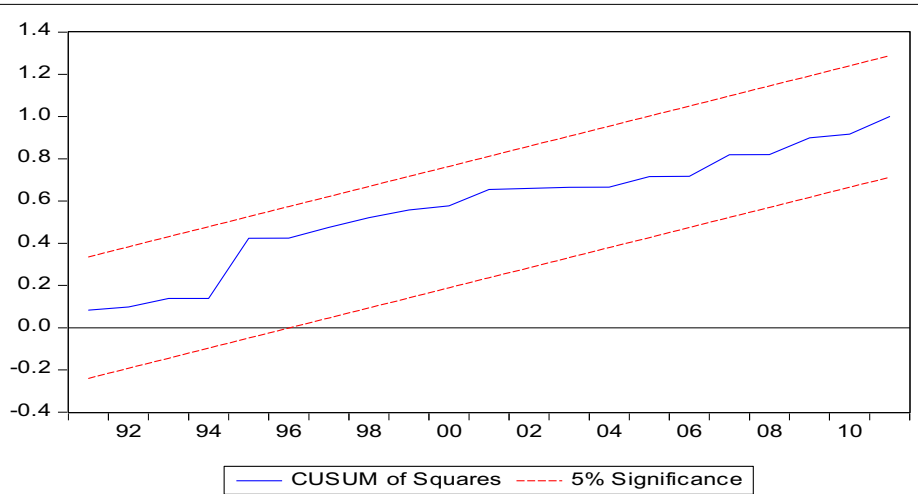

Fig. 2 CUSUM of squares test

Table 7 Long-run estimates based on the Johansen cointegration *Source*: Author's calculation

Dependent variable: lprod		
Regressors	**Coefficients**	**t-statistics**
llabour	−1.91	7.95**
lland	−0.88	11**
lnitr	0.19	4.75**
lphos	−0.30	7.5**
lco2	−0.019	0.01
ps	0.0067	0.25
C	267.75	

** Indicates significance of coefficients at 5% levels of significance

The results show that four of the explanatory variables were statistically significant at a minimum of 10% level. In this equation with log transformation, the coefficients can be called elasticity. The coefficient of labour is 1.91 which is negative and significant. Thus, it means that a 1% increase in labour force can decrease cocoa bean production in Cote d'Ivoire by 1.91% in the long run. Also, after 32 years of cultivation, land degradation in Cote d'Ivoire is at an all-time high and has a negative and significant impact on cocoa production. The coefficient value is 0.88 meaning that for every 1% of land that is used by cocoa farmers, production decreases by 0.88%.

In contrast, the use of nitrogen fertilizers in the cocoa industry has had a positive effect on production with a coefficient of 0.19. The value of the coefficient explains that a 1% increase in nitrogen will increase the cocoa production by 0.19% which was an expected result. Phosphate, another fertilizer, did not have the same effect on production as nitrogen. The coefficient of phosphate is 0.30 which is negative and statistically significant. Given that, we posited that a 1% increase in phosphate can decrease production by 0.30%. Also, a repetition of the test using carbon dioxide yielded similar results. Carbon dioxide reduces production by 0.01%. Political instability generated unexpected results. According to our findings, it positively affects the country's production by 0.0067%. In reality, the coefficient is 0%. The results mentioned above represent new findings in Cote d'Ivoire's cocoa industry.

Most of the research conducted in this sector did not use empirical investigation. While our findings go against the work of previous researchers, we are confident that our approach, which uses empirical data via ARDL regression, is more accurate. We are also confident that this approach is the best way to address the problems in Cote d'Ivoire's cocoa industry. A massive increase in population can decreases production. Mankiw (2003) explains how population, as one of the essential factors in production, can affect production through its marginal production. The production per worker without technology can be the cause of this decline. According to Mankiw, population growth has a negative impact on income. Marginal production of labour allows researchers to measure the surplus production added to the previous production. So in a sense, it gives the difference between productions with total labour in year $n+1$ and n (Mankiw). Once the output becomes stagnant, the production per worker stops increasing. We noticed that the marginal production of labour in Cote d'Ivoire does not appear efficient therefore it is not contributed.

