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Original Research Article

The Stake of Technological Innovation on Agricultural Economic Sustainability: An Empirical Analysis using the Bioeconomy Model

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Abstract

The study fills the void in the literature and make an in-depth analysis of the agricultural sector in the Mediterranean countries to identify their main factors that can improve the economic situation of the rural middle To better understand the impact of technological innovation on economic sustainability in rural areas. The reach of our study covered 21 Mediterranean countries during the 2008- 2019 periods. We employed two econometric methodologies (static panel data and random effects specifications on the one hand and Dual least squares on the other hand). Our empirical results show that technological innovation has a positive impact on economic sustainability.

Keywords: Bio economic model, technological innovation, economic sustainability, Mediterranean countries.
GEL Classification: C23, O1, O3, Q01.

INTRODUCTION

Environmentalists' debates on the current model of agricultural modernization are based on the technical basis itself. Also, there is another type of agriculture called "Organic Agriculture" which is based on a radically different technical base. Moreover, the agrarian crisis encountered in developed countries during a few years has improved the questioning of the model of agricultural modernization and traditional re-farming.

According to recent studies, Louhichi and al (2010), Blazy and al (2011) and Flichman and al (1997), have reached its optimal point without, of course, damaging environmental heritage. These authors would even confirm that to overcome ecological difficulty, efforts are directed toward rationality, while relying on more advanced scientific and technical knowledge.

Alternatively, the social problems engendered by agricultural modernization in developing countries, such as the serious growth of urban centers, unemployment, under the nutrition of large population quotas, are frequently identified as an essential scourge of economic development.

Despite the various theoretical anchorages, most studies attempt to show the technical tendency of agriculture in all its socio-economic, political, and institutional commitments. All these studies are based on thorough research on the truth on the ground and accompanied by a deterministic conception of technical progress.

According to the neoclassical authors, the most effective solution of market economies is the need to increase food production and plant fibers because the self-sufficiency of product regulation processes is guaranteed.

For classical Marxist authors, it is the capitalist productive forces and the modern capitalist farmer who possess the technical ideas of innovation. Other Marxist tendencies view these techniques as an input to capitalist production activities in agriculture.

According to the neoclassical and the Marxists, the current model of agricultural modernization is identical, the only divergence is that for the first school, this model of modernization is examined from all points of view (technical, ecological, socio-economic) That with the second, we work on the balancing of agricultural systems and social strata.

This study fills the void in the literature and make an in-depth analysis of the agricultural sector in the Mediterranean countries to identify their main factors that can improve the economic situation of the rural middle.

To better understand the impact of technological innovation on economic sustainability in rural areas, the reach of our study covered 21 Mediterranean countries during the 2008- 2019 periods. We employed two econometric methodologies. First, we use a static panel data analysis under fixed and random effects specifications and Dual least squares (2LS).

Our results show that when the technological innovation index increases, the economic durability decreases, this negative influence comes from the effect of external innovation and mechanization on agricultural productivity.

Second, we use the dynamic panel data analysis (GMM), we estimated our model using the GMM method in the system.

Our results show that increasing of technological innovation index leads the improving of the economic durability. This positive influence comes from the effect of mechanization (tractors and combine harvesters) and induced innovation (irrigation, biological use, arable production, use of chemical fertilizer and green manures) on agricultural productivity.

Declarations

Estimates of the two methods give us two results be due to bias results of the static panel method estimates.

The remainder of the paper is structured as follows. Section 2 provides a brief literature review of technological innovation trends and their role in improving the agricultural sector as well as the agricultural productivity. Section 3 presents the evolution of the agricultural sector in the Mediterranean countries and the role of technological innovation. Section 4 presents the data and the adopted econometric methodology as well as the empirical results. Finally, section 5 offers some conclusions and policy recommendations.

Agriculture and technical progress: a study on the dynamics of innovations

The neoclassical approach explains technical progress while relying on the dynamics of innovations and forecasting the future trend of technical progress in agriculture. Overall, this model has been practiced to support, at the level of economic theory, conservative modernization policies prepared for traditional agrarian oligarchy. Its central principle is that economic agents are sensitive to changes in prices influencing their costs of production, integrating innovations that spare factors that have become more expensive.

If the market prices explain the relative possibility of factors of production, and if there are no usual problems in the advanced capitalist economy, then the style of The technical extension that leads to market forces will be the most effective, whatever the type of technical solution that will lead to the optimal balance situation.

According to the neoclassical authors, the massive introduction in agricultural techniques, which advocates a reduction in the use of labor is considered a response to the rising costs of labor. They bear, however, that there have been imbalances in relative prices. They are the ones who look at the unusual rural exodus observed since.

On the one hand, it would be possible to subsidize equipment and products that reduce labor and, on the other hand, the cost of labor would be increased because of social protection measures (sickness, insurance, minimum wage, paid leave, etc.). These subsidies were given under pressure from the big landowners.

Research can affect the solution of the difficulties, which arise in series from the introduction of a new agricultural method. It is the case of modern agricultural methods, which increasingly rely on the possibility of applying ' any crop on one part and then banish by several technical means, the impact judged more favorable. Any sustainable innovation has emerged to illuminate, for example, that the deterioration of the physical structure of the soil caused by modern techniques does not influence the yields.

Agricultural modernization is the result either of the development of productive forces (technological determinism) or of capitalist relations of production (determinism of production relations).

The supremacy associated with mass production techniques based on fragmentation and the fragmentation of the labor problem is not called into question. For Marx, the path of the technological trends in agriculture is evident: capitalism upsets the technical principle and the regulation of working procedures in both industry and agriculture. The extension of productive forces from capitalist collaboration is contradicted to sustainable agriculture and self-employed crafts.

Following the emergence of modern chemistry, Lavoisier's analysis was based on the ancient theory of plant nutrition which is based on Aristotle's "alchemist" conceptions, called "humus theory".

