Lisbon School of Economics & Management
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MASTER'S IN ECONOMICS

MASTER'S FINAL WORK
DISSERTATION

AGRICULTURAL POLICY INSTRUMENTS AND AGRICULTURAL PRODUCTION IN MOZAMBIQUE (1995-2019)

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ABSTRACT

Agriculture is one of the most important sectors of the Mozambican economy, directly affecting not only the lives of millions of Mozambicans, whether at the level of employment and income generation, food, and diet of the population, or at the level of some national accounts. This sector, however, remains underdeveloped. The guidelines for the agricultural sector set forth in the agrarian policy are little considered in the different plans, programs, and projects that have been implemented in the sector, which are often based on current acceptable theoretical thinking, the international market's needs and suffering pressures from international public and private actors and financial institutions. However, throughout these strategies for the implementation of the agrarian policy, the policy instruments remain the same. The objective of this thesis is to analyse the dynamic effects of variations in agricultural policy instruments of pricing, funding, and technology on agricultural production in Mozambique, in the short run. To achieve this objective, the author used an Autoregressive Distributed Lag (ARDL) model. The model results suggest a positive relationship between agricultural production per capita and chemical input use, producer price index, agricultural credit, and lagged agricultural GDP; a negative relationship between agricultural GDP per capita and international commodity price index, rural population growth rate, and agricultural land; and a non-significant relationship between agricultural production per capita and agricultural exports, agricultural investment, and agricultural gross fixed capital formation. Some of the results are consistent, and some are not, with the empirical evidence found by other authors for Mozambique and in other countries. Nevertheless, the results may be biased given the small sample size.

JEL Classification: C22, N57, Q18

Keywords: Agriculture, Agricultural Policies, Time Series Analysis, ARDL model, Mozambique

RESUMO

A agricultura é um dos mais importantes setores da economia moçambicana, afetando diretamente não só a vida de milhões de Moçambicanos, seja ao nível de geração de emprego e rendimento, da alimentação e dieta da população, mas também a nível de algumas contas nacionais. Este sector, entretanto, continua subdesenvolvido. A diretrizes para o sector agrícola dispostas na política agrária são pouco tomadas em conta nos diferentes planos, programas e projetos que tem sido implementado para o setor, baseando-se estes, muitas das vezes, no pensamento teórico aceitável da atualidade, nas necessidades do mercado internacional e sofrendo pressões de atores internacionais. Entretanto, ao longo destas estratégias de implementação da política agrária, os instrumentos de política permanecem os mesmos. O objetivo desta tese é de analisar os efeitos dinâmicos das variações nos instrumentos da política agrícola em matéria de preços, financiamento e tecnologia sobre a produção agrícola em Moçambique, a curto prazo. Para se atingir este objetivo, a autora usou de um modelo Autorregressivo de Desfasagens Distribuídas (ARDL). Os resultados do modelo sugerem uma relação positiva entre a produção agrícola per capita e a utilização de insumos químicos, o índice de preços aos produtores, o crédito agrícola e o PIB agrícola desfasado; uma relação negativa entre o PIB agrícola per capita e o índice de preços das mercadorias internacionais, a taxa de crescimento da população rural e as terras agrícolas; e uma relação não significativa entre a produção agrícola per capita e as exportações agrícolas, o investimento agrícola e a formação bruta de capital fixo agrícola. Alguns dos resultados encontrados vão de acordo, e outros não, com as evidências empíricas encontradas pelas pesquisas de outros autores em relação à Moçambique e em outros países. Entretanto, os resultados podem estar enviesados dado ao tamanho pequeno da amostra.

Classificação JEL: C22, N57, Q18

Palavras-chave: Agricultura, Políticas Agrícolas, Análise de Séries Temporais, modelo ARDL, Moçambique

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ACRONYMS LIST

ADF	Augmented Dickey-Fuller
AGRICOM	Agricultural Marketing Company
APIEX	Investment and Export Promotion Agency
ARDL	Autoregressive Distributed Lag Model
BM	Bank of Mozambique
CAADP	Comprehensive Africa Agriculture Development Programme
CEMO	Centro de Estudos Moçambicanos e Internacionais
CPI	Investment Promotion Centre
CUSUM	Cumulative Sum
CUSUMQ	Cumulative Sum Square
DDF	District Development Fund
EDR	Rural Development Strategy
ESAN	Food Security and Nutrition Plan
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
FDA	Agrarian Development Fund
FDHA	Hydraulic Development Fund
FDI	Foreign Direct Investment
FTA	Agricultural Development Fund
GAZEDA	Office of Economic Development Zones
GDP	Gross Domestic Product
ICM	Institute of Cereals of Mozambique
IPEX	Export Promotion Institute
IMF	International Monetary Fund
KR-2	Japan’s Kennedy 2
MADER	Ministry of Agriculture and Rural Development

MINAG	Ministry of Agriculture
MITADER	Ministry of Land, Environment and Rural Development
MZN	Mozambican Metical
NEPAD	New Partnership for Africa's Development
NIS	National Institute of Statistics of Mozambique
OIIL	Investment Budget to Local Initiatives
OLS	Ordinary Least Squares
PAPA	Action Plan for Food Production
PCA	Principal Component Analysis
PDEA	Agriculture's Extension Master Plan
PEDSA	Strategic Plan for Agricultural Development
PNISA	National Investment Plan for the Agrarian Sector
PODA	Operational Plan for Agricultural Development
PROAGRI	National Programme for Agricultural Development
PRONEA	National Agrarian Extension Program
PP	Phillip-Peron
pp	Percentage Points
R&D	Research and Development
SAP	Structural Adjustment Program
SARL	Société à Responsabilité Limitée
SIMA	Agricultural Market Information System
SSA	Sub-Saharan Africa
USD	United States Dollars
VIF	Variance Inflation Factors
WB	World Bank

1. INTRODUCTION

In most developing countries, namely in Sub-Saharan (SSA) countries and in Mozambique, particularly, the agrarian sector plays a central role in the economy, whether in terms of employment and income generation, the feeding of the population or the relationship with national accounts. In Mozambique, agricultural production accounted for 27% of the Gross Domestic Product (GDP) in the last 30 years and employs around 80% of the economically active population (Di Matteo & Schoneveld, 2016; National Institute of Statistics of Mozambique, NIS, 2022; Pernechele *et al*, 2018).

However, despite its importance on the country's economy, the agricultural activity is still highly rudimental, although an heterogeneous sector, producing in small plots of land by smallholders, dependent on edaphoclimatic conditions and with a low degree of modernization (low usage of inorganic inputs, mechanization, etc.), thus producing below the productive potential with low levels of productivity, which translates into the weak capacity of this sector to positively contribute to the eradication of poverty, malnutrition, inequality, among others (Guanziroli & Guanziroli, 2015; Marassiro *et al*, 2021; Nova, 2021).

Agricultural policies in SSA, and in Mozambique in particular, are tied to the currently acceptable theoretical thinking, the international market needs and pressures from international financial institutions (World Bank, WB and International Monetary Fund, IMF) and international public and private actors, which, over the years, have followed different objectives, where the final stated goal is the development of agriculture. For instance, in the 1980s/90s there was a great concern with economic stabilization and agriculture reforms, so the Structural Adjustment Program (SAP) were implemented in Mozambique; in the 1990s to 2010s, the attention moved to poverty and agriculture to accelerate 'pro-poor' growth; and from the years 2000s onwards, with the food and energy price crisis in 2007/08, the focus shifted again to agriculture and food production and security. In Mozambique, for instance, this latter manifested with the adoption of the Action Plan for Food Production (PAPA, 2008) and more recently, the SUSTENTA programme, currently in implementation. Nonetheless, even with this variation in the priorities defined for the agricultural sector, the concern with the modernization of the sector remained a cross-cutting issue and, basically, the agricultural policy instruments remained the same: subsidies, credit, investment, prices, chemical inputs, etc. (Badiane & Makombe, 2014; Lindert, 1991; Mosca, 2011).

Therefore, this thesis aims *to analyse the dynamic effects of variations in agricultural policy instruments of pricing, financing, and technology on the agricultural output in Mozambique, in the short run.* This topic will be addressed between the years 1995-2019, the period that followed the country's socialist experience and coinciding with the approval of the agrarian policy and its respective implementation strategies. In order to achieve the general objective, the following specific objectives were defined: 1) to identify, based on the literature review and theoretical framework, the impact of the agricultural policy instruments on the agricultural sector, 2) to describe the evolution of the Mozambican agricultural policy instruments from 1995 to 2019 and 3) to measure the effect of the agricultural policy instruments on the Mozambican agricultural output.

The author, therefore, formulated the following research question, considering positive economics: *How the agricultural policy instruments impact agricultural output in Mozambique?* As an attempt to answer this question, the following hypotheses were defined:

- H0: Not all agricultural policy instruments positively impact agricultural output in Mozambique.
- H1: All agricultural policy instruments positively impact agricultural output in Mozambique

For instance, the pricing policy (subsidies on input, output and export, boundary, and minimum prices, import tariffs and quotas, credit, and crop insurance) were found to have a positive effect on low- and middle-income countries agricultural production. In some cases, however, the minimum price policy seemed to harm farmers and, generally, it has a negative impact on consumers income. The credit and investment policies have both usually a positive relationship with agriculture, noting also that the impact of investment, both in practice and in research and development (R&D), present a high rate of return, suggesting underinvestment in this area (Hemming *et al*, 2018; Neto, 1996; Pernechele *et al*, 2018; Sunmer *et al*, 2010).

In Mozambique, studies have often found non-significant relationship among these variables or results contrary to those expected based on theories of agricultural development and evidence from other contexts. However, even though the effect of agricultural policies is not linear and certain on agriculture, a characteristic of the studies in Mozambique are that most of them are bibliographic studies, are based on descriptive statistics or on simple and multiple regressions (with variables other than those in this study) or are usually based on very short time series. Therefore, it is in the light of generating more empirical literature on this subject and to give some subsidy to the debate on agricultural development and the role of the State, that this thesis seeks to contribute, by using an autoregressive distributed lags (ARDL) model, that considers the dependent variable as a function of its own past lagged values as well as current and lagged values of the explanatory variables, analysing this relationship in the short-run (Shrestha & Bhatta, 2018).

In synthesis, the results found on this work suggest that agricultural output, the use of chemical inputs, the prices to producers and credit have a positive impact on agricultural GDP; the commodity prices, the rural population growth rate and agricultural land have a negative effect on agricultural production; and agricultural exports, investment and agricultural gross fixed capital formation are not significant in explaining agricultural output.

In addition to Chapter 1, this thesis is composed of five more sections. The second section, Chapter 2, is the literature review and seeks to explain the context of the main concepts in Mozambique, makes a small compilation of empirical results of other research on the relationship between agricultural policy instruments and agriculture in Mozambique and in other countries, and a brief description of the theoretical model. Chapter 3, the methodology, seeks to explain the process of data collection and processing, explains the method of analysis and the reasons for choosing this method. The fourth section, Chapter 4, analyses the evolution of each of the chosen variables representing agriculture and agricultural policy instruments in Mozambique. The analysis of the econometric model results is done on Chapter 5. The concluding section, Chapter 6, summarizes the key findings of the thesis.

2. LITERATURE REVIEW

Before presenting the main findings, a literature review was done to briefly explain the agricultural production systems and the agricultural policy context in Mozambique, the dynamic effects of different agricultural policies in different contexts, and a theoretical model of agricultural development in developing countries.

2.1.Agriculture in Mozambique

Mozambique is an agrarian country, where this sector plays a crucial role in the economic growth and development, having been responsible, in the last 30 years, for an average of 27% of the GDP and employs around 80% of the economically active population (Di Matteo & Schoneveld, 2016; NIS, 2022).[1]

The agricultural sector is heterogeneous, including a multiplicity of production systems, where the vast majority of the agricultural activity is practiced by the family sector: small farmers in small plots of land (1.2 - 1.6 ha per family and 0.39 - 0.47 ha per adult), representing 97.8% of total farms, producing mainly for self-consumption and income earning, with the sale of products being either intensive (cash crops) or less intensive (the sale of the surplus) (Ministry of Agriculture and Rural Development, MADER, acronym in Portuguese, 2021; Mosca, 2014). This family farming is characterised for being labour intensive, with limited use of capital and modern inputs (inorganic inputs, machinery, etc), with little access to private and public financing sources, technical assistance, extension services, information and markets, low

[1] The term "agrarian" corresponds to the breeding, extraction and cultivation of plant and animal products (agriculture, livestock, fishery, and forestry) and the processing and improvement of these products by both agroindustry and industry (Rocha, 1999). The term "agriculture" is contained in the broad concept of agrarian, including "activities such as cultivation, domestication, horticulture, arboriculture, and vegeculture, as well as forms of livestock management such as mixed crop-livestock farming, pastoralism, and transhumance" (Harris & Fuller, 2014, p.104). In this thesis, both terms will be considered as agriculture, following Pernechele *et al* (2018) considerations on the subject, due to the difficulty in accessing information on agrarian and agricultural variables separately and because agriculture proper in Mozambique is the largest activity within the agrarian sector: data shows that in the last 18 years agriculture output accounted for about 81% of the total agrarian production (NIS, 2022).

integration into value chains, and dependence on the edaphoclimatic conditions of the regions (Marassiro *et al*, 2021; Nova, 2021).

Given these characteristics, and for other reasons, such as the country's vulnerability to suffer from extreme climate phenomena (droughts, floods, and cyclones), the agricultural sector has low levels of productivity, which, in turn, negatively affect the productive capacity, household income, contributes to hunger, malnutrition, food insecurity, poverty, negative trade balance, and the economic and social state of the country (Marassiro *et al*, 2021).

However, not all producers present these characteristics and at the same intensity, existing other production systems apart and within the familiar system identified by Nova (2021): 1) *agribusiness or the large-scale investment model*, characterised by large-scale agroforestry and intensive agricultural production systems (monoculture), linked to the globalized value-chains, producing for exports and highly dependent on Foreign Direct Investment (FDI), imported technologies, knowledge, and human resources, 2) the *contract farming* or *out-grower scheme*[2], where farmers, individually or in associations, sign a contract with the concession companies[3], from which they receive ameliorated inputs, machinery rentals, technical assistance and funding, on credit and at subsidized rates, and in return they must sell the harvest to the monopsonic company at the prices and quantities previously agreed upon, deducting from the farmers pay check the costs of inputs and services provided; and, 3) the *small commercial farmer model,* that envisions the transformation/upgrade of small and mid-sized farmers and farmers' associations into commercial producers or enterprises, the so called "emergent producers", by their integration in value chains, where they receive direct support for mechanization, introduction of technological innovations, and technical assistance (Mosca, 2014; Mosca *et al*, 2016; MADER, 2020; Nova, 2021).