Here we elaborate on our findings which challenge previous conclusions made about the agricultural sector and serve to guide future researchers.

In this study, the purpose was to investigate how the long-run cocoa production in Cote d'Ivoire was affected by its production factors. It was an empirical study that collected data covering 32 years. The sample used spanned from 1980 to 2012 and gave clear results which were objectively analysed using the ARDL approach to cointegration techniques. These findings reinforce some aspects of previous research while challenging others and it is hoped that they will spur future research in the sector.

Contrary to previous research, we found that an increase in the use of fertilizer did not always directly increase production. We also found that phosphate, a major component in the fertilizers currently being used in Cote d'Ivoire, is unable to eliminate the pests that prevent the growth of cocoa trees. Based on our findings we, therefore,

recommend that plant pathologists and agronomists expand their research to look at ways to enhance fertilizers and boost their effectiveness against pests.

Researchers have always declared that political instability has a negative impact on crop production. However, in Cote d'Ivoire, we found that political instability had zero effect. This was due, in no small extent, to the fact that when the crises broke out in the cities, they prompted a mass exodus to the rural areas which in turn created an informal labour force for the farmers. Hence, in the case of Cote d'Ivoire potential investors have nothing to fear.

Climate change also has a negative impact on agricultural production. This finding is significant because the issue is under-researched as a potential factor that makes the world production inefficient. The study has proved that CO_2 emissions are a real concern for the chocolate industry.

It is universally accepted that cocoa production is labour intensive and as such requires a large workforce. However, our findings show that it is not that simple. The workforce needs to be skilled and efficient in order to boost production. Given that child labour is neither skilled nor efficient, we, therefore, add our voice to the call for the end of child labour in the sector. We believe that the government should not only enforce this policy but also put in place a mechanism that will encourage farmers to hire adult labourers.

As expected land, which was more abundant in the past, is becoming rare. This scarcity hinders global output and gives rise to a shortage. Farmers try to expand their plantations to produce more cocoa beans, but they are faced with a severe land shortage. Inadequate land supply causes frictions within the farming community and often results in land disputes. It also leads to deforestation as some farmers raze sections of the forest to expand their crop yield.

Finally, our findings support the hypothesis that there will be a shortage of cocoa by 2020. Using the Cobb–Douglas production function to identify and analyse the production factors in Cote d'Ivoire's cocoa industry, we studied the different periods of cocoa production and their evolution. We saw that from the pre-colonial to the post-colonial period, the country was in need of an active labour force to work on the cocoa plantation. The authorities at that time opted for the importation of labour through open migration. Then people migrated en masse from neighbouring countries in order to fill the gap. Therefore, from 1955 (4.8) to 1980 (11.3) we saw a fast increase in migration.

As a consequence of this, the country became the world leader in cocoa production surpassing Ghana in 1979. However, it should be noted that a robust labour force is not the only factor influencing an increase in production in the post-colonial era. As was discussed earlier, easy access to land was also a key contributor to the industry's rapid growth. The liberalization of the sector characterized the second period. During this period, the price of cocoa beans decreased significantly as a direct result of a decline in income and investment. This problem was further compounded by a lack of skilled labour and scarcity of land. Farmers are still facing the same problem today as there remains the question of whether cocoa farmers can produce enough to supply world demand. These findings provide new evidence regarding the future of Cote d'Ivoire's cocoa industry and should be taken into consideration going forward.

4 Conclusion

The results and conclusions from this study are based on the following: to investigate the determinants that cause the insufficient world production of cocoa beans: the case of Cote d'Ivoire. With a multitude of factors influencing cocoa production in Cote d'Ivoire, we implement an augmented Cobb–Douglas function with carbon dioxide, land and political stability as our additional variables. We were not able to measure public policy-driven incentives; this variable could have captured the real impact of government intervention to encourage cocoa farmers. Examples of such government policy in the cocoa sector could be the law on land use by foreign or native farmers. Also, the ratio between national price and stock market price influences the farmer's production and encourages investment in cocoa production.