However, the basis of this theory is stronger and it is considered events observed empirically by the exploitation of all time. This basis will give way to the pressure of a rigorous chemical design of plant nutrition resulting in the idea that chemical fertilizers alone can guarantee the fertility of the soil indefinitely.

Chemical fertilizers ensured the simplification of the cropping system by yielding livestock and alternations too restrictive, to make only the most productive crops. According to this chemical design, soil is simply a reservoir of mineral nutrients for plants. Nevertheless, this perception has been examined scientifically in favor of a less reductionist approach, assuming the soil as an organism difficult to understand, as the seat of innumerable chemical and biological reactions.

The concept of soil physical fertility is based not only on its granulometry composition, but also on internal biological activity. Consequently, the importance traditionally associated with topsoil has been scientifically known. The progress made so far, whether in the basic scientific branches or in the observation and measurement procedures, has confirmed this general view of the soil/climate / plant complex that emerged at the beginning of the century. Consequently, there has been a permanent opposition between the agricultural uses recommended by this scientific study, the relative differentiation of agricultural systems and the profits of the wealthiest farmers, who have developed a regional specialization for their interest.

At the application level, the soil will continue to be merely assumed as a deposit of mineral nutrients and a pool of water.

As part of the offer of technical innovation, ecological distortions caused by increased simplification of culture programs cause a systematic research effort to resolve the issues that impact yields. This dialectic between ecological defects and technical effort to mitigate their impacts on yields gives to a large extent particular chain of innovations.

At present, the new methods of genetic functioning make it possible to partially reduce the use of such chemical and mechanical means that have become too expensive and ineffective without modifying the approach followed by the (Intervening at the level of the effects rather than at the level of the causes of the problems). However, the great ability to play with the intensities of nature offered by biotechnology has given the remarkable waste that current agricultural uses are linked to the use of the force offered by the environment at the birth of favorable conditions to the production of food and plant fibers.

The abundance of harmful agriculture (conventional agriculture) is the concentration of population in environmentally friendly agriculture (sustainable agri-culture). This concentration will lead to an ecological change, which is the disappearance of the forest which is substituted by a herbaceous and root carpet, farmers will be obliged to have their subsistence in a more limited space and under agro-ecological problems.

More work is needed to get the same amount of product. Plow innovation and the fallow production system are considered a technical and economical solution to the new agro-ecological requirements.

The summer fallow production is the most economical method of unraveling and preparing the surface layer. Without fallow, the area can increase by a third, but at the cost of extensive weed removal continuously throughout the agricultural calendar and a decline in yields. The total production would have been equal to that with the fallow system that therefore, requires less labor.

The appearance of the plow causes a distortion, with the use of a far-fetched system such as the plowing implement, the coupling system and the traction force used to this day.

A new production technique such as the plow, the new coupling system and the horse make it possible to switch to the triennial rotation system by integrating spring operations between winter cereal and fallow. This crop improves the availability of livestock raising (capital) provided that it allows feed more horses.

In this techno-economic context, medieval institutional constraints are organized as detailed regulations on the parceling and distribution of the parties. These "super structural" medieval institutional innovations respond to the modification of the material origin insofar as their legal and ethical foundations finally succeed in placing these transformations in the infrastructure.

Economic development, in particular, the commercial and urban development brought about by this increase in productive forces, will gradually decompose the feudal socio-institutional fabric.

In terms of production conditions, the spread of this new mode of production has begun since the Middle Ages, thanks to the progress of what Mazoyer (1977) calls "harnessed culture", which implies the generalization of the horse as the sole driving force The extension of means of transport and hence efficient craftsmanship in cities.

New techniques are more productive but require strong investments with a relatively long maturation period.

To meet the needs of consumers, these large nutrient requirements, instead of encouraging farmers to resort to new methods have, in contrast, deteriorated the agro-ecological base of the old cropping system, causing the black plague regression of the entire socio-economic system that had developed up to the hour. The black plague, which brings repercussions of this pressure on the natural heritages, thus closes the first crisis of the feudal system.

Among the problems which are linked to the generalization of these new techniques are the potentials with the logic of the search for the greatest profit, which will be responsible for their modification. The aim is to apply the most profitable crops that maximize the gains of the best-placed farms with dependence on the less developed farms, the long-term ecological reproduction of the agricultural ecosystem.

The specialization is a method that allows large farmers in good land areas to the opportunity to take advantage of high differential rents, this differential rent is due to unequal soil quality. Monoculture reinforces this inequality, while the more differentiated modes of production decrease it, as well as the differential rent due to the extent of exploitation.

The maximization of the best placed producers is also achieved through the long-term reproduction of the agricultural ecosystem. As ultra-simplified production methods degrade the soil, producers are forced to apply cereal crops that participate in the natural physical fertility of the soil. The generations of peasants have protected and reinforced this method of exploitation. The rate of erosion in the most affected regions has decreased with the application of chemical fertilizers and mechanical means of soil restructuring, which finally lead to mitigating the impacts of the deterioration of the soil on yields.

A living example is that the integration of modern Western techniques in the form of associated machinery and equipment has failed, while agricultural science has been absorbed and developed with methods adapted to local socio-economic and ecological specificity. The agricultural sector plays a major role in absorbing the population surpluses that cannot find jobs in the urban-industrial sector. It is perfectly possible to examine a practice that is both ecologically balanced, economically viable and socially desirable. In agriculture, there is no contradiction between ecological balance and economic efficiency, at a time when this contradiction has emerged since the industrial revolution, due to well-defined socio-economic and institutional factors are capable of being changed.

In addition, the employment problems in agriculture are related to the ecological problem. Indeed, the biggest obstacle and the highest overall yields of an ecologically balanced farming method allow the efficient use of a large amount of labor, without this method leading to painful manual work, labor productivity is too low and therefore wages are too low to reach an acceptable level of vice.