[2] Glover (1990) makes a distinction between the two concepts, considering contract farming when involves private enterprises and out-grower scheme when applied by public enterprises or parastatals. In this thesis, both terms are considered to have the same meaning.

[3] In these models, the companies are granted concessions by the government, meaning that inside a delimited area and for a limited period, they are the sole buyers of a certain crop (Nova, 2021).

These three models can positively contribute to the modernization of the agricultural sector, albeit with limitations, increase productivity, production and farmer's net income and improve the balance of some national accounts, as long as there are actions to minimise the negative effects and difficulties faced by producers, such as difficulties in adapting sophisticated practices and technologies, lack of financial capacity, capital accumulation centred abroad, social and environmental problems, for example land grabbing, soil degradation and impoverishment, etc. (Mosca *et al*, 2016; Nova, 2021; Porter & Phillips-Howard, 1997).

2.2.Agricultural Policies in Mozambique

Agricultural policies are governmental instruments for intervening, influencing and/or controlling the agricultural sector, usually aiming the development of agriculture[4], and therein, economic development. The need for these policies is explained by some authors using the farm-problem theory, that defends the existence and persistence of the farm problem: low income and earnings, low rate of return and price volatility, and their goal is the elimination of these problems[5]. Some other authors explain the need for these policies to solve problems arising from market failures, such as the instability of agricultural activity, imperfect markets for inputs, output, and the economy in general, difficulty in accessing information on public goods, the generation of new technological

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[4] Agricultural development is the process that creates the conditions, such as accumulation of knowledge, availability and adoption of technology, input, and output allocations, to achieve the agricultural potential and, therefore, improve the material and social welfare of the people directly and indirectly involved with the activity. This process generates three main outcomes of interest, namely: "1) the level and composition of production (food vs. cash crops); 2) the sustainability of production processes and agricultural growth; and 3) the efficiency of the allocation of agricultural produce" (Laiglesia, 2006, p.10).

[5] Some authors defend that the farm-problem result from the inelastic demand, supply prices, the biological and market characteristics of agriculture, the macroeconomic environment, among others. Due to industrialization and development, this theory was abandoned as it was understood that, in developed economies, the farm-problem ceased to exist. This disappearance, however, still needs to be proved (Bonnen & Schweikhardt, 1998; Gardner, 1992). Bonnen & Schweikhardt (1998) defended that the farm-problem still subsist in developing countries and, therefore, they still need to be studied, analysed, and discussed.

knowledge, environmental externalities associated with agricultural activity, among others (Gardner, 1992).

Mozambique does not have an agricultural policy[6], although it has an agrarian policy since 1995. The fundamental principle and objective of this policy is "to develop agrarian activity seeking to achieve food security, through the diversification of the production for the consumption, supply to the national industry and for export, based on the sustainable use of natural resources and ensuring social equity" (Resolution no. 11/95, 1995, p.3).

Upon the approval of this policy, regarding the agricultural sector, general and specific plans, strategies, programs, and projects were designed, approved, and implemented, namely: National Programme for Agricultural Development phase I 1998-2004 and phase III (PROAGRI I and II, acronym in Portuguese, 1998, 2005), Food Security and Nutrition Plan phase I and phase II (ESAN I and II, acronym in Portuguese, 1998, 2007), Agriculture's Extension Master Plan 1999-2004 (s/d), Agenda 2025 (2003), Green Revolution (2007), Rural Development Strategy (EDR, acronym in Portuguese, 2007), Agriculture's Extension Master Plan (PDEA, acronym in Portuguese, 2007), Programme for Intensifying and Diversifying Agriculture and Livestock in Mozambique (2008), Action Plan for Food Production (PAPA, acronym in Portuguese, 2008), Strategic Plan for Agricultural Development 2011-2020 (PEDSA, acronym in Portuguese, 2011), National Strategic Fertilizer Programme (2012), National Agrarian Extension Program (PRONEA, acronym in Portuguese, 2012), National Irrigation Programme (2013), Operational Plan for Agricultural Development 2015-2019 (PODA, acronym in Portuguese, 2017), National Water Resources Management Plan (2019), National Investment Plan for the Agrarian Sector 2013-2017/19 (PNISA, acronym in Portuguese, s/d) and SUSTENTA (2016, 2020) (Beula, 2020; Mosca, 2011).

At the core, these documents had as the main goal the rise of the productivity, production, competitivity, income and rentability of the agricultural sector, to fuel the

[6] The SUSTENTA programme, approved in 2017 and extended to the national level in 2020, was initially intended to be transformed into the National Family Farming Policy, having, in the end, remained a programme. The overall objective of this programme was "improving the quality of life of the rural families by promoting sustainable agriculture (social, economic and environmental)" (Ministry of Land, Environment and Rural Development, MITADER, acronym in Portuguese, 2018; MADER, 2020, p.2).

domestic (staple crops) and international (cash crops, such as food, feed, wood products, textile, and bioenergy) markets, to solve the country's problem of hunger, malnutrition, poverty, unemployment, external accounts deficit, and to speed the growth and development of the economy. They converged on the main approach to achieve the central objective: the modernization of the sector, signifying the rise on the use of ameliorated seeds and inorganic inputs, mechanization, irrigation, on the provision of extension and technical assistance, credit, marketing support and infrastructure access along the value chains, whilst promoting the sustainable use of the natural resources and preservation of the environment (Di Matteo & Schoneveld, 2016; Mosca, 2011). Casamo *et al* (2013) understood these policy goals and instruments as belonging to the first stage of a country's economic development, which should be accompanied by favourable tax incentives, macroeconomic, customs and indirect agricultural policies, and be applied over the long term on a stable and continuous basis and be adjusted when necessary.

However, these plans, strategies, programs, and projects diverged when they either followed a rural development approach as a whole and considering agriculture as an integral part of the rural space, or stressed the importance of multi-sectoral planning and coordination, or prioritized small farmers and family farming, the creation of "emergent farmers" and their integration into value chains, or promoted the ideals of cooperativism, or followed a value chain approach, prioritizing a set of crops and regions of high productive potential (Mosca, 2011).

This discrepancy on the approaches is not a sole characteristic of Mozambique, as it happened across the SSA countries with the continuously shifting objectives of the development paradigms, especially after the independence, with these being usually in accordance with the current accepted theoretical thinking, with the directives of international financial institutions (WB and IMF), with the needs of the international market, and very rarely with the focus on Africa's agriculture and needs. For instance, in the early 1960s, the Johnston & Mellor (1961) and Schultz (1964) ideals predominated, where smallholders had a central role on agriculture development; by 1970s the focus turned to poverty, growth and equity issues; simultaneously, in the 1960s/70s predominated the import-substituting industrialization ideals, via protection of infant industries, derived from Lewis (1954) and Rannis & Fei (1961) models; by the years 1980s to 1990s there was a great concern with economic stabilization and agricultural reforms, so SAP was implemented; in the 1990s to 2010s, the poverty was again at the agenda and agriculture became important in accelerating 'pro-poor' growth and; from the years 2000s to 2010s, agriculture was again at the center of economic development with the approval of New Partnership for Africa's Development (NEPAD)/Comprehensive Africa Agriculture Development Programme (CAADP) (Badiane & Makombe, 2014; Lindert, 1991).

Nevertheless, after more than 25 years of the agrarian policy and its operationalization, the Mozambican agricultural sector remains underdeveloped and with limited capacity to feed its growing population, as the existing instruments of agricultural policies have not been efficient and effective: 1) budgetary restrictions, and the budget allocations that do not prioritize agriculture and the rural environment, 2) there is no general price policy[7] to protect prices from shocks and imperfect market structures, 3) input price subsidies benefit medium and large farmers the most, 4) information access through the Agricultural Market Information System (SIMA, acronym in Portuguese)[8] is still limited, slow, and not available to all actors in the value chain, 5) the credit access is weak and the governmental initiatives, such as the Agricultural Development Fund (FDA, acronym in Portuguese) and the Investment Budget to Local Initiatives (OIIL, acronym in Portuguese), generally provide services and public investment, benefiting public institutions and very small-scale projects, in many cases not linked to agriculture[9], and 6)

[7] In 1987, 45 crops had their prices set by the government, and since then the number has decreased annually as part of the SAP. In 1989/90, a minimum price policy was instituted for nine commodities, namely: beans, cashew nuts, copra, cotton, groundnuts, *mafurra*, meat products, sorghum, and sunflower (Tarp, 1990). This policy was initially implemented by the Institute for Cereals in Mozambique (ICM, acronym in Portuguese), which in 1981, during the socialist period, was transformed into the State Agricultural Marketing Company (AGRICOM, acronym in Portuguese), and in 1994 was transformed again into the ICM. In 1997, price support policies were abandoned, and currently a small group of products still benefits from price support policies: cashew nuts and cotton have their prices fixed administratively, and sugar benefits from a reference price policy that serves as a protectionist mechanism against dumping and foreign competition (Aiuba, 2018a; Bruna, 2014; Mosca & Abbas, 2013).

[8] The SIMA is operational since 1991 and disseminates information through television, radio, mobile phone, internet, and in writing (Mosca, 2011).

[9] The OILL is operational since 2006, in lieu of the District Development Fund (DDF, acronym in Portuguese) that functioned from 1998-2008.The FDA was created in 2006, as a fusion of the Hydraulic

poor connection between the agrarian research and the extension services, lacking both services financial resources and human capital, hampering the production and dissemination of information about production technologies and better production practices (Casamo *et al*, 2013; Centro de Estudos Moçambicanos e Internacionais - CEMO, 2010; Official Gazette, 2004; Mosca, 2014; Mosca & Abbas, 2013; Mosca *et al*, 2013, 2014a).

In addition, there is low transparency on the usage of governmental funds, corruption, limited participation of stakeholders on the policies design, and the mismatch between the policies and the economic, technical, social, and cultural realities on the ground. Moreover, these policies are generally unfavourable for most farmers, with the government prioritising other economic sectors and, within agriculture, medium and large-scale producers, private companies, investors, value chains in the upstream stages of primary production, and export crops (Casamo *et al*, 2013, Marassiro *et al*, 2021; Monjane & Bruna, 2018; Mosca, 2014).

The agrarian policy has been applied incoherently and in a disjoint manner, not tackling the main issues that continuously hinder the agricultural development. Hence, most of the issues that the sector present today are the same or even worse as the ones of decades ago (CEMO, 2010). Given this context, Mosca (2011, pp. 234) denominates the actions in the agricultural sector after the SAP as “the policy of no policy”. Nonetheless, the agrarian policy and its operationalization tools are not totally flawed, constituting still a support tool for the development of the agriculture in Mozambique.

2.3.The Effect of Agricultural Policy Instruments on Agriculture

Agricultural policies can be used individually or in combination, this latter, generally, producing greater results. A crucial factor for the implementation of any agricultural policy is the public funds expenditure directed to the sector, being this variable usually positively related to agricultural production (Casamo *et al*, 2013).

Development Fund (FDHA, acronym in Portuguese) and Agricultural Development Fund (FTA, acronym in Portuguese).

Agricultural subsidies are one of the most important agricultural policies, and can take different forms, either for input or output or both, some examples being: tax exemptions, crop insurance, free provision of inputs, credit, price subsidies or provision of vouchers (Alston, 2007; Hemming *et al*, 2018). A meta-analysis on input subsidies in low- and middle-income countries found that they are generally directed towards fertilizers and/or seeds, positively impacting their adoption, contributing for the rise on yields, production, farmers' incomes, and GDP and reduction of the output prices (Hemming *et al*, 2018). In Mozambique, Mosca *et al* (2014b) pointed that the subsidies are applied *ex ante*, making it difficult to evaluate their effects on the agricultural sector.

The trend of subsidizing and protecting agriculture, instead of taxing it, began throughout the history after the post-wars, especially to exportable crops in developed economies. In some Asian, Latino America and African countries, this trend was seen starting from the 1960s/70s (Lindert, 1991).

Price policy is another of the most important agricultural policies, and can be of maximum, minimum or reference prices, the last two being the most common. The minimum price policy benefits farmers by reducing uncertainty around their incomes and increasing their bargaining power and negatively affects the consumer through higher prices. In some cases, this policy may harm farmers when the fixed price is used as an indicative price, not allowing them to benefit from increased market prices on the international market. An example is the cotton production in Mozambique and Benin (Neto, 1996; Pernechele *et al*, 2018; Sunmer *et al*, 2018). An important point to highlight is that, for the minimum price policy to function, the price administratively set must be above the market clearing price (Pernechele *et al*, 2018).

Tarp (1990) found in Mozambique, during the period when more generalised fixed and minimum price policies were active, that producers seemed to respond to price changes, and that this behaviour was more intensive for cash crops than for food crops. A study by Berthemly & Morisson (1989) *apud* Mosca (2011) found that in Mozambique and Tanzania, rising prices lead to decrease on output supply.

The credit policy positively impacts the agricultural production, nonetheless its potential can be disrupted by inflationary pressures (Neto, 1996). Mosca *et al* (2013) did not find a causal relationship between agricultural credit and the agricultural GDP in Mozambique, although both variables are positively correlated.

Private investment positively affects agricultural production in Mozambique, although at low levels, and public investment is not significative to explain the output production, since they are usually directed to areas that little contribute for the productivity and production, such as debt burdens, administrative expenditure, and institutional support (Casamo *et al*, 2013; Mosca & Dadá, 2014). Dercon & Gollin (2014) asserted that the literature suggests a high rate of return on public investments in agriculture, although they hardly address the question of the costs of this policy intervention on the economy.

Crop insurance was found, in the US economy, to have a potentially positive effect on agricultural production, although with negative effects on input, suggesting a negative impact on the income of the farmers (Sunmer *et al*, 2010).

The export restriction policy on the one hand, increases the availability of production in the domestic market, but on the other increases price volatility, negatively affecting farmers' income. An example is the case of staple crops in Ethiopia and Tanzania (Pernechele *et al*, 2018). Export dumping policies favour the country's exports, increasing farmers' income (Sunmer *et al*, 2010).