In this research, we used an autoregressive distributed lag approach to investigate the determinants of insufficient production of cocoa in Cote d'Ivoire. The study conducted aims to identify and swiftly address a probable cocoa shortage in the mid-to-long term. To achieve this, we use data from the post-independence period on Cote d'Ivoire. The sample used in this research starts from 1980 to 2012, annual time series data. First of all, we test for unit roots by applying ADF and PP to determine the stationary properties of the variables.

Further, we investigate the cointegration of the econometric model to determine the presence of a long-term relationship. Based on the presence of this relation, we will be able to analyse the effect of each independent variable on cocoa output. It enables an estimation in the long-run and short-run relation. The explanatory variables utilized are nitrogen and phosphate as fertilizers, labour, land, carbon dioxide and political instability as our dummy variable. Using Johansen cointegration, our results confirm the long-run relationship between cocoa production and the explanatory variables as well as in short run in the case of Cote d'Ivoire. Cote d'Ivoire has so far experienced severe crises in the course of its development, but the cocoa sector has always been one of the key contributors associated to the country's economic growth. Due to its large cocoa production, the world's chocolate manufacturers put more attention to its annual trend. Considering this dependence, we find it essential to analyse the factors that should influence global demand. Finally, we found shortcomings in the cocoa production function. Most of the production factors in Cote d'Ivoire are sub-optimally implemented to secure future production. The marginal production of labour which is in the form of active force working in the cocoa plantations is becoming more saturated, so it is inefficient to increase faster annual production to meet world demand. Significant facts can explain this change; there is no younger generation ready to relay the old generation due to rural exodus towards urban development. Younger people are moving to Abidjan, the capital city of Cote d'Ivoire for a better life which is very different from agricultural activities. Industries and services sector are growing faster in the country since 1973, so they are in the position to attract labour coming from rural areas. Also with the lack of land, land access is a crucial problem for the increase in cocoa production. In the long run, there will be no forest lands for farmers who intend to expand or invest in the cocoa industry because only 12% of arable land for cocoa production is left. There are disputes over these arable lands, and the regulations established, which is not registered, could have a serious negative impact on cocoa production. Also, the fertilizers used show a significant

limitation. On an ageing piece of land, the plantations are opened to the presence of many types of pests; and as a consequence, the death of cocoa pods is frequent—climate change and political instability impact cocoa production in Cote d'Ivoire differently: the first by decreasing rainfall and warming the temperature, the second by proceeding to a vast migration from urban to rural areas which help crop production like cocoa. These findings mentioned above have validated several tests to check for the robustness and stability of results.

As far as it concerns Cote d'Ivoire, it is desirable to understand the competitive spirit which guides farmers to ensure the satisfaction of world demand. Therefore, the determinants mentioned can be corrected as soon as possible if farmers are involved in the process, understood and finally guided. They can still be the leaders of world cocoa production in order to satisfy consumers.

Authors' contributions
Professor Cao Erbao reviewed the manuscript and the building of the theoretical framework of the production model implemented in this paper. Both authors read and approved the final manuscript.

Author's informations
Salifou K. Coulibaly's research is focused on entrepreneurship and innovation in the agricultural sector in developing countries (especially cocoa production). He has coauthored a research paper that was presented at the Allied Social Science Association (ASSA) Annual Meetings organized by the American Economic Association (AEA) of which he is a member. He is also a member of the African Finance and Economic Association (AFEA).

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Competing interests
The authors declare that they have no competing interests.

Availability of data and materials
These empirical data measure the annual production of cocoa beans in tons as the dependent variable (Prod), labour (L) as active population, nitro defined as imported nitrogen in tons, phostphate (Phos) imported in tons, land is the total area harvested in hectares for cocoa beans, Co_2 carbon dioxide in Kt and finally the political instability (PS) as a dummy variable. The datasets generated and/or analysed during the current study are available in the World Bank Data, FAO and systematic peace organization repository, http://microdata.worldbank.org/index.php/home, http://www.fao.org/faostat/en/, http://www.systemicpeace.org/. All data generated or analysed during this study are included in this published article and its supplementary information files.

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