The agriculture evolution in the Mediterranean countries

The Mediterranean basin is a region united by a multicultural history and characterized by a traditional concern, concerning the management of common resources.

Political problems, urbanization, emigration, the destruction of natural resources and socio-economic inequalities are causing considerable concern in the world.

Sustainable agriculture plays an important role and is a necessary part of political discourse and development assistance programs at the national and international levels.

Sustainable agriculture has developed partially in the Mediterranean basin. However, this new agriculture fails to make a significant contribution to balancing the agri-food trade balances, which are deficient in several Mediterranean countries. Sustainable agriculture does not contribute significantly to the protection and sustainable development of rural areas.

It exists an obvious north-south division in the Mediterranean basin, with an economically and aging Mediterranean northern edge of the Mediterranean, mainly comprising the EU Member States and Southeast edge with the younger and poorer ones, including Arab States. There exists considerable economic disparity between the Mediterranean countries (GDP, per person $ 20,800) and North Africa (average GDP per person $ 2,100), and a considerable migratory flow from the poorer south to the richer north.

The urban and industrialized society that characterizes the northern shore of the Mediterranean, with a high average income level, low population growth, increasing and intensive agricultural production and a declining rural population, widespread urban concentration and increased tourism in rural areas. Alternatively, countries on the south-east Mediterranean coast have a low average income level and a high rate of population growth, compared to a high population density in rural areas. Much of the population depends on natural resources to survive, including some pastoral activities deemed vital for rural inhabitants. It exists a dominance of ownership of the state of forest resources, and a model of rapid degradation of natural resources due to destructive interventions. Urban expansion increased rapidly, so the pressure of tourism quickly distinguished itself, especially in coastal areas.

The main socio-economic figures describing the Mediterranean basin are:

- These countries account for 7% of the world's population (approximately 450 million inhabitants).

In the southeastern shore of the Mediterranean, the population has doubled in the past 30 years, reaching 234 million, and hoping for an additional 70 to 120 million in 2030.

-There is 32% of international tourism, with an increase in four times between 1970 and 2000.

-There is 13% of GDP with a decreasing trend.

-There is 5.7% Earth mass of the planet, including many desertsand mountain regions,

-There are 8% CO_2 emissions,

-Every year, 30% circulation of international maritime transport,

-20 to 25% of oil passes from maritime transport in the Mediterranean basin.

It shows the importance of the sustainability of the use of goods and services in the Mediterranean.

The development model is largely dependent on environmental resources, especially for tourism, but it also drives a considerable economic migratory flow from the southern to the northern Mediterranean because of the European basic tourism companies.

The Mediterranean basin has experienced accelerated globalization during the last decades.

International cooperation policies and economic reforms have been focused on essentially reducing state participation, trade liberalization without, however, the distribution of impacts on sustainable development and cancelation of premiums and privatization.

This globalization has brought conflicts. Politically, in the northern Mediterranean, the European Union (EU) has brought peace, democratic and economic reforms, a consolidated community, free movement of people, a social market economy and economic and environmental convergence. However, this model of regional integration has no equivalent in the southern and eastern Mediterranean. Therefore, despite restrictive EU migration policies (imposing strict visa requirements for non-EU citizens), migration flows remain considerable.

Several initiatives have been developed to bring about convergence and cooperation in the region. Perhaps the most important is the Euro-Mediterranean Association (1995), which established a common region of "stability and shared prosperity". However, the Euro-Mediterranean cooperation, which has been integrated into the new policy in the European neighborhood since 2003, still lacks resources, mutual commitment and motivation.

Economically, the Mediterranean basin is a declining region, particularly in the southern Mediterranean shore, where, for example, the relative share of international financing has fallen sharply (10% in the 1990s compared to 17% in the 1970s).

For terrestrial ecosystems, evergreen agricultural land and woodlands dominate the region today, and the marine and coastal resources of the region are vast and the sea has an enormous influence on the socio-economic development of the region. Therefore, a sound understanding of the social and economic context for the Mediterranean basin is essential to designing a well-targeted ecosystem profile.

Data and econometric methodology

To build our bio-economic model in the economic aspect, this study is an inspiration from the work of Bachta and Chebil (2002) and Semih and al (2009).
The equation takes the following form:

$$Ln(y)_{it}=\beta_0+\beta_1 Ln(TF)_{it}+\beta_2 Ln(SEF)_{it}+\beta_3 Ln(EF)_{it}+\gamma u_{it}+\varepsilon_{it} \quad (1)$$

i = 1, ..., n (number of countries, n = 21); t = 1,…….., Ti; ε_{it} is the error term.
Where y_{it} refers to the indicator of agricultural productivity of countries i, TF_{it}: Technology factors are composed of the general innovation index (I), external innovation (I1), induced innovation (I2) and mechanical innovation (I3), Internet use (IU).
βk, γp, are production elasticity's.
SEF: socio-economic factors are composed of life expectancy (LE), education rate (ER), the rural population (APOP), labor force in the agricultural sector (L), the mortality rate (MR).
EF: environmental factors are composed of cropland (CW) and access to water (AW). U: control variable, official development assistance (ODA).
The model we have estimated is

$$Ln\ (AP)_{it}=\beta 1+\beta 2 ln\ (I)_{it}+\beta 3 ln\ (I1)_{it}+\beta 4 ln\ (I\ 2)_{it}+\beta 5 \ln(LE)_{it}+\beta 6 \ln(ER)_{it}+\beta 7 \ln(APOP)_{it}+\beta_8 \ln(L)_{it}+\beta_9 \ln(MR)_{it}+\beta_{10} \ln(CW)_{it}+\beta_{11} \ln(AW)_{it}+\beta_{12} \ln(UI)_{it}+\gamma \ln(ODA)_{it}+\varepsilon_{it} \quad (2)$$

After estimating the impact of technological innovation on economic sustainability, we assessed the impact of each type of innovation on agricultural productivity, and we have decomposed the index of technological innovation under the form of three indicators innovation such as external innovation (I1), induces innovation (I2) and mechanization(I3).