The protectionist import policy creates price incentives, positively affecting agricultural production, as in the case of rice in some SSA countries, with varying levels of effectiveness. In Mozambique, for the case of rice, this policy consisted of an import tariff of 2.5% and the 17% value added tax to the product, and in the case of sugar, a surcharge on imports when the product enters the country at a price lower than the domestic market price (Aiuba, 2018a; Pernechele *et al,* 2018).

Investment on R&D has proven over the years that increases farms productivity, causing the rise in production and consumption and reduction on the output price, being a long-term policy. Despite these positive impacts on agriculture, the agricultural research is usually underinvested, especially in low and middle-income countries, given its high rate of return on output and productivity (Alston *et al*, 2010; Casamo *et al*, 2013; Mosca & Dadá, 2014; Sunmer *et al*, 2010).

A point to notice is that the effects of the agricultural policies on the sector are not linear, depending on a number of factors that can make them produce stronger, weaker, or even opposite results, such as: the policies' targeted actors and time horizon, the complementary policies and investments, budgetary constraints, the existing infrastructure, the market and communication channels efficiency, the supply and demand elasticities of output and inputs, the elasticity of substitution between inputs, the inputs' price, the type of agricultural and economic systems, the stability of the economic, institutional and political environment, corruption and transparency, the environmental conditions, among others (Hemming *et al*, 2018; Pernechele *et al*, 2018; Sunmer *et al*, 2010).

2.4.Theoretical Framework: Theory of the Self-Control Mechanism

In SSA countries, governmental actions and agricultural policy decisions are tied to the currently acceptable theoretical thinking and pressures from international financial institutions, rarely depending on the reality and needs of African agriculture, as explained above. In all these different agricultural growth paradigms and policies, it resonates the concern of moving agriculture away from a subsistence orientation towards higher productivity and a market orientation activity, and technical change or modernization of agriculture is assumed to be a key feature to achieve a sustainable growth and development, following developed nations examples (Badiane & Makombe, 2014; Dercon & Gollin, 2014). Therefore, this subsection will explore an agricultural modernization model, the self-control mechanism theory, that focuses on agricultural development in developing countries.

The self-control mechanism model was first presented by Ruy Miller Paiva, in the 1970s, where the author argued that the modernization of agriculture is responsible for the rapid increase in productivity, production, farmers' net income, agricultural development, intensification of economic growth and economic development. This modernization process of agriculture is linked to a self-control mechanism that works as follows: the diffusion and adoption of modern techniques lead to an increase in productivity and output, a reduction in the prices of output and traditional factors (labour and land). The expansion of modern techniques intensifies the mechanism and the economic advantages of their use become smaller. As output prices continue to decline, the production surplus increases and the domestic and foreign markets approach the limit of production absorption, the economic advantage of the new technique becomes continuously smaller, or even disadvantageous for farmers to make the transition, discouraging further modernization and thus agriculture losing its dynamic role in economic development (Bacha, 1992; Nichols, 1973; Paiva, 1975; Schuh, 1973; Silva & Costa, 2006).

As noted, the maximum degree of modernization is endogenous to the model and is measured by 1) the intensity degree of the accumulated capital, which corresponds to the proportion of the accumulated capital and modern inputs incorporated into the production process and 2) the diffusion degree, that is the proportion of the farmers that use modern inputs. The maximum degree of modernization is determined by a reduction in production costs, an increase in productivity, and the price elasticity of demand of the output. There are some factors, however, that can extend the modernization optimum level, such as the emergence of a new technology, the development of the non-farm sector, the rise in exports and subsidies to the modern inputs[10] (Paiva, 1975; Silva & Costa, 2006).

Given this self-control mechanism, technological dualism or multiplicity becomes a stage of the modernization process, desirable to a certain limit, and not a deficiency of the developing countries' agriculture (Nichols, 1973; Paiva, 1975; Silva & Costa, 2006). Schuh (1973) points out that this phenomenon is also a characteristic of developed countries.

The self-control mechanism has some limitations: 1) not occurring at the beginning of the modernization process, 2) not affecting technologies that augment the productivity and reduce the production costs without further capital expenses, for instance soil management and conservation techniques, 3) not affecting certain products that by their economic and social characteristics hardly modernize, and 4) partially affecting exportable goods, as the demand is perfectly elastic and the prices are determined externally to the economy (Bacha, 1992; Paiva, 1973, 1975).

[10] Paiva (1975) says that subsidy policies to modern inputs in developing countries, on the one hand extend the maximum degree of modernization but on the other hand lead to an inefficient allocation of the modern factors, to a reduction of the salaries and the income of the farmers that do not modernize and the migration of the labour force that do not find job allocation at the urban areas, expanding thus low-income activities such as informal commerce, domestic services and retail.

The self-control mechanism model, like other existing theories, has been criticized, the two main critics being William H. Nichols and G. Edward Schuh. Nichols (1973) criticized 1) the non-inclusion of demand dynamics, 2) the failure to recognize the uncertainty surrounding the agricultural production and prices as one of the most important components of the "subjective transfer costs", 3) the non-recognition that some of the remote and distant areas from urban centres also present labour shortages and 4) the little emphasis given to the transportation services and communication infrastructures. Schuh (1973) criticized the model's failure to recognize that 1) the new production technology is an enormous income source that creates dynamism for the expansion of the non-farm sector, 2) the transfer potential and adaptability of the new technologies is very limited in different regions, thus requiring R&D locally, 3) the right policies can minimize the labour absorption problem and 4) the incorporation of the fixed asset theory would help better explain certain aspects of the model and make it more acceptable among the neoclassical economists.

Paiva (1973) accepted most of both authors' suggestions, pointing even that some of the concerns raised were already incorporated in the model, lacking only their clear explanation. The author, however, was sceptic about the graphical representation of its model by Nichols (1973) stating that it established only a mechanical and not a dependency relationship between the variables during the modernization process, and he also expected that Nichols would expand and mathematically explain the potential supply curve of agricultural produce.

Paiva (1973) agrees with both critics with regards to their discussion about the policy problems. Some of the implications of his model for the developing countries is that: 1) the modernization will not be generalized to all farmers and crops, 2) the salaries of the rural workers will continue to be low unless the sector modernizes, the non-farm sector develops and the exports rise and 3) the technological dualism leads to the increase of income inequality, poverty intensification and unemployment (Bacha, 1992; Paiva, 1975; Silva & Costa, 2006).

Given these concerns, Paiva (1975) presented some policy recommendations to support farmers who were unable to modernize and accelerate the process of agricultural modernization: 1) improvement of research and technical assistance services, 2) application of restrictions on the use of some modern technologies that require high capital expenditure and lead to large labour substitution, 3) provision of unconventional assistance to traditional farmers, promoting the use of local resources, techniques and use of capital that do not require greater expenditures and 4) promotion of exports.

3. METHODOLOGY

This thesis is based on a combination of two approaches: 1) bibliographic research, which comprises consulting books, scientific articles, and other types of documents to explain the dynamic relationships between agricultural policy instruments and the agricultural sector, both in Mozambique and in other contexts, and 2) quantitative research, which seeks econometrically to describe the relationships between the variables under study in Mozambique.

3.1.Data and Sources

The data used are aggregated annual secondary data, covering the period from 1995 to 2019 and were collected from the following institutions: Investment and Export Promotion Agency (APIEX[11],acronym in Portuguese), Bank of Mozambique (BM), Food and Agriculture Organization Statistics (FAOSTAT), National Institute of Statistics of Mozambique (NIS) and World Bank (WB).

The variables chosen to represent agricultural policy instruments and agriculture in Mozambique followed Mendoza (2020) classification of direct agricultural policies, the theoretical model (this essentially as a base to help explain the obtained results) and the data availability (Grant & Osanloo, 2016). The variables are: agrarian GDP per capita[12] (*agrgdp*), agricultural exports (*agrexpo*), agrarian gross fixed capital formation (*capitalform*), real agricultural approved investment volume (*rinvestment*), real agricultural bank credit volume (*rcredit*), agricultural commodities price (*commdprice*) and producer price (*prodprice*) inflations, fertilizer (*fertilizer*), manure (*manure*), and

[11] Instituted in 2016, by Decree no. 60/2016, with entry into effect in 2017, APIEX is a combination of the Investment Promotion Centre (CPI), the Office of Economic Development Zones (GAZEDA, acronym in Portuguese) and the Export Promotion Institute (IPEX, acronym in Portuguese).

[12] This variable was calculated based on the population in rural areas rather than the general population, since agricultural activity is basically carried out in the rural side of the country.

pesticide use (*pesticide*), agricultural land area (*land*) and rural population growth (*ruralpopl*).

Prior to the development of the econometric model, the data underwent some treatment. First, the volume of approved agricultural investment collected in foreign United States Dollars (USD) was converted to Mozambican Metical (MZN) and then, together with the variables agricultural GDP and real volume of agricultural bank credit, were adjusted for inflation with the base year 2014 (2014=100), following NIS guidelines.

Then the number of variables was reduced and aggregated through multivariate analysis, more precisely Principal Component Analysis (PCA). The PCA method reduces data complexity by transforming a set of correlated variables into a smaller set of independent variables (scores) (Marôco, 2021). Using the *correlation* method, since the variables had different measurement units, the following variables were created: *interinvest* (real agricultural credit volume), *forginvest* (real agrarian approved investment volume and agrarian fixed capital formation index), *inorginput* (fertilizer and pesticides use) and *orginput* (manure use). In both PCAs, the first two principal components were retained, where in the financing variables (*forginvest* and *interinvest*) explained 78.28% of the variance and in the input variables (*inorginput* and *orginput*) explained 92.13% of the variance explained. See tables VI and VII in annex. Note that as part of the regressors were created using a PCA, this generated some additional sampling uncertainty.

Next, we applied the logarithm transformation to all the variables as to stabilize the variations of the data across different levels of the series and then, tested for stationarity (Hyndman & Athanasopoulos, 2018). As each variable has a low number of observations, we decided not to use the results of unit root tests in isolation as they have low power and are susceptible to size distortions (DeJong *et al*, 1992). Therefore, we used a combination of the results of the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) tests, correlogram analysis, a simple regression without and inlaid with trend and literature review of the stationarity properties of the variables included in this study[13]. See figures 11 and 12 and tables VII, VIII, IX and X in annex.

Overall, it was found evidence of non-stationarity for all variables in levels and stationarity at first differences, and therefore, they were differentiated.

The data processing and the econometric model development were done using the Microsoft Excel spreadsheet editor and the EViews 12 statistical software package.

3.2.The Model

Since the variables are all integrated of order 1, I (1), and the sample size is small, the ARDL model was deemed to be the most appropriate regression model to conduct the analysis. An ARDL model is based on the ordinary least squares technique (OLS) and allows to analyse the short-run effects of the independent variables on the dependent variable (Shrestha & Bhatta, 2018).

More generally, the ARDL model was defined according to the following relationship:

$$agrgdp = f(commdprice, forgninvest, inorginput, interninvest, prodprice, ruralpopl) \quad (1)$$

We describe the relationship presented in equation (1) by the following dynamic model:

$$dlnagrgdp_{t}=\beta_{0}+ \sum_{k=1}^{n} \beta_{1k} dlnagrgdp_{t-k}+\sum_{k=0}^{n1} \beta_{2k} dlncommdprice_{t-k} + \sum_{k=0}^{n2} \beta_{3k} dlnprodprice_{t-k}+\sum_{k=0}^{n3} \beta_{4k} dlninorginput_{t-k} + \sum_{k=0}^{n4} \beta_{5k} dlnforginvest_{t-k} + \sum_{k=0}^{n5} \beta_{6k} dlninterninvest_{t-k} + \sum_{k=0}^{n6} \beta_{7k} dlnruralpopl_{t-k} + \sum_{k=0}^{n7} \beta_{8k} dlnland_{t-k} + \varepsilon_{t} \quad (2)$$

where *t* and *k* represent time period and lag length, respectively, β_0 stands for the intercept term, and β_{nk} are the parameters of each of regressors: *dlnagrgdp* (agricultural GDP per capita) is the dependent variable, and *dlncommdprice* (agricultural commodities prices index), *dlnprodprice* (producer price index), *dlninorginput* (fertilizer and pesticide use), *dlnforginvest* (agrarian gross fixed capital formation and real agricultural approved investment volume), *dlninterinvest (real* agricultural bank credit volume), *dlnruralpopl* (rural population growth) and *dlnland* (agricultural land use) are the independent

[13] For the stationarity of the variables in study see Ahmed *et al* (2021), Ali *et al* (2021), Awanyo-Vitor & Sackey (2019), Bal *et al* (2016), Dorestani & Arjomand (2006), Joy (2019), Kuhe (2019), Ozuzu & Ewubare (2020), Ukpong *et al* (2013), Wang & Tomek (2007) and Yu *et al*, (2020).

variables. Note that both dependent and independent variables are in their logarithmized, and first order differentiated forms (see section 3.1 for the reasons for this data transformation). The last item, ε_t represents the error term. The equation (2) should satisfy the standard conditions of econometric models for time series data that justify the general use of OLS (Wooldridge, 2015).

The variable that represents manure use, *dlnorginput*, was not include in the model, as it presented multicollinearity (see section 5.3).

4. GRAPHICAL ANALYSIS OF AGRICULTURE AND AGRICULTURAL POLICY INSTRUMENTS IN MOZAMBIQUE

This section briefly analyses the evolution of the representative variables of agriculture and agricultural policy instruments in Mozambique, between 1995 and 2019, seeking to identify reasons for their behaviour and relevant points in time.