The variables

**Technological innovations (I1, I2 and I3)*

The concept of "innovation" has been developed for a long time by the neoclassical approach, such as Adam Smith, David Ricardo, Marx and improved by the Austrian school of which Joseph Schumpeter. Technological innovation is defined as the set of innovations that induce a transformation or an upheaval of the means of production, work organization, products, markets and structures of the economy.

Schumpeter distinguished five types of innovation, such as product innovation (production of a new product, the innovation of the process (a new production method), the discovery of a new source of raw materials or energy, innovation and new types of organizations.

For the neoclassical school, technological innovation or technical progress is a factor, which makes it possible to improve production with quantities of capital and labor unchanged. It is an unexplained residue like a manna falling from heaven. For J. Schumpeter, technological innovation is the engine of economic development.

In this study, we focus on three types of innovations, such as product innovation or induced innovation (organic fertilizer and irrigation), process innovation or mechanization (tractor and combine harvester) and we have added another type of innovation based on R&D called external innovation.

The external innovation (I1) is defined as the composite index of technology innovation that includes spending on R&D, patent received from abroad (PFA) and the mark received from abroad (MFA). Clark and Youngblood (1992) have shown that the "technology" variable, such as R&D spending changes the flexible utility form over time and fits into the specification of the function. This variable I1 solves the time trend problem. R&D is the key to the development and modernization of the agricultural sector. Empirically, we have defined external innovation (I1) by equation (3).

-I1: the R&D expenditure, patent and mark applications received from abroad, measure the external innovation indicator (I1), this indicator is calculated as follows:

$$I1_t = \sum_{k=1}^{L} b_k.(R\&D + PFA + MFA)_{t-k} \quad (3)$$

b_k is the delayed effect (lag) of the R&D expenditure and patent and mark received from abroad in a given year on external innovation, k years later.

-**Induced innovation (I2)** is defined as the synthetic indicator of technological innovation which groups together agricultural practices (irrigation, biological use).

Van Rijn and al (2012) construct an index of agricultural innovation based on various innovations available in the fields of agricultural management and production and post-harvest innovations that improve the fertilization process.

Most potential technological innovations in agricultural land in the Mediterranean region include various methods to improve land management, water resources and prevent post-harvest losses.

Even in developed countries, meaningful research on agricultural systems is devoted to testing and refining farmers' innovations and adapting exotic farming varieties and animal species.

Empirically, equation (4) defines the induced innovation (I2).

I2: induced innovation indicator that encompasses biological area (BA) and irrigated area (IA).

$$I2_t = \sum_{k=1}^{L} a_k.(BA + IA)_{t-k} \quad (4)$$

a_k is the delayed effect (lag) of the biological surface and the irrigated area at a given year on the induced innovation k years later.

- **Mechanization (I3)** is defined as the synthetic indicator of technological innovation, which includes the number of agricultural machinery such as tractors and combine harvesters, excluding used backyard tractors in agriculture at the end of the Or the first quarter of the following year.

Empirically, we have defined mechanization (I3) by the equation (5).

I3: mechanical innovation indicators that include tractors (T) and combines harvesters (H).

$$I3_t = \sum_{k=1}^{L} c_k.M_{t-k} \quad (5)$$

c_k is the delayed effect (lag) of mechanization in a given year on mechanical innovation, k years later.

I is the general innovation factor that encompasses I1, I2 and I3.

$$I_t = \sum_{k=1}^{L} d_k.(I1 + I2 + I3)_{t-k} \quad (6)$$

d_k is the delayed effect (lag) of I1, I2, I3 in a given year on innovation, k years later.

-Subscription to fixed broadband internet (per 1000 people) (IC): subscribers to fixed broadband Internet are the number of subscribers with access to broadband Internet with a digital line, cable modem or technology High Speed. Table 1

Agriculture includes the Divisions 1 to 5 of the ISIC and includes forestry, hunting, fishing as well as the cultures and animal production. To measure the impact of technological innovation on the economic aspect of agriculture, we have chosen to test the effect of technological innovation on the productivity of the agricultural sector.

According to the World Bank (2013), this measure is defined as the value added per worker (% of GDP) in other words it is the added value of the net production of a sector after added all outgoing and entertain all incoming intermediaries. It is calculated without consequence on the decrease of the goods manufactured or the deterioration of natural resources. Alani (2012) confirms that productivity is considered a technological progress that allows improving growth and development.

Determinants such as R&D, training in rural areas, the quality of resources, infrastructure and institutions measure agricultural productivity.

****Socio-economic factors***

The protection of natural resources and the development of sustainable agriculture are part of regional development. To measure the level of sustainability in the sector, socio-economic determinants such as enrollment rate, life expectancy at birth, infant mortality rate, official development assistance, labor Agriculture and

Table 1. Descriptive statistics of technological innovation (I1, I2 and I3)

Innovation index	Variable	Mean	Std.Dev.	Min	Max
I1	ERD	.0244417	1.568446	-.7909872	2.937503
	PFA	.6808216	1.765136	-2.787185	4.046554
	MFA	2.498519	.7442968	1.564418	4.048266
I2	IA	1.001187	2.232082	-.5060589	3.945972
	BA	4.661331	1.554162	2.794339	6.957685
I3	T	3.613566	1.358313	3.332886	6.43238
	H	.6396261	.9904072	-.9423581	2.747116

**agricultural productivity (AP)*

agricultural population. These variables are related to human capital, human development and the role of public investment in improving these factors.

The primary school enrollment variable (ER) corresponds to the total primary school enrollment, irrespective of age, expressed as a percentage of the total population of the primary school age group. This variable is considered as the state's investment in improving human capital. The level of primary education is unevenly developed between rural and urban areas and between women and men.