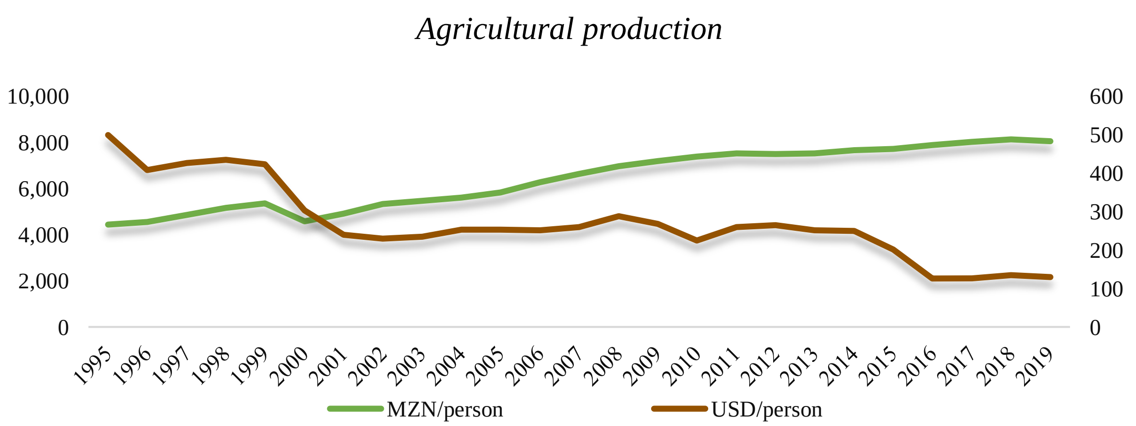


FIGURE 1. Agricultural GDP Per Capita

Note: The per capita values were calculated in relation to the rural population. Right-hand scale for GDP USD/person. 2014=100.

Source: Calculated by the author based on BM (2022a), NIS (2022) and WB (2022) data.

Figure 1 illustrates the evolution of agricultural GDP per capita in MZN and USD. Both series show an opposite behaviour, despite measuring the same variable: agricultural GDP in MZN had an upward trend and in USD showed a downward trend. These differences are due to the strength of the USD and the devaluation of the MZN.

The average annual growth rate of agricultural GDP from 1995 to 2019 was 5.4%, above the average growth rate of total and rural population, 2.8% and 2.3%, respectively

(NIS, 2022; WB, 2022). Nevertheless, the production cannot meet the food and dietary needs of the Mozambicans. A study by Aiuba (2018b) sought to verify whether the production and supply of four staple crops: groundnuts, rice, beans, and maize covered the food needs of Mozambicans according to the food needs of an adult, and concluded that, on average, between 1961 and 2016, the supply covered about 43% of food needs and national production covered about 32% of per capita food needs.

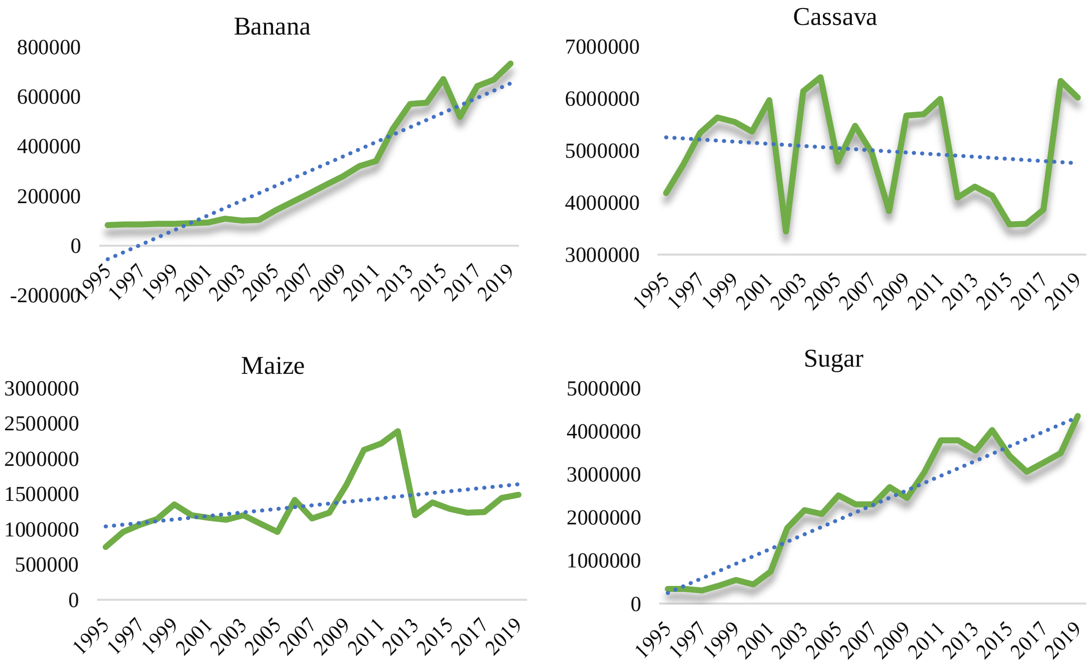


FIGURE 2 - Production of Banana, Cassava, Maize, and Sugar, in tons

Source: Calculated by the author based on FAOSTAT (2022) data.

Figure 2 displays the production in tons of four of the most produced crops in the 25 years under analysis. Cassava and maize are produced almost exclusively for the subsistence of farmers and their families, and surpluses are sold domestically and through cross-border trade. The production of bananas and sugar is intended to feed the domestic and international markets, being the former exported to the South African market and the latter to the European Union markets (Kegode, 2015; Uazire *et al*, 2008).

Cassava is the second most important staple food crop in the country, representing around 6% of the country's GDP (Cuambe & Avijala, 2018). Its production presented a slightly negative trend and a large variability over the years for no apparent reason, as pointed out by Costa & Delgado (2019), since there were no large variations in its cultivated area.

Maize production fluctuated over the years, showing a slight upward trend and important increases in production from 2009 to 2011. Although maize is essentially a staple food crop, market-oriented production is done using fertilizers. It is estimated that in the 2014/15 agricultural campaign, about 23% of maize monocultures and 28% of polycultures (with pulses) used this input (Food and Agriculture Organization, FAO, 2019).

Sugar production has been continuously increasing, reaching in 2019 a production volume of 4.4 million tons and contributing about 5% of agricultural GDP. Production takes place in a typical oligopsonic market structure, with sugarcane produced and controlled by four companies: Açucareira de Xinavane, SARL and Maragra Açúcar, SARL, located in Maputo province and Mafambisse, SARL and Companhia de Sena, SARL, located in Sofala province, and distribution follows a monopolistic market structure, where the National Sugar Distributor is responsible for supplying national wholesalers and exports (Aiuba, 2018a).

Banana production has had a positive trend over the years, having started in 2005 to grow at higher rates, an average of 14% per year. This growth is attributed to the expansion of commercial production. Banana is the second most exported crop, being traditionally produced by small producers and commercially, until 2014, by a group of 15 medium and large companies located in the provinces of Nampula, Manica, and Maputo (Calima *et al*, 2014; Dadá & Nova, 2018).

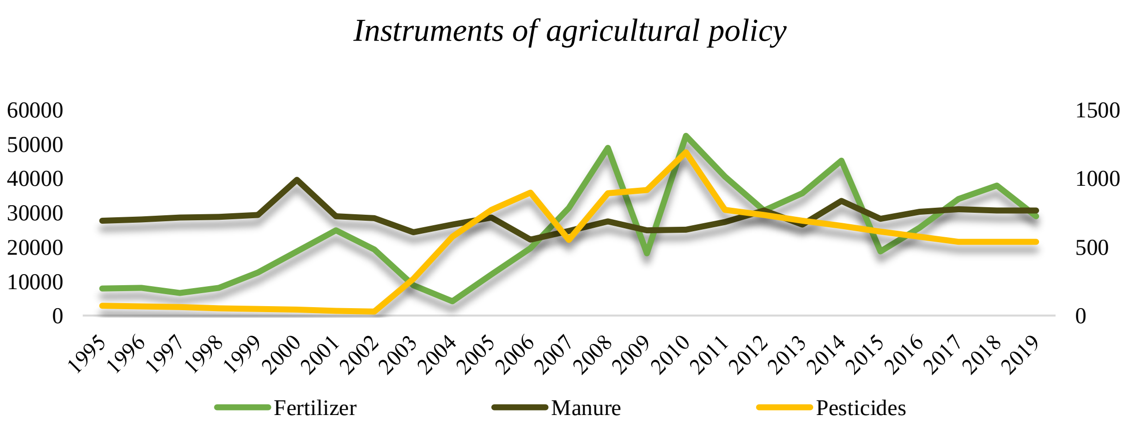


FIGURE 3 - Volume of Fertilizer, Manure, and Pesticide Use, in tons

Note: Right-hand scale for pesticides use.

Source: FAOSTAT (2022).

Inorganic inputs (fertilizers and pesticides) are more likely to be combined during the production process, although they can be used separately. The series on figure 3 show that in the first 15 years, they evolved not following the same pattern, however from 2011 onwards they presented a decreasing trend. Generally, the evolution of inorganic input use can be explained by the behaviour of some crops: in the case of pesticides, by cotton production and in the case of fertilizers, by rice, tomato, sugarcane, and tobacco production, representing these latter two crops about 90% of the national fertilizer consumption (Benson *et al*, 2012). From 2001 to 2004, the decrease on fertilizer consumption is partly due to the withdrawal of the public operators from the market, specially of the Japan's Kennedy 2 or the KR-2 programme (Ministry of Agriculture, MINAG, 2012).

It is also noticeable bigger movements of these series from late 1990s and beginning 2000s. These big movements on the consumption of chemical inputs can be related to the Mozambican government increasingly acknowledgement, over the course of 2000s, of the role of modernization and the intensification of this process to combat rural poverty and national food insecurity (Di Matteo & Schoneveld, 2016).

Manure consumption remained relatively stable, with a slight upward trend. This organic fertilizer is almost exclusively used by the farmers that own livestock.

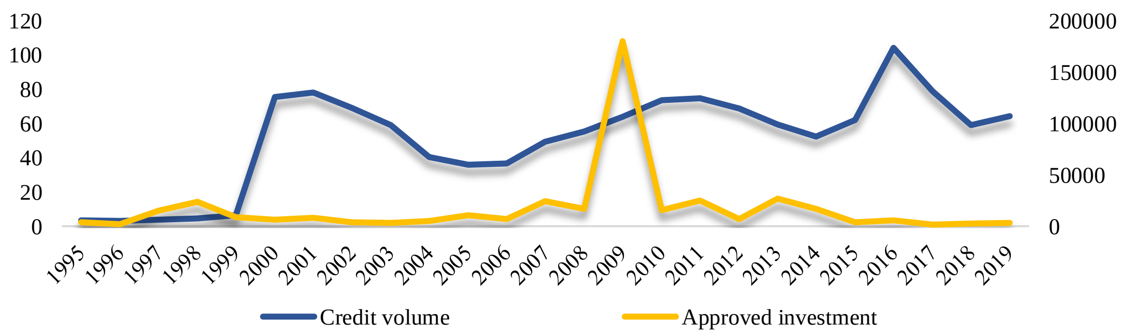


FIGURE 4 - Real Volume of Credit and Approved Investment in Agriculture, in millions MZN

Note: 2014=100. Right-hand scale for approved investment.
Source: BM (2022b) and APIEX (1995 – 2019).

The series on figure 4 illustrate an upward trend for bank credit, with large peaks in 2000 and 2016, followed by a sharp decline in 2017. The behaviour of 2017 is attributed to the contraction of credit to the economy as a result of the persistence of the restrictive monetary policy, which was initially applied in 2016 to face the negative effects of the “hidden debt” crisis on the economy (WB, 2017).

Despite the growth in volume, the proportion of bank credit dedicated to the agricultural sector in the total credit granted to the Mozambican economy has been decreasing: in 1995, it represented about 26% and in 2019, roughly 4% of the total granted credit. However, at the same time, there was a tendency of rise in bank credit to services that support the extractive industry (energetic minerals) (Muianga, 2021).

The approved investment volume was volatile throughout the series, although it is not clearly visible on the graph. The peak verified in 2009 is due to the approval of 2 projects: Grown Energy Zambeze and Agro-Pecuária PROAL, which together represented 49% of the total value of agricultural approved investment that year (APIEX, 2009). There has been a steady annual increase in the number of approved investments since 2002 and coinciding with this period, investment in agriculture has come to be seen as key to modernizing and developing the sector. Since 2007/2008, with the food and energy price crisis, the number of agricultural investments in the country has more than doubled (Di Matteo & Schoneveld, 2016).

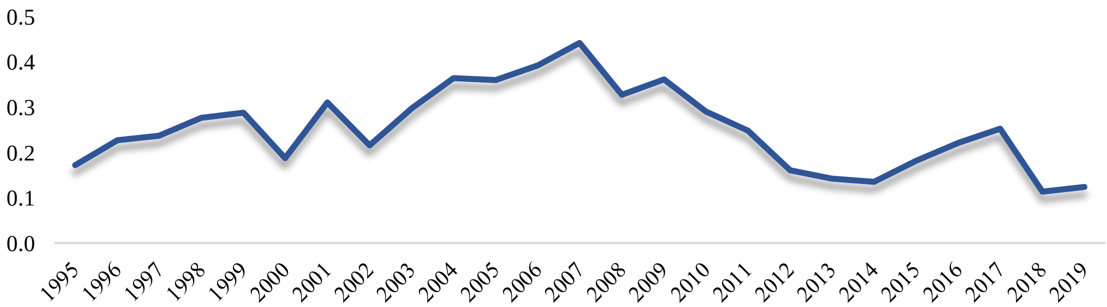


FIGURE 5 -Agricultural Gross Fixed Capital Formation Index

Note: The values of the index start from 0 up to values above 1.

Source: FAOSTAT (2022).

The capital accumulation index values were below 0.5 on the 25 years in analysis, reflecting a lower investment orientation toward the agriculture sector, meaning that the sector receives a lower share of investment relative to its contribution to the economy’s value added, which in turn negatively affects its productivity growth and technical progress. A downward trend can also be observed from 2008, meaning that in this period the gross capital formation grew faster in the rest of the economy comparing to agriculture

(United Nations Statistics, 2022). Mosca & Dadá (2014) alert that the descending trend of the capital accumulation, not only on agriculture, but in the economy as a whole, will require huge investments and the recovery of productive capacity will take years.

The acquisition of capital by smallholders to invest in their farms in Mozambique usually comprises the purchase of chemical inputs, long-handled hoes, improvement of sheds/barns, opening of water wells, etc. The investment (acquisition) in tractors and other productive machinery is made, usually, by large farmers, specific projects and programmes and farmer associations, and medium and small farmers access them through rent.