Human capital, such as improving the enrollment rate in rural areas, is an essential factor in the development of innovation in the agricultural sector through the enhancement of labor productivity.

The theoretical analysis of Barro (1991) and the empirical analyses of Denison (1962), Kendrick (1976), Jorgenson and Griliches (1967) confirms that the correlation between human capital and education and productivity is positive. Human capital generates technical efficiency by improving the quality of work in rural areas.

The total life expectancy at birth variable (LE) determines the number of years a newborn should live if the general rules of mortality at the time of birth remain the same throughout life. Life expectancy is important dimension of human development.

The level of human development is improved by reducing poverty, hunger and child mortality and improving health. In the same context, the infant mortality rate (MR) measures the level of malnutrition. These social problems have higher rates in rural than in urbanareas.

The variable of official assistance for net development (ODA) reveals disbursements of loans granted at concessional rates (excluding the return of capital) and subsidies from member agencies of the Development Assistance Committee (DAC), multilateral organizations and countries Non-DAC members to stimulate economic development and welfare in the countries and territories on the DAC list of ODA beneficiaries. ODA estimates loans with a grant element of at least 25% (calculated at a discount rate of 10%) . The ODA variable stimulates agricultural production, although the share of ODA devoted to rural areas is lower than that of urban areas. ODA builds infrastructure in rural areas, educating rural people, improving the health of the rural population (the fight against AIDS), protecting the environment (against pollution), Food security (combating terrorism and trafficking in hazardous materials). The flow of ODA is shifted from developed to developing or least developed countries.

The Labor Force Variable in Agriculture (L) is defined as all persons working for an employer in the agricultural sector who receive wages, salary, commission, piecework or compensation (WDI, 2013). This variable is essential for improving agricultural production. It is divided into two categories: recruited labor and family labor and, in another sense, skilled labor and unskilled labor. agricultural labor can achieve environmental sustainability through the abstraction of grass and tearing. This method is more advantageous than mechanization, since the latter consumes energy intensively and releases CO2 into the soil. Alternatively, the unskilled labor force increases the ecological footprint, which prevents the achievement of sustainability in the agricultural sector.

In the same sense, the agricultural population (APOP) does not live exclusively in rural areas, the urban environment is home to agricultural producers. The agricultural population is close to the rural population in its meaning, these are quasi-equivalent terms. FAO defines the agricultural population as "all people living on agriculture, hunting, fishing, or forestry. It is not necessarily a population derived exclusively from the rural population ". FAO is defined agricultural labor force as part of the labor force that has work or research in agriculture, hunting, fishing or forestry.

**Environmental factors*

To analyze the environmental sustainability of the agricultural sector in the countries of the Mediterranean basin, we choose two environmental variables such as access to water and cultivated area. These two variables are essential for improving the agricultural sector, but the misuse of these resources leads to scarcity.

Water access (AW) is the annual freshwater withdrawal that determines the total freshwater withdrawal, without considering the ruins of vaporization of the accumulation basins. The withdrawals also contain water from desalination plants in countries where they are a remarkable water point. The total setbacks are greater than 100% of the natural renewable heritages, while grubbing from nonrenewable aquifers is important when the reuse of water is considerable. Downturns for agriculture and industry are total declines for irrigation and livestock production as well as for direct industrial use (including withdrawals to cool thermoelectric power plants). Withdrawals for domestic use contain drinking water, household use or subsistence, and water absorption by utilities, business organizations and households. The irrigation system, the gout taste, arable farming are methods for exploiting water.

In the same context, the World Bank defines areas permanently cultivated (CW) as "land occupied by crops for long periods and which can be re-harvested after each collection, such as land for cocoa, coffee and rubber. This category includes land on which flowering shrubs, fruit trees, walnut trees and vines grow, but excludes land on which wood or wood trees grow ".

Caswell and Zilberman (1986) developed one of the first models for examining the adoption of irrigation techniques, considering the quality of the land and the quantity of water, their analysis assumes that the production of a single crop is based on a constant technology-scale performance. The sustainability of agriculture begins with the use of the sustainable irrigation system, which ensures good management of water and soil.

ECONOMETRIC METHODOLOGY, RESULTS AND INTERPRETATION

*The results of the bioeconomic model estimation by the static panel data method

Estimating the impact of technological innovation (general innovation (Model I), external innovation (Model II), induced innovation (Model III) and mechanization (Model IV)) on agricultural productivity using the static panel data method (FE: fixed effect, RE: random effect, 2SLS: two-Stage least squares) is summarized on the table 2 below.

The coefficients of technological innovation (I) and external innovation (I1) are negative and significant at the threshold of 1% and 10% in the two models 2SLS I and 2SLS II, while the coefficients of induced innovation And mechanization are not significant and have two signs, respectively, positive and negative.

The result of the estimate shows that technological innovation has a negative effect on economic sustainability through its impact on agricultural productivity. These results are similar to Doole's study (2012).

The use of intensive technologies such as mechanization for years reduces production and productivity over time, especially by tenants who are no longer motivated to use sustainable agricultural practices to natural resources.

In the exploitation of land, farmers do not consider the causes and consequences found by researchers and engineers. The practice remains very far from theoretical.

In the same context, coefficients of life expectancy at birth are negative and significant at the threshold of 1% and 10% in all models, except in the RE III model, the coefficient is non-significant and negative.

This variable has a strong negative impact on agricultural productivity because of the low income of the agricultural labor force and even the agricultural population and the low purchasing power, which causes a low standard of living in these regions in the medium term.

Similarly, the mortality rate (MR) has non-significant coefficients in all models, except in the 2SLS IV model, the coefficient is negative and significant at the 1% threshold. This negative result explains why the agricultural sector is difficult to meet the needs of households when farmers use mechanization as production technology. The use of other farming techniques such as sustainable farming practices cannot feed the entire population because of low yields.

Official development assistance (ODA) has a single positive and significant coefficient at the 1% threshold in the 2SLS IV model. In all other models, the coefficients are not significant. ODA has positive impacts on productivity by improving the quality of the labor force through the development of training organization in the agricultural sector.

Similarly, education (ER) has positive and significant coefficients at the threshold of 1% and 5% in all models, except in the 2SLS IV model, the coefficient is negative.

Official development assistance in rural areas builds rural schools that increase the enrollment rate at the primary level.

Coefficients of access to water are not significant in all models can be due to irrelevant data.

For land that is permanently exploited, its coefficients are significant only in the two models 2SLS I and 2SLS IV. In the first model (2SLS I), the coefficient of land is significant and positive at the 10% threshold, in this model we measured the negative relationship of the general innovation index and agricultural productivity.

In the second model (2SLS IV), the coefficient of land is negative and significant at the 1% threshold, in this

Table 2. Estimation of Bio-economic model by the static Panel method

EQUATION		**(I)**			**(II)**			**(III)**			**(IV)**	
Dependent Variable AP	FE	RE	2SLS	FE	RE	2SLS	FE	RE	2SLS	FE	RE	2SLS
Ln(I)	-.0332637 (0.832)	-.0843415 (0.210)	*-.444722 (0.061)**									
Ln(I1)				-.0686791 (0.120)	-.1406051 (0.000)***	*-.1328319 (0.000)****						
Ln(I2)							-.004969 (0.912)	.0118477 (0.651)	*.0118225 (0.653)*			
Ln(I3)										.1655293 (0.399)	-.0221145 (0.751)	*-.0863373 (0.148)*
Ln(ODA)	-.0226663 (0.318)	.0039707 (0.863)	-.0319692 (0.128)	-.0282142 (0.181)	-.0146567 (0.488)	-.0174659 (0.403)	-.0221684 (0.326)	.0255574 (0.281)	.0201313 (0.390)	-.0187044 (0.408)	.0080053 (0.728)	.224883 (0.000)***
Ln(LE)	-5.028448 (0.005)***	-2.998342 (0.043)**	-4.742268 (0.002)***	-5.859693 (0.000)***	-4.41608 (0.001)***	-4.559902 (0.001)***	-5.119194 (0.003)***	-2.248989 (0.134)	-2.468776 (0.1)*	-5.299779 (0.002)***	-3.009566 (0.045)**	5.174523 (0.003)***
Ln(DR)	1.351678 (0.002)***	1.122256 (0.012)**	1.027432 (0.008)***	1.000998 (0.012)**	.8942763 (0.024)**	.9108482 (0.020)**	1.345217 (0.002)***	1.002963 (0.034)**	1.040351 (0.025)**	1.3711 (0.002)***	1.106319 (0.013)**	-1.373049 (0.070)*
Ln(CW)	.0928006 (0.434)	-.0214311 (0.758)	.1528451 (0.095)*	.0964423 (0.317)	.0862336 (0.183)	.0912827 (0.169)	.0897114 (0.448)	-.0661053 (0.338)	-.0626863 (0.377)	.0892744 (0.436)	-.0376646 (0.588)	-.1088402 (0.003)***
Ln(RM)	.5815743 (0.285)	-.04272 (0.865)	.2075173 (0.629)	-.0932914 (0.831)	-.1243029 (0.571)	-.1008831 (0.664)	.554512	.0344006 (0.871)	.0486495	.5114541 (0.3)	.0362342 (0.890)	-.6760065 (0.000)**
Ln(AW)	.026953 (0.957)	-.3121424 (0.457)	.0440943 (0.912)	-.1278507 (0.749)	-.3446949 (0.329)	-.3101775 (0.383)	.0063912 (0.990)	-.4486473 (0.273)	-.4299973 (0.297)	-.1831471 (0.732)	-.3423454 (0.433)	.2411446 (0.447)
Ln(IC)	-.0331242 (0.033)**	-.0367586 (0.013)**	-.0178104 (0.186)	-.0290294 (0.020)**	-.0263796 (0.032)**	-.0269037 (0.027)**	-.0339599 (0.024)**	-.0402507 (0.009)***	-.0396032 (0.009)***	-.0396047 (0.017)**	-.0379309 (0.011)**	-.0440469 (0.069)*
Ln(APOP*L)	.0404348 (0.476)	.0638067 (0.077)*	-.1416448 (0.021)**	-.056045 (0.306)	.0287444 (0.401)	.0249052 (0.481)	.0408811 (0.514)	.0909707 (0.004)***	.0892431 (0.006)***	.0470296 (0.379)	.076515 (0.033)**	-.0827515 (0.466)
Constant	15.3358 (0.049)**	11.16032 (0.079)*	19.03369 (0.008)***	23.80384 (0.000)***	18.09479 (0.002)***	18.44275 (0.002)***	15.84558 (0.030)**	8.745872 (0.174)	9.401622 (0.144)	16.94573 (0.018)**	11.08709 (0.085)*	-13.99411 (0.028)**
Test d'Hausman	12.74 (0.1210)		15.85 (0.0701)		6.05 (0.7348)		8.45 (0.4890)					
Test Ramsey Reset			0.24 (0.9934)			11.828 (0.0049)			14.36 (0.1101)			12.22 (0.2014)

Note: **** significativity at 1% , ** significativity at 5% and *significativity at 10%. The study period 2000-2011. The Hausman test favors the fixed effect since the p-value is less than 5% .The endogéniéte test shows that we have endogenous variables in the model, for this reason we had to 2SLS method residues are normal, there is an absence of autocorrelation and heteroscedasticity. According to the Ramsey Reset test, there is a relevant explanatory variable. Agricultural productivity is considered an endogenous and dependent variable. The innovation index and macroeconomic control variables are considered weakly exogenous or predetermined variables. The indicator variable was included in the estimate of the models and was considered strictly exogenous variable.*

model we replace the general innovation index with mechanization.