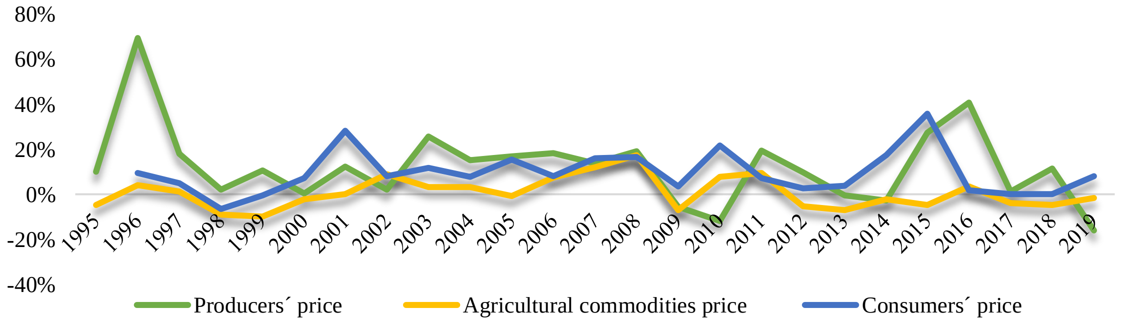


FIGURE 6 - Inflation of the Agricultural Producers' and Commodities Prices and Consumers' Food Prices

Note: The consumer's inflation prices series is solely for illustration, and it presents the following specifics: 1) data not available for 1995, 2) data for the years 1996-2016 have 2010=100 and 3) data for the years 2017-2019 have 2016=100.

Source: Calculated by the author based on FAOSTAT (2022) and WB (2022) data.

The variables displayed on figure 6 presented high volatility, with producer and consumer prices showing greater amplitude of variation. This behaviour generates uncertainty, negatively affecting the decision-making process of the economic agents and, ultimately, the country's GDP.

The proportion of the value added received by farmers is very low and is concentrated in the downstream stages of the value chain, as pointed out in a study by Aiuba & Nova (2022) that covered three crops: cowpea, maize, and sugar. The factors that explain this low prices are the following: 1) the smallholders weak negotiating capacity, due to low training and limited information access about markets and prices, 2) the precariousness of the storage systems and the immediate need for liquidity that force them to sell the produce shortly after the harvest, 3) poor harvest quality, due to low use of modernized inputs, lack of standardization and production quality control system and lack of processing, 4) the market structures and price formation system and 5) the armed conflict starting in mid-2010s, centred in the central provinces of the country, that hindered the transportation of goods (Nova, 2018).

Regarding the commodities price, it was observed a sharp decrease on the prices in 1998/99 resulting from 1) financial crisis that initiated in the East Asian countries, leading to economic slowdown and devaluations of currencies of the major exporters, 2) the rise in expectations and supply of some commodities (cocoa, coffee, sugar, palm oil) and 3) the exports tax reduction for palm oil in Indonesia. In the years 2006-2008, the price of agricultural commodities rose two digits and it was due to the factors: 1) production below the expectation, 2) low supply prospects resulting from extreme climate events and other factors that lead to strong speculative buying, 3) strong demand for food and biofuel for oil production, 4) high energy-related fertilizer prices, which lowered yields and rose production costs, 5) seasonal high prices for new Kolkata premium tea and, 6) exports constraints due to protests in Cote d'Ivoire. In the following year (2009), the prices decreased as the trend of these factors reversed (WB, 1998-2009).

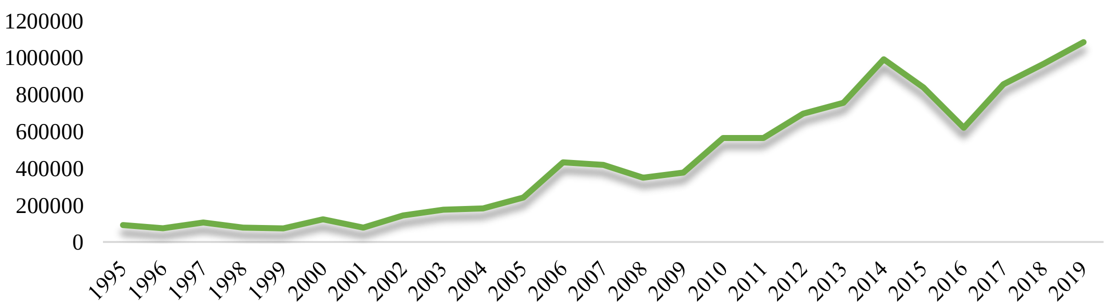


FIGURE 7 - Agricultural Exports, in tons

Source: FAOSTAT (2022).

The agricultural exports on figure 7 showed an upward trend over the 25 years analysed, with the value in 2019 corresponding about 12 times the exports value of 1995. The agricultural exports were dominated for the following crops: bananas, beans, cashew nuts, cotton and its derivatives, maize, oils, sugar and its derivatives, tobacco, and sesame seeds (FAOSTAT, 2022).

Although agriculture is one of the most important productive sectors in Mozambique, agricultural exports represented, between the years 2011-2021, around 10% of the total exports, whilst the exports of the extractive and manufacturing industries represented, on average, 33% and 32% of the total exports, respectively (BM, 2022c).

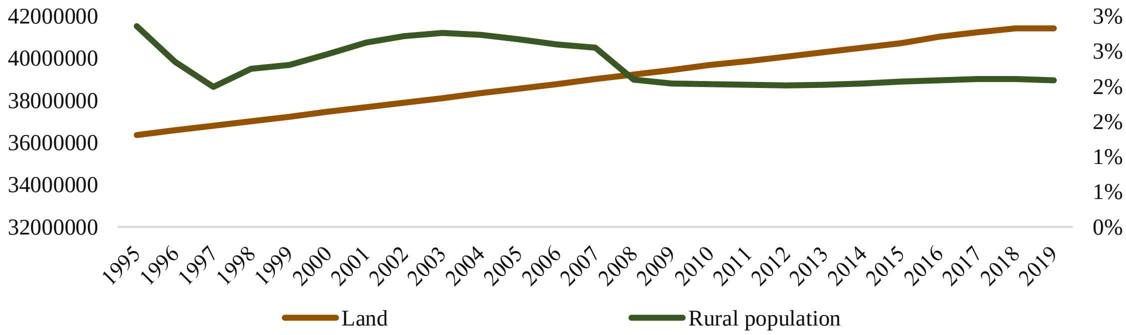


FIGURE 8 - Agricultural Land Use, in ha and Rural Population Growth Rate

Note: Right-hand scale for rural population growth rate.

Source: FAOSTAT (2022) and WB (2022).

From figure 8, one can see an upward trend for agricultural land use, with an average annual growth rate of 0.55%. This increase in land use is essentially the result of the need to increase production to feed the growing population, among other reasons, and is done fundamentally through deforestation, forest degradation, and burning, activities with negative effects on the environment (Chandamela, 2021; Ministry for the Coordination of Environmental Affairs, 2007).

The rural population growth rate presented a slowly downward trend, from a 2.9% rate in 1995 to a 2.0% rate in 2019. Overall, this growth rate is not so different from the country's general population growth rate, with an average difference of 0.5 percentage points (pp) in favour of the latter.

5. EMPIRICAL RESULTS

This section performs the descriptive and correlation analysis of the data, presents, and discusses the model results, and verifies if the model meets the assumptions of homoskedasticity, no serial correlation and normality of the residuals distribution and stability in order to be considered a valid model.

5.1.Descriptive Statistics and Correlation

Table I

DESCRIPTIVE STATISTICS

	AGREXPO	AGRGDP	CAPITALFO...	FERTILIZER	COMMDPRI...	LAND	MANURE	PESTICIDE	PRODPRICE	RCREDIT	RINVESTME...	RURALPOPL
Mean	434825.2	6420.846	0.253167	23915.37	82.28066	38983869	28429.91	483.5200	59.71800	51222519	1.18E+10	0.023011
Median	376245.0	6644.613	0.248016	19540.00	83.74787	39001102	28440.17	549.0000	57.63000	58947551	4.24E+09	0.021063
Maximum	1083325.	8127.703	0.442188	52356.00	109.4827	41413832	39534.19	1189.000	147.0500	1.04E+08	1.31E+11	0.028557
Minimum	73407.00	4435.887	0.113546	4151.000	61.41815	36355000	22115.21	29.00000	9.840000	3105400.	4.67E+08	0.019913
Std. Dev.	334878.7	1297.341	0.090114	14157.42	14.13030	1603816.	3417.578	347.9667	39.88987	27994362	2.58E+10	0.002953
Skewness	0.495194	-0.153110	0.236782	0.397623	0.163614	-0.025142	1.129458	-0.013009	0.769521	-0.549497	4.186886	0.545107
Kurtosis	1.879861	1.452293	2.163959	2.082720	1.874678	1.776868	5.845893	1.903520	2.583234	2.453922	19.87716	1.689853
Jarque-Bera	2.328730	2.592882	0.961695	1.535228	1.430653	1.561022	13.75188	1.253068	2.648277	1.568739	369.7487	3.026094
Probability	0.312121	0.273503	0.618259	0.464119	0.489032	0.458172	0.001032	0.534441	0.266032	0.456407	0.000000	0.220238
Sum	10870629	160521.1	6.329177	597884.2	2057.017	9.75E+08	710747.7	12088.00	1492.950	1.28E+09	2.95E+11	0.575284
Sum Sq. Dev.	2.69E+12	40394269	0.194894	4.81E+09	4791.970	6.17E+13	2.80E+08	2905940.	38188.84	1.88E+16	1.60E+22	0.000209
Observations	25	25	25	25	25	25	25	25	25	25	25	25

Source: Author's computation.

From Table I, one can see that the average agricultural GDP per capita in Mozambique is 6.4 thousand MZN, with the maximum and minimum of 8.1 and 4.4 thousand MZN, respectively and a standard deviation of 1.3 thousand MZN. The total average land dedicated to agriculture is 38.9 million ha, with a discrepancy between the maximum and minimum values of 5 million ha. The average manure use is of 28.4 thousand tons, having at some point of time achieved 39.5 thousand tons. The agricultural commodity prices index had a maximum of 109, a minimum of 61 and an average of 82.

The rural population growth rate and the agricultural gross fixed capital formation index have small standard deviations, 0.003 and 0.09 and a mean of 2.3% and 0.25, respectively.

The agricultural exports, the volume of credit, pesticide and fertilizer use, the agricultural investment and producer price index have high discrepancies between the maximum and minimum values, with the former four been justified by the gradual increase in the use of inorganic inputs, volume of credit and exports over the years. In the case of the investment and producer prices, the reasons are not so clear, hence further research on the cause of the extreme values should be done.

Regarding the normal distribution of the series, the variables *agrexpo*, *agrgdp*, *capitalform*, *commdprice*, *fertilizer*, *land*, *pesticide*, *prodprice*, *rcredit* and *ruralpopl* presented skewness values close to zero, suggesting a normal distribution. The Jarque-Bera test confirms this normality of the variables, since their *p-value* is above the 5% significance level, not rejecting the null hypothesis. These variables are also platykurtic (kurtosis values less than 3), which means that most values of the series are below the sample mean.

The variables *manure* and *rinvestment* have a positive skewness and the Jarque-Bera test *p-value* below the 5% significance level, meaning that the series do not have a normal distribution. The kurtosis values are greater than 3, being interpreted as leptokurtic curves with a long tail to the right and most sample values above the mean.

Table II

CORRELATION ANALYSIS

Correlation Probability	AGREXPO	AGRGDP	CAPITALFO...	FERTILIZER	COMMDPRI...	LAND	MANURE	PESTICIDE	PRODPRICE	RCREDIT	RINVESTME...	RURALPOPL
AGREXPO	1.000000 -----											
AGRGDP	0.923965 0.0000	1.000000 -----										
CAPITALFORM	-0.494873 0.0119	-0.263779 0.2026	1.000000 -----									
FERTILIZER	0.658536 0.0003	0.725419 0.0000	-0.197404 0.3442	1.000000 -----								
COMMDPRICE	0.675176 0.0002	0.807656 0.0000	-0.196761 0.3458	0.736947 0.0000	1.000000 -----							
LAND	0.941184 0.0000	0.974517 0.0000	-0.313877 0.1265	0.677965 0.0002	0.696957 0.0001	1.000000 -----						
MANURE	0.152403 0.4671	-0.026286 0.9007	-0.587682 0.0020	0.077612 0.7123	-0.151728 0.4691	0.081138 0.6998	1.000000 -----					
PESTICIDE	0.568753 0.0030	0.734587 0.0000	0.208071 0.3182	0.628278 0.0008	0.757136 0.0000	0.665093 0.0003	-0.368483 0.0699	1.000000 -----				
PRODPRICE	0.886037 0.0000	0.909496 0.0000	-0.350369 0.0860	0.570708 0.0029	0.599014 0.0016	0.945610 0.0000	0.139803 0.5051	0.513158 0.0087	1.000000 -----			
RCREDIT	0.508028 0.0095	0.611000 0.0012	-0.129453 0.5374	0.581588 0.0023	0.427999 0.0328	0.692942 0.0001	0.197071 0.3451	0.426892 0.0333	0.602540 0.0014	1.000000 -----		
RINVESTMENT	0.074484 0.7235	0.250679 0.2268	0.224042 0.2817	0.093277 0.6574	0.333819 0.1029	0.165306 0.4297	-0.259725 0.2099	0.391388 0.0530	0.087789 0.6765	0.157197 0.4530	1.000000 -----	
RURALPOPL	-0.623920 0.0009	-0.683687 0.0002	0.405905 0.0441	-0.565230 0.0032	-0.736714 0.0000	-0.591726 0.0018	-0.195012 0.3502	-0.419425 0.0369	-0.575853 0.0026	-0.256857 0.2152	-0.305270 0.1378	1.000000 -----

Source: Author's computation.

The correlation analysis on table II indicates that there is a very strong positive link (yellow cells) of agricultural GDP per capita with agricultural land (0.97), agricultural exports (0.92) and the producer price index (0.91). There is also a positive very high correlation between agricultural land use and the variables producer price index (0.95) and agricultural exports (0.94).

The agricultural GDP per capita has also a high positive correlation (blue cells) with the agricultural commodity price index (0.80) and with the use of chemical inputs, fertilizers, and pesticides, both with a coefficient value of 0.73. The agricultural commodity price index has a high positive correlation with the use of pesticides (0.76) and fertilizers (0.74) and a high negative correlation with the rural population growth rate

(-0.74). The producer price index is highly positively correlated with agricultural exports (0.89).