These two results have shown that land improves agricultural productivity when farmers use technological innovation based on induced innovation and external innovation.

Mechanization is considered to be destructive to land factor and the energy factor. The spread of pollution destroys the soil.

Internet use coefficients are negative and significant in all models except 2SLS I. The Internet is used for other purposes in the rural environment and not for the dissemination of sustainable exploitation methods. Researchers and engineers are using the Internet to improve research in the agricultural sector, while the results and solutions found have remained in research laboratories and are not applied in the field. The study of Esposti (2002) confirms our result.

The labor variable has significant coefficients at the threshold of 1%, 5% and 10% in the RE I, 2SLS I, RE III 2SLS III and RE IV models.

In model I, the labor force coefficient is negative, while in models III and IV the labor force coefficients are positive in which we have replaced the technological innovation index induced innovation and mechanization, respectively. These results confirm that labor and labor factors work better when farmers use induced innovation and mechanization. These two types of innovations are the most widely used in Mediterranean agriculture.

Agricultural productivity measures the economic efficiency of factors of production. Our results confirm that the technological factor, such as external innovation is not effective in agricultural production, and that the land factor loses its effectiveness when farmers use mechanization, whereas the labor factor that is measured by the hand can be effective when producers use mechanization and induced innovation. This finding confirms that the type of mechanization used by Mediterranean farmers is unsustainable and causes soil destruction, while labor is skilled in some developed countries.

According to the result of the estimate, the economic efficiency of factors of production in Mediterranean agriculture is not realized, due to unsustainable technologies and the destruction of the land factor.

***The results of the bioeconomic model estimation by the dynamic panel data method**

Estimating the bioeconomic model with static panel data yields biased and not efficient coefficients. To solve these problems, we use a dynamic model based on the system-based GMM method proposed by Blundell and Bond (1998). This estimator is the most effective in solving problems of endogeneity, auto-correlation etc.

The table 3 below presents the results of the estimation of equation (1) that measures the impact of technological innovation on the economic aspect via its effect on agricultural productivity.

The coefficients of variables I, I1, I2 and I3 are significant at the threshold of 1%, 5% and 10% in the four models, but with two signs. The coefficients of the general innovation index (I), induced innovation (I2) and mechanization (I3) are positive. Alternatively, the coefficient of external innovation (I1) is negative.

Technological innovation that is based on the mechanization and induced innovation, improves productivity and agricultural production. This result is similar to the studies of Douillet and al (2013) and Roudart and Mazoyer (2007). In their analysis, they show that through technical and organizational innovation, agricultural productivity is enhanced.

Mechanization contributes to the improvement of labor productivity, following extensive areas exploited.

The positive effect of induced innovation on agricultural productivity is explained by the method followed in developed countries, such as France, which is based on the selection of plant seeds with high production potential. It follows a productivist and conventional model. The induced innovation that is based on the irrigation system stimulates agricultural productivity, but it consumes several water resources, when used unsustainable.

The external innovation negatively affects agricultural productivity. R&D in the agricultural sector is developed in laboratories, but to date, it is not applied to the land, especially in its first phase. The link between producers and R&D is access to the Internet. We note in our results that the coefficients of Internet use are negative for all models and significant at the 5% threshold only in models I and IV. In rural areas, the Internet is used for leisure and not to stimulate the agricultural sector through the search for new sustainable farms.

Official development assistance (ODA) has only one positive and significant coefficient at the 1% threshold in model IV. The small share of ODA devoted to the agricultural sector is the main cause of the weak relationship between agricultural productivity and official development assistance. In the same context, the coefficients of life expectancy at birth are positive in all models and significant at the 5% threshold only in models I and IV. However, the education rate has only one significant coefficient at the 5% threshold with a negative sign in model IV. These results confirm the study by Feder and Umali (1993), school enrollment and age are unessential determinants for technological innovation in the agricultural sector.

The increase in productivity increases both producers' incomes and in the purchasing power of consumers, due to lower unit production costs. It stimulates production and consumption and is a major driver of economic growth and the improvement of the standard of living in the medium term.

Table 3. Estimation of Bio-economic model by the GMM method

Dependent variable AP	***(I)***	***(I)***	***(II)***	***(I)***
Ln(AP)T-1	.9169807 (0.000)***	.4099026 (0.003)***	.8591014 (0.000)***	.7413453 (0.000)***
Ln(I)	*.1289936* *(0.063)**			
Ln(I1)		-*.204491* *(0.001)****		
Ln(I2)			*.036194* *(0.049)***	
Ln(I3)				***.091363*** ***(0.066)****
Ln(ODA)	.0311587 (time: 0.202)	-.0076819 (0.764)	.0136562 (0.579)	.0322461 (0.004)***
Ln(LE)	3.602919 (0.032)**	.519785 (0.669)	1.865413 (0.147)	3.573546 (0.032)**
Ln(DR)	-.574649 (0.253)	.2040327 (0.877)	-.1573779 (0.625)	-1.017985 (0.032)**
Ln(APOP)	.1299397 (0.27)	.2685694 (time: 0.202)	-.0291871 (0.771)	.1228551 (0.458)
Ln(L)	-.0390743 (0.719)	-.1187242 (1.977)	.0905161 (0.426)	-.0031197 (0.983)
Ln(CW)	-.0337332 (0.056)*	.0120419 (0.769)	-.0505035 (0.037)**	-.0152509 (0.338)
Ln(MR)	.2322003 (0.1)*	-.0511955 (0.770)	.1104565 (0.234)	.2063301 (0.158)
Ln(AW)	-.3690477 (0.1)*	-.5630412 (0.007)***	-.3094186 (0.014)**	-.453654 (0.014)**
Ln(IC)	-.0456882 (0.031)**	-.0019107 (0.932)	-.0235908 (0.181)	-.0488985 (0.040)**
Constant	-12.04257 (0.054)	-.3084569 (0.973)	-5.755771 (0.143)	-9.311187 (0.113)
Test de Sargan	3.98 (0.409)	0.4 (0.994)	2.93 (0.569)	7.24 (0.202)
Test de Hansen	4.07 (0.397)	0.86 (0.973)	2.76 (0.535)	2.04 (0.844)