5.2.ARDL Model[14]

Table III

ARDL MODEL

Dependent Variable: DLNAGRGDP
Method: ARDL
Date: 10/05/22 Time: 18:39
Sample (adjusted): 1997 2019
Included observations: 23 after adjustments
Maximum dependent lags: 1 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (1 lag, automatic): DLNAGREXPO DLNCOMMDPRICE DLNPRODPRICE DLNINORGINPUT DLNFORGINVEST DLNINTERINVEST DLNRURALPOPL DLNLAND
Fixed regressors: C
Number of models evaluated: 256
Selected Model: ARDL(1, 0, 0, 1, 1, 1, 1, 1, 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
DLNAGRGDP(-1)	0.383364	0.155503	2.465310	0.0431
DLNAGREXPO	-0.027713	0.021911	-1.264775	0.2464
DLNCOMMDPRICE	-0.330440	0.124618	-2.651630	0.0329
DLNPRODPRICE	0.206551	0.078930	2.616890	0.0346
DLNPRODPRICE(-1)	0.151620	0.058046	2.612061	0.0348
DLNINORGINPUT	0.155672	0.047091	3.305798	0.0130
DLNINORGINPUT(-1)	0.303820	0.055485	5.475730	0.0009
DLNFORGINVEST	-0.050824	0.033341	-1.524401	0.1712
DLNFORGINVEST(-1)	-0.064535	0.032571	-1.981344	0.0880
DLNINTERINVEST	-0.133287	0.025516	-5.223626	0.0012
DLNINTERINVEST(-1)	0.196510	0.049075	4.004284	0.0052
DLNRURALPOPL	-0.077189	0.093083	-0.829253	0.4343
DLNRURALPOPL(-1)	-0.178471	0.077211	-2.311460	0.0541
DLNLAND	5.089689	6.307100	0.806978	0.4462
DLNLAND(-1)	-49.42126	12.56613	-3.932894	0.0057
C	0.219413	0.058262	3.765995	0.0070

R-squared	0.950019	Mean dependent var	0.024895
Adjusted R-squared	0.842917	S.D. dependent var	0.047149
S.E. of regression	0.018687	Akaike info criterion	-4.920252
Sum squared resid	0.002444	Schwarz criterion	-4.130343
Log likelihood	72.58289	Hannan-Quinn criter.	-4.721592
F-statistic	8.870226	Durbin-Watson stat	2.677325
Prob(F-statistic)	0.003602		

*Note: p-values and any subsequent tests do not account for model selection.

Source: Author's computation.

The ARDL model, table III, assesses the short-term relationships between the variables in analysis. The model was estimated with one lag for both independent and dependent variables, following the lag criteria based on Akaike information[15]. The estimated ARDL model is significant, F-statistic *p-value* (0.0036) below the 5% level of

[14] See equation 3, in annex, for the fitted model.

[15] See the results of the lag criteria on table XI in annex.

significance and the independent variables explain around 95% (R^2 value) of the dependent variable variance.

The results above illustrate that, *ceteris paribus*, agricultural exports (*dlnagrexpo*) are not significant in explaining the *proxy*, agricultural GDP per capita. Paiva's self-monitoring mechanism model suggested a positive relationship between both variables, since increased exports are considered a way to increase the predisposition of farmers to modernize the production process, which in turn leads to increased productivity and output. In Mozambique, improved inputs are used the most by cash crop producers, who produce for both domestic and export markets, and the share of these exports in total agricultural production is low, accounting for about 2%[16] according to FAOSTAT (2022) data, which contributes to the observed results.

Approved investment and gross fixed capital formation, given by the variable *dlnforginvest*, and agricultural production per capita have also a non-significative relationship, keeping other factors fixed. This result may be related to the low percentage of investment in agriculture in relation to the contribution of this sector to the country's GDP. Mosca & Dadá (2014), however, found in their study different results: investment in agriculture is significant and positively related to agricultural production.

The lagged coefficient of agricultural production per capita, *dlnagrgdp*, is positive, meaning that, *ceteris paribus*, current agricultural production depends on the previous year's agricultural production. This can be explained by the farmers' difficulty in accessing up-to-date market information, and therefore, basing their production decisions on last year's production.

The use of inorganic inputs, *dlninorginput*, has a positive impact on agricultural output per capita, keeping remaining factors fixed. This is consistent with the results of several studies, for example Alston (2007) in the United States and Hemming *et al* (2018) in low- and middle-income countries. Paiva's self-control mechanism theory also attests to these results, that technological change, in this case given by the use of chemical inputs, increases productivity and agricultural output. This result may also mean, to some extent,

[16] It is estimated that this share is higher, since a large portion of cross-border transactions are not controlled and documented by the responsible authorities.

that government incentives to use chemical inputs have been positively benefiting the agricultural sector. Nonetheless, Abbas (2015) found a different result: the use of fertilizer, one of the components of the *dlninorginput* variable, was not significant in explaining agricultural output.

Credit to agriculture, denoted by the *dlninterinvest* variable, has a negative impact on output per capita. However, in the first lagged period, credit to agriculture had a positive impact on current agricultural GDP per capita. The latter result is consistent with the results found by Neto (1996) for Brazil and Joy (2019) for India. Abbas (2015), however, found in her study that credit was not significant in explaining agricultural production in Mozambique, this being explained by the low access to this service by small and medium-sized producers, estimating that only 0.6% of producers had access to this service in 2020 (MADER, 2020).

The rural population growth rate, *dlnruralpopl*, has a coefficient below zero, meaning that there is a negative association, *ceteris paribus*, between this variable and agricultural production per capita. This is because the more the population increases in rural areas (by birth and migration) and given the fact that most people in these areas depend on agriculture-related activities, the number of people working in the fields increases and the output per person decreases.

An increase in the producer price index, *dlnprodprice*, has a positive impact on agricultural output per capita, as seen by the positive value of the parameter, holding other factors fixed. This result suggests that farmers are encouraged by positive price changes to produce more, as a way to obtain higher yields and, perhaps, higher profits. The study by Pernechele *et al* (2018) confirms these results for Mozambique and found similar results for other SSA countries. The study by Berthemly & Morisson (1989) *apud* Mosca (2011), however, contradicts these results, explaining that Tanzanian and Mozambican farmers reduce supply when prices rise, signifying a negative relationship between those variables.

The variable *dlncommdprice*, agricultural commodities price index, keeping the other variables constant, has a negative impact on agricultural output. This result is odd as, even if the added value of an increase in commodity price to the farmer is low, it should produce a positive impact on agricultural production.

Agricultural land (*dlnland*), *ceteris paribus*, negatively affects agricultural GDP per capita. This is a strange result, since it is widely known and accepted that one of the main ways to increase agricultural production in Mozambique, especially among smallholders, is by expanding the land devoted to this activity.

A remark from the model, is that the variable representing manure use, *dlnorginput*, was eliminated from the ARDL model, since it had high levels of multicollinearity, which created problems for model estimation and reduced the accuracy of the estimated coefficients.

5.3.Diagnosis Test Results

Table IV

HETEROSKEDASTICITY, SERIAL CORRELATION AND NORMALITY TESTS

Test	Values	Probability
Breusch-Godfrey Serial Correlation LM test		
F-statistic	0.693661	0.5462
Breusch-Pagan-Godfrey Heteroskedasticity test		
F-statistic	1.310207	0.3741
Jarque-Bera test		
F-statistic	4.516374	0.104540

Source: Author's computation.

Table IV presents a compilation of the results of the diagnostic tests of the residuals as to verify that the model is correctly specified and does not lead to misleading conclusions. The Breusch-Godfrey serial correlation LM test, the Breusch-Pagan-Godfrey heteroskedasticity test and the Jarque-Bera normality test display that the model has no autocorrelation problem, is homoscedastic and the residuals have a normal distribution, as their *p-value* (0.55), (0.37) and (0.10) are above the 5% level of significance, respectively, non-rejecting the null hypotheses.[17][18] The non existence of an

[17] The null hypothesis of each of these tests are, in order: 1) H0: No serial correlation, 2) H0: Homoscedasticity and 3) H0: The errors are normally distributed.

[18] Although normal distribution is here being tested, this is not a key assumption from the framework of linear regression models with time series data.

autocorrelation problem can also be read by the correlogram of residuals q-stastistics test, by the probability values above 5%.[19]

Table V

VARIANCE INFLATION FACTORS (VIF) MULTICOLLINEARITY TEST

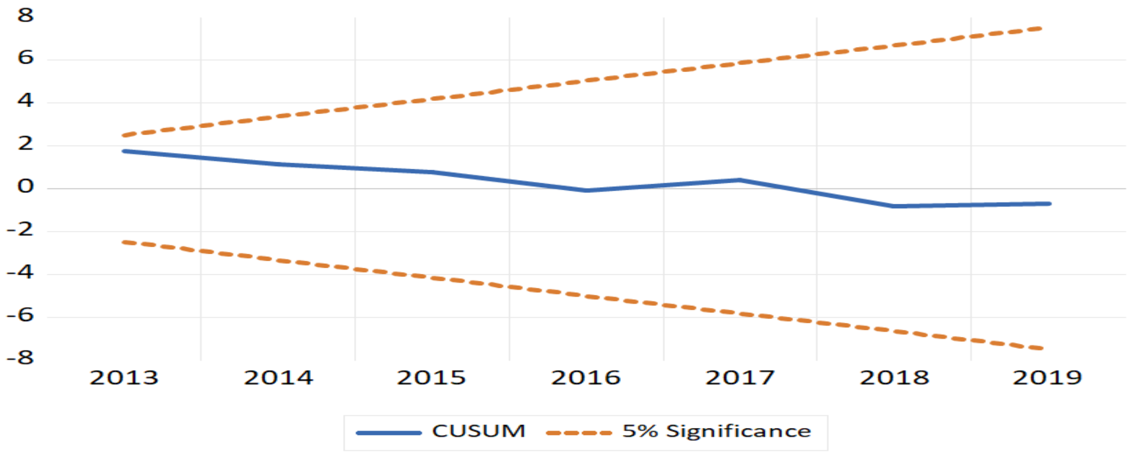
Variable	Coefficient Variance	Uncentered VIF	Centered VIF
DLNAGRGDP(-1)	0.024181	4.411698	3.307694
DLNAGREXPO	0.000480	2.956590	2.533226
DLNCOMMDPRICE	0.015530	4.854248	4.834582
DLNPRODPRICE	0.006230	8.944553	5.836238
DLNPRODPRICE(-1)	0.003369	7.222111	4.154142
DLNINORGINPUT	0.002218	5.029645	4.962787
DLNINORGINPUT(-1)	0.003079	6.921041	6.800848
DLNFORGINVEST	0.001112	5.621058	5.592862
DLNFORGINVEST(-1)	0.001061	5.420156	5.404799
DLNINTERINVEST	0.000651	2.101062	2.055725
DLNINTERINVEST(-1)	0.002408	7.784133	7.656542
DLNRURALPOPL	0.008664	2.312287	2.296880
DLNRURALPOPL(-1)	0.005962	2.250124	2.181354
DLNLAND	39.77951	80.80505	4.309894
DLNLAND(-1)	157.9076	337.0721	3.361116
C	0.003394	223.5690	NA

Source: Author's computation.

The table V displays the VIF multicollinearity test results. The table shows that none of the independent variables in the ARDL model present a value equal or above 10, which is an indication of a not so high correlation between the variables and non-existence of multicollinearity problems in the model.

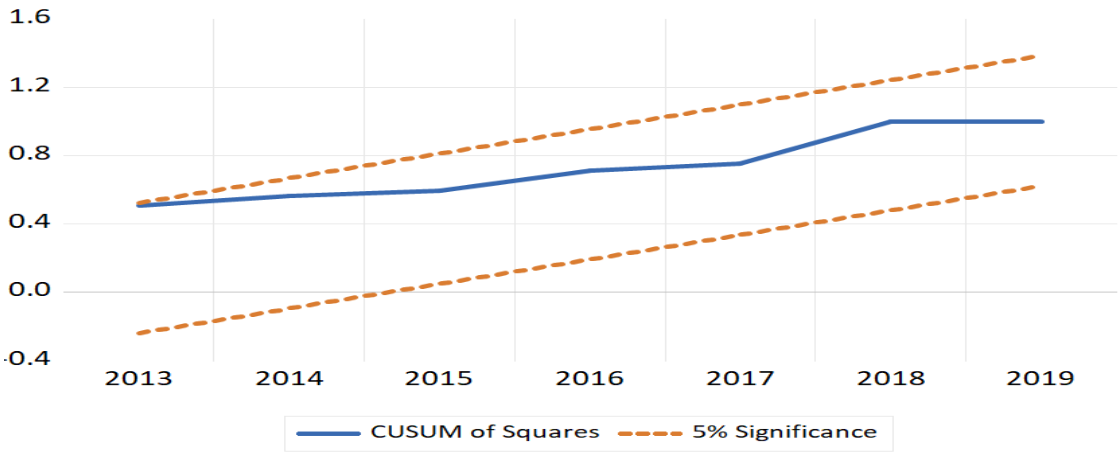
[19] See table 12 in annex.

FIGURE 9 - Stability Check CUSUM Test



Source: Author's computation.

FIGURE 10 - Stability check CUSUM of Squares Test



Source: Author's computation.

Both CUSUM and CUSUMQ tests, figures 9 and 10, respectively, show that the ARDL model is stable and credible in its form, at a 5% of significance. This can also be seen by the fact the blue line is inside the red lines.

6. CONCLUSIONS

Agriculture in Mozambique is one of the most important productive activities of the economy, as well as in most SSA countries, directly affecting the lives of millions of Mozambicans. Although agricultural production grows annually, this sector is still underdeveloped, and it is in reversing this characteristic that agricultural policies play an important role. During the last half century, agricultural policies applied in the SSA region, including Mozambique, have been guided by the ideals of the international financial institutions (World Bank and International Monetary Fund), by the current acceptable theoretical thinking, and by the needs of international markets, changing every decade the focus of these policies. However, despite these changes, the policy instruments have remained essentially the same.

The theoretical review has shown that agricultural policy instruments generally affect agricultural production in a positive manner, however the effects are not linear and certain, being these instruments susceptible to various factors that can affect their efficiency and effectiveness.

The descriptive and graphical analysis of the evolution of agricultural policy variables and agriculture output in Mozambique, allows us to draw the following observations: 1) although increasing, agricultural production per capita in rural areas is still very low compared to the food needs of the Mozambican population, 2) the agricultural policy instruments analysed show an increasing trend, except for manure use, rural population growth rate and agrarian gross fixed capital formation, and 3) agricultural production has a very strong positive correlation with agricultural exports, the producer price index and land devoted to agriculture and strong positive correlation with fertilizer use, pesticides use and the commodity price index. Points 2) and 3), *a priori*, would suggest a positive relationship between agricultural policy instrument variables and agricultural output.

Nonetheless, the results of the ARDL model, in the short-run, showed that not all variables were significant or had a positive relationship with agricultural production per capita: 1) inorganic input use (*inorginput*), producer price index (*prodprice*) and lagged values of agricultural credit (*interinvest*) and agricultural output itself (*agrgdp*) have a positive relationship with agricultural output per capita, 2) agricultural commodity price index (*commdprice*), land devoted to agriculture (*land*), rural population growth rate (*ruralpopl*) and credit to agriculture (*interinvest*) were negatively related to agricultural output and 3) agricultural exports (*agrexpo*), investment (*forginvest*) and gross fixed capital formation index (*forginvest*) were not significant in explaining agricultural output. Given these results, we do not reject the H0: Not all agricultural policy instruments positively impact agricultural output in Mozambique. Note that, of the variables that showed a positive correlation with agriculture, only agricultural exports and land devoted to agriculture were not significant and positive in explaining agricultural production, respectively.

These results reveal a low utilization of the potential of these agricultural policy instruments, partly as a result of the high dependence of these policies on external public and private actors and ideals, limiting their contribution on the production growth, rise of farmers' income, agricultural and economic development, eradication of poverty, inequality, malnutrition, food insecurity, among other issues.

The theoretical model, was used essentially to help explain the results of the econometric model, succeeded only in explaining the relationship of inorganic inputs with agricultural production, justified by the process of modernization of agriculture, not allowing to draw allusions about the relationship of agricultural exports and prices with agricultural production. The fact that the ARDL model is unidirectional does not allow testing whether Paiva's self-control mechanism holds in Mozambique or not.

A remark to make is that the econometric model was based on a small sample (25 observations), and also some of the regressors were generated using the PCA, so some cautious when reading the results is advised. This small sample size, covering the period 1995-2019, also did not allow exploring the possibility of long-run relationships between the variables under study, due to size distortions of the cointegration and bound tests, nor testing Paiva's self-control mechanism, nor allowing for certain important events for the Mozambican economy to be analysed (Dyrhmes & Thomakos, 1997; Nkoro & Uko 2016). Therefore, with the possibility of expanding the time horizon and the number of observations in the sample, these aspects could be an interesting subject for future research projects.

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ANNEXES

Table VI

PCA INPUTS USE

Principal Components Analysis
Date: 09/13/22 Time: 21:21
Sample: 1995 2019
Included observations: 25
Computed using: Ordinary correlations
Extracting 3 of 3 possible components

Eigenvalues: (Sum = 3, Average = 1)

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	1.696370	0.628819	0.5655	1.696370	0.5655
2	1.067552	0.831474	0.3559	2.763922	0.9213
3	0.236078	---	0.0787	3.000000	1.0000

Eigenvectors (loadings):

Variable	PC 1	PC 2	PC 3
FERTILIZER	0.616630	0.500965	-0.607291
MANURE	-0.313414	0.863853	0.394373
PESTICIDE	0.722177	-0.052849	0.689687

Ordinary correlations:

	FERTILIZER	MANURE	PESTICIDE
FERTILIZER	1.000000		
MANURE	0.077612	1.000000	
PESTICIDE	0.628278	-0.368483	1.000000

Source: Author's computation.

Table VII

PCA FUNDS

Principal Components Analysis
Date: 09/13/22 Time: 21:58
Sample: 1995 2019
Included observations: 25
Computed using: Ordinary correlations
Extracting 3 of 3 possible components

Eigenvalues: (Sum = 3, Average = 1)

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	1.296232	0.244161	0.4321	1.296232	0.4321
2	1.052072	0.400375	0.3507	2.348304	0.7828
3	0.651696	---	0.2172	3.000000	1.0000

Eigenvectors (loadings):

Variable	PC 1	PC 2	PC 3
CAPITALFORM	0.724604	-0.157165	0.671005
RCREDIT	-0.154315	0.911925	0.380235
RINVESTMENT	0.671667	0.379066	-0.636532

Ordinary correlations:

	CAPITALFORM	RCREDIT	RINVESTME...
CAPITALFORM	1.000000		
RCREDIT	-0.129453	1.000000	
RINVESTMENT	0.289838	0.071597	1.000000

Source: Author's computation.

Table VIII

ADF AND PP UNIT ROOT TESTS

UNIT ROOT TEST RESULTS TABLE (ADF)
Null Hypothesis: the variable has a unit root

	At Level										
		LNAGREX...	LNAGRGDP	LNCOMM...	LNFORG...	LNINORG...	LNINTERI...	LNLAND	LNORGIN...	LNPROD...	LNRURALPOPL
With Constant	t-Statistic	-0.6654	-5.6034	-1.0377	-0.8976	-5.3996	-2.2001	-4.2901	-3.4254	-2.1847	-1.6241
	Prob.	***0.8365***	***0.0003***	***0.7226***	***0.7704***	***0.0004***	***0.2113***	***0.0038***	***0.0200***	***0.2164***	***0.4547***
		n0	***	n0	n0	***	n0	***	**	n0	n0
With Constant & Trend	t-Statistic	-3.1197	-1.7982	-1.0680	-1.4660	-0.7241	-5.7289	0.1336	-3.7356	-3.5706	-3.2749
	Prob.	***0.1244***	***0.6738***	***0.9139***	***0.8117***	***0.9587***	***0.0009***	***0.9953***	***0.0392***	***0.0542***	***0.0977***
		n0	n0	n0	n0	n0	***	n0	**	*	*
Without Constant & Trend	t-Statistic	2.4232	2.6067	0.3745	-0.6762	0.6106	0.1358	1.0825	0.2636	2.8607	0.0832
	Prob.	***0.9945***	***0.9965***	***0.7845***	***0.4130***	***0.8410***	***0.7162***	***0.9210***	***0.7533***	***0.9981***	***0.6993***
		n0	n0	n0	n0	n0	n0	n0	n0	n0	n0
	At First Difference										
		d(LNAGR...	d(LNAGR...	d(LNCOM...	d(LNFOR...	d(LNINO...	d(LNINTE...	d(LNLAND)	d(LNORG...	d(LNPRO...	d(LNRURALPOPL)
With Constant	t-Statistic	-6.8477	-4.1620	-3.4333	-7.8953	-7.6581	-5.3831	-1.1606	-5.0957	-4.7688	-4.1854
	Prob.	***0.0000***	***0.0042***	***0.0202***	***0.0000***	***0.0000***	***0.0002***	***0.6699***	***0.0005***	***0.0010***	***0.0038***
		***	***	**	***	***	***	n0	***	***	***
With Constant & Trend	t-Statistic	-6.6814	-4.1669	-3.3559	-8.1560	-7.7332	-5.4122	-4.9318	-4.9723	-4.6961	-3.9973
	Prob.	***0.0001***	***0.0175***	***0.0824***	***0.0000***	***0.0000***	***0.0012***	***0.0047***	***0.0033***	***0.0055***	***0.0238***
		***	**	*	***	***	***	***	***	***	**
Without Constant & Trend	t-Statistic	-5.7347	-1.7137	-3.5119	-8.0149	-1.5654	-5.3762	-4.7657	-5.1701	-4.0433	-4.3252
	Prob.	***0.0000***	***0.0816***	***0.0012***	***0.0000***	***0.1079***	***0.0000***	***0.0001***	***0.0000***	***0.0003***	***0.0001***
		***	*	***	***	n0	***	***	***	***	***

Notes:
a: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1% and (no) Not Significant
b: Lag Length based on AIC
c: Probability based on MacKinnon (1996) one-sided p-values.

UNIT ROOT TEST RESULTS TABLE (PP)
Null Hypothesis: the variable has a unit root

	At Level										
		LNAGREX...	LNAGRGDP	LNCOMM...	LNFORG...	LNINORG...	LNINTERI...	LNLAND	LNORGIN...	LNPROD...	LNRURALPOPL
With Constant	t-Statistic	-0.2288	-1.3050	-1.1607	-2.2049	-1.4415	-2.2001	-2.4154	-3.3878	-2.1847	-2.2163
	Prob.	***0.9220***	***0.6101***	***0.6739***	***0.2097***	***0.5451***	***0.2113***	***0.1482***	***0.0218***	***0.2164***	***0.2060***
		n0	n0	n0	n0	n0	n0	n0	**	n0	n0
With Constant & Trend	t-Statistic	-3.1197	-1.8233	-1.4081	-2.6877	-1.5488	-2.5810	0.6509	-3.7233	-3.6167	-2.3138
	Prob.	***0.1244***	***0.6616***	***0.8321***	***0.2495***	***0.7829***	***0.2909***	***0.9991***	***0.0402***	***0.0496***	***0.4114***
		n0	n0	n0	n0	n0	n0	n0	**	**	n0
Without Constant & Trend	t-Statistic	4.5774	3.2606	0.3213	-0.6180	0.3939	0.2087	18.8080	0.2134	2.7095	0.7043
	Prob.	***1.0000***	***0.9993***	***0.7702***	***0.4390***	***0.7896***	***0.7381***	***0.9999***	***0.7395***	***0.9972***	***0.8607***
		n0	n0	n0	n0	n0	n0	n0	n0	n0	n0
	At First Difference										
		d(LNAGR...	d(LNAGR...	d(LNCOM...	d(LNFOR...	d(LNINO...	d(LNINTE...	d(LNLAND)	d(LNORG...	d(LNPRO...	d(LNRURALPOPL)
With Constant	t-Statistic	-8.2134	-4.7079	-3.4462	-7.8257	-7.6298	-5.3836	-0.7868	-11.1574	-4.8138	-4.2458
	Prob.	***0.0000***	***0.0011***	***0.0196***	***0.0000***	***0.0000***	***0.0002***	***0.8040***	***0.0000***	***0.0009***	***0.0033***
		***	***	**	***	***	***	n0	***	***	***
With Constant & Trend	t-Statistic	-8.2611	-4.8456	-3.3702	-8.1560	-7.7332	-5.4180	-1.3496	-12.0601	-4.7240	-4.0490
	Prob.	***0.0000***	***0.0040***	***0.0803***	***0.0000***	***0.0000***	***0.0012***	***0.8485***	***0.0000***	***0.0052***	***0.0214***
		***	***	*	***	***	***	n0	***	***	**
Without Constant & Trend	t-Statistic	-5.7347	-3.7409	-3.5227	-7.9319	-7.3886	-5.3762	-1.0559	-10.8959	-4.0420	-4.4120
	Prob.	***0.0000***	***0.0007***	***0.0012***	***0.0000***	***0.0000***	***0.0000***	***0.2539***	***0.0000***	***0.0003***	***0.0001***
		***	***	***	***	***	***	n0	***	***	***

Notes:
a: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1% and (no) Not Significant
b: Lag Length based on AIC
c: Probability based on MacKinnon (1996) one-sided p-values.

Source: Author's computation.

From the table X, the reader can see that, with a 5% probability, the variables *lnagrgdp, lninorginput, lnland and lnorginput* were stationary in level and the rest of the variables were only stationary at first differences. The PP unit root test show that in level, only the variable *lninorginput* is stationary at a 5% level of significance, and the rest of the variables only become stationary at the first differences.

Nonetheless, as stated at section 3.1, all variables were treated as nonstationary in level and stationary at first differences.

FIGURE 11 – Correlograms in Level

Correlogram at Level lnagrgdp

	AC	PAC	Q-Stat	Prob
1	0.883	0.883	21.928	0.000
2	0.759	-0.093	38.839	0.000
3	0.660	0.044	52.203	0.000
4	0.576	0.002	62.870	0.000
5	0.490	-0.056	70.987	0.000
6	0.337	-0.356	75.029	0.000
7	0.205	0.014	76.610	0.000
8	0.094	-0.072	76.962	0.000
9	-0.021	-0.147	76.981	0.000
10	-0.137	-0.110	77.821	0.000
11	-0.242	0.019	80.639	0.000
12	-0.322	-0.072	86.009	0.000

Correlogram at Level lnagrexpo

	AC	PAC	Q-Stat	Prob
1	0.880	0.880	21.766	0.000
2	0.775	0.004	39.384	0.000
3	0.694	0.052	54.170	0.000
4	0.584	-0.166	65.138	0.000
5	0.449	-0.188	71.935	0.000
6	0.323	-0.089	75.643	0.000
7	0.181	-0.183	76.873	0.000
8	0.063	0.011	77.033	0.000
9	-0.046	-0.064	77.123	0.000
10	-0.156	-0.074	78.214	0.000
11	-0.229	0.057	80.743	0.000
12	-0.265	0.071	84.392	0.000

Correlogram at Level lncommdprice

	AC	PAC	Q-Stat	Prob
1	0.914	0.914	23.485	0.000
2	0.789	-0.281	41.737	0.000
3	0.661	-0.036	55.136	0.000
4	0.508	-0.249	63.426	0.000
5	0.324	-0.249	66.971	0.000
6	0.131	-0.174	67.578	0.000
7	-0.068	-0.227	67.753	0.000
8	-0.211	0.241	69.526	0.000
9	-0.329	-0.104	74.083	0.000
10	-0.403	0.237	81.381	0.000
11	-0.446	-0.101	90.980	0.000
12	-0.459	-0.018	101.94	0.000

Correlogram at Level lnprodprice

	AC	PAC	Q-Stat	Prob
1	0.841	0.841	19.869	0.000
2	0.710	0.012	34.665	0.000
3	0.596	-0.013	45.567	0.000
4	0.474	-0.090	52.795	0.000
5	0.377	0.002	57.598	0.000
6	0.284	-0.050	60.457	0.000
7	0.198	-0.037	61.929	0.000
8	0.098	-0.121	62.313	0.000
9	0.017	-0.025	62.326	0.000
10	-0.052	-0.038	62.446	0.000
11	-0.131	-0.098	63.268	0.000
12	-0.206	-0.092	65.470	0.000

Correlogram in Level lninorginput

	AC	PAC	Q-Stat	Prob
1	0.820	0.820	18.916	0.000
2	0.770	0.298	36.318	0.000
3	0.632	-0.185	48.592	0.000
4	0.490	-0.239	56.306	0.000
5	0.324	-0.215	59.840	0.000
6	0.078	-0.464	60.058	0.000
7	-0.013	0.191	60.064	0.000
8	-0.176	0.098	61.290	0.000
9	-0.252	0.116	63.962	0.000
10	-0.381	-0.209	70.481	0.000
11	-0.397	0.025	78.082	0.000
12	-0.372	0.077	85.278	0.000

Correlogram in Level lnorginput

	AC	PAC	Q-Stat	Prob
1	0.293	0.293	2.4149	0.120
2	0.224	0.151	3.8837	0.143
3	0.168	0.076	4.7489	0.191
4	-0.044	-0.153	4.8114	0.307
5	-0.136	-0.150	5.4322	0.365
6	-0.058	0.032	5.5523	0.475
7	-0.060	0.034	5.6868	0.577
8	-0.096	-0.055	6.0506	0.642
9	-0.125	-0.129	6.7048	0.668
10	-0.100	-0.054	7.1553	0.711
11	-0.102	-0.012	7.6567	0.744
12	-0.051	0.032	7.7943	0.801

Correlogram in Level lninterinvest

	AC	PAC	Q-Stat	Prob
1	0.695	0.695	13.588	0.000
2	0.445	-0.073	19.406	0.000
3	0.195	-0.168	20.572	0.000
4	-0.013	-0.125	20.577	0.000
5	-0.114	0.009	21.014	0.001
6	0.022	0.347	21.031	0.002
7	0.195	0.197	22.458	0.002
8	0.236	-0.182	24.662	0.002
9	0.224	-0.132	26.770	0.002
10	0.025	-0.321	26.798	0.003
11	-0.099	0.203	27.273	0.004
12	-0.219	0.109	29.773	0.003

Correlogram in Level lnforgninvest

	AC	PAC	Q-Stat	Prob
1	0.527	0.527	7.7994	0.005
2	0.459	0.251	13.979	0.001
3	0.217	-0.142	15.425	0.001
4	0.139	-0.031	16.048	0.003
5	0.013	-0.060	16.054	0.007
6	-0.059	-0.075	16.177	0.013
7	-0.208	-0.186	17.797	0.013
8	-0.176	0.028	19.032	0.015
9	-0.416	-0.340	26.344	0.002
10	-0.264	0.101	29.491	0.001
11	-0.167	0.239	30.833	0.001
12	-0.159	-0.199	32.143	0.001

Correlogram in Level lnland

	AC	PAC	Q-Stat	Prob
1	0.886	0.886	22.096	0.000
2	0.765	-0.094	39.291	0.000
3	0.645	-0.067	52.042	0.000
4	0.526	-0.061	60.951	0.000
5	0.415	-0.047	66.761	0.000
6	0.307	-0.064	70.106	0.000
7	0.203	-0.063	71.652	0.000
8	0.104	-0.063	72.085	0.000
9	0.011	-0.063	72.090	0.000
10	-0.075	-0.063	72.343	0.000
11	-0.153	-0.059	73.474	0.000
12	-0.223	-0.058	76.053	0.000

Correlogram in Level lnruralpopl

	AC	PAC	Q-Stat	Prob
1	0.739	0.739	15.342	0.000
2	0.512	-0.074	23.034	0.000
3	0.399	0.104	27.906	0.000
4	0.218	-0.218	29.439	0.000
5	0.075	-0.024	29.629	0.000
6	-0.037	-0.113	29.677	0.000
7	-0.124	-0.022	30.253	0.000
8	-0.172	-0.037	31.428	0.000
9	-0.194	-0.011	33.013	0.000
10	-0.208	-0.050	34.967	0.000
11	-0.170	0.062	36.366	0.000
12	-0.191	-0.172	38.264	0.000

Source: Author´s computation.

FIGURE 12 - Correlograms at First Difference

Correlogram at First Difference lnagrgdp

	AC	PAC	Q-Stat	Prob
1	-0.024	-0.024	0.0162	0.899
2	-0.270	-0.271	2.0906	0.352
3	-0.070	-0.092	2.2353	0.525
4	0.169	0.097	3.1308	0.536
5	0.061	0.033	3.2516	0.661
6	-0.163	-0.106	4.1702	0.654
7	-0.095	-0.070	4.4982	0.721
8	-0.034	-0.127	4.5434	0.805
9	0.019	-0.066	4.5577	0.871
10	-0.035	-0.066	4.6123	0.916
11	-0.039	-0.045	4.6870	0.945
12	0.056	0.036	4.8529	0.963

Correlogram at First Difference lnagrexpo

	AC	PAC	Q-Stat	Prob
1	-0.357	-0.357	3.4559	0.063
2	-0.103	-0.264	3.7590	0.153
3	0.229	0.109	5.3222	0.150
4	-0.107	0.009	5.6771	0.225
5	-0.043	-0.030	5.7368	0.333
6	-0.082	-0.198	5.9724	0.426
7	0.038	-0.084	6.0244	0.537
8	0.074	0.066	6.2394	0.620
9	-0.084	0.025	6.5319	0.686
10	-0.056	-0.114	6.6696	0.756
11	-0.057	-0.249	6.8262	0.813
12	0.078	-0.064	7.1411	0.848

Correlogram at First Difference lncommdprice

	AC	PAC	Q-Stat	Prob
1	0.282	0.282	2.1629	0.141
2	0.006	-0.080	2.1641	0.339
3	0.043	0.070	2.2197	0.528
4	0.087	0.060	2.4560	0.653
5	0.002	-0.041	2.4562	0.783
6	0.004	0.023	2.4568	0.873
7	-0.327	-0.378	6.3904	0.495
8	-0.181	0.033	7.6621	0.467
9	-0.246	-0.298	10.182	0.336
10	-0.202	-0.048	12.001	0.285
11	-0.165	-0.096	13.310	0.274
12	-0.161	-0.161	14.662	0.260

Correlogram at First Difference lnprodprice

	AC	PAC	Q-Stat	Prob
1	0.073	0.073	0.1441	0.704
2	-0.146	-0.152	0.7501	0.687
3	-0.167	-0.148	1.5816	0.664
4	-0.063	-0.066	1.7059	0.790
5	0.029	-0.009	1.7341	0.885
6	-0.261	-0.323	4.1033	0.663
7	0.043	0.064	4.1713	0.760
8	0.064	-0.041	4.3302	0.826
9	0.176	0.110	5.6253	0.777
10	0.183	0.167	7.1151	0.715
11	0.011	0.081	7.1206	0.789
12	0.129	0.186	7.9814	0.787

Correlogram at First Difference lninorginput

	AC	PAC	Q-Stat	Prob
1	-0.472	-0.472	6.0418	0.014
2	0.262	0.050	7.9853	0.018
3	0.012	0.197	7.9895	0.046
4	0.096	0.213	8.2784	0.082
5	0.072	0.199	8.4463	0.133
6	-0.300	-0.377	11.574	0.072
7	0.205	-0.280	13.117	0.069
8	-0.262	-0.313	15.788	0.046
9	0.163	0.107	16.897	0.050
10	-0.283	0.106	20.458	0.025
11	-0.044	-0.166	20.552	0.038
12	0.124	-0.061	21.347	0.046

Correlogram at First Difference lnforgninvest

	AC	PAC	Q-Stat	Prob
1	-0.489	-0.489	6.4917	0.011
2	0.328	0.117	9.5444	0.008
3	-0.221	-0.029	10.992	0.012
4	0.038	-0.141	11.037	0.026
5	-0.111	-0.146	11.438	0.043
6	0.144	0.096	12.158	0.059
7	-0.274	-0.226	14.918	0.037
8	0.445	0.274	22.631	0.004
9	-0.447	-0.159	30.931	0.000
10	0.265	-0.148	34.070	0.000
11	-0.054	0.238	34.210	0.000
12	0.080	0.132	34.547	0.001

Correlogram at First Difference lnland

	AC	PAC	Q-Stat	Prob
1	0.189	0.189	0.9705	0.325
2	-0.014	-0.051	0.9758	0.614
3	-0.272	-0.270	3.1677	0.366
4	0.082	0.206	3.3785	0.497
5	0.070	0.009	3.5412	0.617
6	0.083	-0.019	3.7814	0.706
7	0.074	0.162	3.9821	0.782
8	0.055	0.014	4.1000	0.848
9	-0.008	-0.034	4.1029	0.905
10	-0.017	0.051	4.1163	0.942
11	-0.025	-0.043	4.1475	0.965
12	-0.033	-0.068	4.2055	0.979

Correlogram at First Difference lnruralpopl

	AC	PAC	Q-Stat	Prob
1	0.290	0.290	2.2817	0.131
2	-0.055	-0.151	2.3661	0.306
3	-0.018	0.049	2.3759	0.498
4	-0.178	-0.218	3.3624	0.499
5	-0.244	-0.135	5.3172	0.378
6	-0.242	-0.198	7.3515	0.290
7	-0.231	-0.178	9.3054	0.231
8	-0.154	-0.159	10.230	0.249
9	-0.045	-0.117	10.313	0.326
10	-0.142	-0.347	11.212	0.341
11	0.208	0.172	13.291	0.275
12	0.333	-0.027	19.059	0.087

Source: Author´s computation.

The figures 11 and 12 illustrate that the variables *lninterinvest* and *lnorginput* do not present trend in level and the rest of the variables have a trend in level, which is an indication of nonstationary data. At the first differences however, the trend is eliminated, suggesting that the variables become stationary.

Table IX

OLS SIMPLE MODEL

Dependent Variable: LNAGRGDP
Method: Least Squares
Date: 10/04/22 Time: 17:49
Sample: 1995 2019
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNCOMMDPRICE	-0.130702	0.248973	-0.524966	0.6060
LNFORGNINVEST	-0.182532	0.074508	-2.449837	0.0248
LNINORGINPUT	0.420885	0.106104	3.966701	0.0009
LNINTERINVEST	0.147856	0.071408	2.070587	0.0531
LNORGINPUT	-0.074012	0.095205	-0.777388	0.4470
LNRURALPOPL	-0.618574	0.242304	-2.552878	0.0200
C	6.527610	0.707230	9.229830	0.0000

R-squared	0.886745	Mean dependent var	8.746695
Adjusted R-squared	0.848993	S.D. dependent var	0.209830
S.E. of regression	0.081539	Akaike info criterion	-1.943970
Sum squared resid	0.119676	Schwarz criterion	-1.602685
Log likelihood	31.29963	Hannan-Quinn criter.	-1.849312
F-statistic	23.48882	Durbin-Watson stat	1.527040
Prob(F-statistic)	0.000000		

Source: Author´s computation.

Table X

OLS MODEL WITH TREND

Dependent Variable: LNAGRGDP
Method: Least Squares
Date: 10/04/22 Time: 18:15
Sample: 1995 2019
Included observations: 25

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNCOMMDPRICE	0.127480	0.087331	1.459739	0.1626
LNFORGNINVEST	0.065405	0.032894	1.988363	0.0631
LNINORGINPUT	0.077084	0.046344	1.663280	0.1146
LNINTERINVEST	-0.046114	0.029299	-1.573933	0.1339
LNORGINPUT	-0.006346	0.032834	-0.193272	0.8490
LNRURALPOPL	-0.153333	0.091245	-1.680456	0.1111
C	7.202161	0.246867	29.17427	0.0000
@TREND	0.023849	0.002022	11.79442	0.0000

R-squared	0.987667	Mean dependent var	8.746695
Adjusted R-squared	0.982588	S.D. dependent var	0.209830
S.E. of regression	0.027688	Akaike info criterion	-4.081307
Sum squared resid	0.013033	Schwarz criterion	-3.691267
Log likelihood	59.01634	Hannan-Quinn criter.	-3.973127
F-statistic	194.4822	Durbin-Watson stat	1.820587
Prob(F-statistic)	0.000000		

Table XI

LAG CRITERIA

VAR Lag Order Selection Criteria
Endogenous variables: DLNAGRGDP DLNAGREXPO DLNCOMMDPRICE DLNFORGINVEST DLNINORGINPUT DLNINTERINVEST DLNLAND DLNPRODPRICE DLNRURALPOPL
Exogenous variables: C
Date: 10/07/22 Time: 19:30
Sample: 1995 2019
Included observations: 23

Lag	LogL	LR	FPE	AIC	SC	HQ
0	270.9037	NA	1.04e-21	-22.77423	-22.32991*	-22.66249
1	369.1401	111.0498*	4.06e-22*	-24.27305*	-19.82981	-23.15559*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Author´s computation.

Equation 3.

THE FITTED ARDL MODEL

$$\mathrm{dlnagrgdp}_t = 0.02 + 0.34\mathrm{dlnagrgdp}_{t-1} - 0.33\mathrm{dlncommdprice}_t + 0.21\mathrm{dlnprodprice}_t + 0.15\mathrm{dlnprodprice}_{t-1} + 0.16\mathrm{dlninorginput}_t + 0.30\mathrm{dlninorginput}_{t-1} - 0.05\mathrm{dlnforginvest}_t - 0.06\mathrm{dlnforginvest}_{t-1} - 0.13\mathrm{dlninterinvest}_t + 0.20\mathrm{dlninterinvest}_{t-1} - 0.08\mathrm{dlnruralpopl}_t - 0.18\mathrm{dlnruralpopl}_{t-1} + 5.09\mathrm{dlnland}_t - 49.42\mathrm{dlnland}_{t-1} \quad (3)$$

Table XII

CORRELOGRAM OF RESIDUALS - Q-STATISTICS

Date: 11/24/22 Time: 15:15
Sample (adjusted): 1997 2019
Q-statistic probabilities adjusted for 1 dynamic regressor

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.342	-0.342	3.0654	0.080
		2	0.045	-0.082	3.1206	0.210
		3	-0.191	-0.231	4.1661	0.244
		4	-0.078	-0.269	4.3484	0.361
		5	0.002	-0.196	4.3485	0.500
		6	0.040	-0.140	4.4027	0.622
		7	-0.045	-0.231	4.4746	0.724
		8	0.149	-0.045	5.3254	0.722
		9	-0.001	0.005	5.3254	0.805
		10	0.076	0.096	5.5798	0.849
		11	-0.229	-0.153	8.0881	0.705
		12	0.057	-0.043	8.2603	0.764

*Probabilities may not be valid for this equation specification.