Note: **** significativity at 1%, ** significativity at 5% , and *significativity at 10% .The study period is 2000-2011. Hansen testing is the statistical validity of the instruments, with the p-value in parentheses. Agricultural productivity is considered an endogenous variable. The innovation index and macroeconomic control variables are considered weakly exogenous or predetermined variables. The indicator variable was included in the estimate of all models and was considered a strictly exogenous variable.*

Our results are similar to the study by Roudart and Mazoyer (2007) who performed a comparison analysis between mechanization work (the case of Europe) and manual labor (the case of Africa) and have shown that the productivity of the agricultural sector is increasing with the use of mechanization more than manually. The exploitation of large agricultural areas requires a great deal of human resources.

The labor force coefficients in the agricultural sector and the agricultural population are not significant in the four models with two positive and negative signs. These results are explained by the problem of relevance of the data.

Permanently cultivated land coefficients are negative and significant at the 5% and 10% in models I and III. We note that the land factor negatively influences agricultural productivity, when farmers use mechanization as technology in agriculture. Similarly, the coefficients of access to water in rural areas are negative and significant at the 1%, 5% and 10% thresholds in all models.

Increasing agricultural productivity is seen as a critical issue for several developing countries, where agriculture is represented as a main activity, and food absorbs a high share of household income. Douillet and al (2013) indicated that increasing agricultural productivity in harmony with the protection of resources and biodiversity achieves sustainable development in the agricultural sector. In contrast, in this study, mechanization increases efficiency and ensuring economic efficiency, but it does not respect the environment. Mechanical technology is the most widely used in Mediterranean agriculture. It affects natural resources such as land and water via their intensive use. These results confirm that technological innovation can no longer be a lever for the economic sustainability of the agricultural sector.

The mortality rate has only one positive and significant coefficient at the 10% threshold in model I. Technological innovation improves agricultural productivity and yield and ensures economic well-being. However, it diffuses pollution in the air and in the soil, like CO_2, which subsequently causes the development of diseases and the increase in the mortality rate.

Although the objectives of economic sustainability of the agricultural sector are achieved in the countries of the Mediterranean basin, the objectives of environmental sustainability are not realized because technological development does not take account of environmental factors (Result of static panel data).

Finally, we can conclude that external innovation (training) has a negative effect in both models (static panel data and dynamic panel data). The lack of agricultural training in the countries of the Mediterranean basin, especially the south-eastern shore explains the results obtained.

Our results are similar to those of Esposti (2002) with his study on the effect of Italian agricultural R & D. Esposti (2002) shows that the level of R&D in Italy is very far away in the agricultural sector because Italy is the second largest producer of organic farming in the world and is the first in the country of the Mediterranean basin.

The weak role of the State in the improvement of the agricultural sector in a particular way and the rural environment generally explains the negative impact of external innovation in the south-east Mediterranean countries).

Public support to the agricultural sector for R & D and extension is still weak. It exists a wide gap between theory and practice, R & D remains up to now in research laboratories and does not apply in exploited areas, especially in the southeastern Mediterranean shore.

Research is conducted in agricultural experimental stations. According to recent studies with OECD (2010), research takes a long time to exert an effect on productivity and production. The part of the problem of obtaining the fruits of research lies in the dynamic *link between research spending, knowledge stock and productivity.*

CONCLUSION AND POLICY RECOMMENDATION

The technological innovation is called to solve problems in the agricultural sector in the event of absence or insufficiency of sustainable development policy, since it is considered an engine, which releases a continuous way of favorable solutions.

It allows to absorb the accumulated deficits in the three sustainability, in economic matters (their inability to create the wealth for the height of the population needs), in social matters (lack of human development) and in environmental terms (destruction of nature and the depletion of resources by an industrialization uncontrolled), or through the product's diversification, either through new production methods or by the use of techniques developed such as biotechnology, nanotechnology, the communication and information technology, which ensure the rapidity and diversification.

To measure the impact of technological innovation (general innovation index (I), external innovation (I1), induced innovation (I2) and mechanization (I3)) on economic sustainability, we estimate a calibrated bioeconomic model coupled with a linear Cobb-Douglas production function by two methods (static panel data (fixed effect, random effect and 2GLS) and dynamic panel data (GMM in system) for 21 countries in the Mediterranean basin, for a period from 2000 to 2011 by two methods: static panel data and dynamic panel data.

The result of the estimation by a static panel method shows that the technological innovation index has a negative effect on agriculture productivity, which is explained by the negative impact of external innovation index (R&D, patent received by foreign and mark received offoreign).

Contrarily, the result of the estimate from the system GMM method shows that the technological innovation index has a positive effect on agriculture productivity, this result is explained by the positive effect of induced innovation (irrigation, organic management) and mechanization (tractors and combine harvesters).

According to the analysis of several economists and econometrics, the static panel method is biased, so we take the system GMM method in our analysis as the most effective method.

Our findings have important policy implications of Mediterranean countries:

**Ensure the coherence of national policies for rural development and their compatibility with other policies* (free-trade agreements and trade policies…) In this context, it is for the countries of the South particularly important to measure the risks associated with the process of the euro- Mediterranean trade liberalization at a time, on the maintenance of agricultural production systems (promoting food security of the local rural population), employment and the fight against poverty, and avoids ultimately environmental and social structuring.

* *To commercialize these various products, it is necessarily built infrastructure in the rural areas that facilitate the transport of products to the markets.*

**The investment in rural infrastructure and the creation of viable rural institutions to provide the services that are lacking, such as the agricultural credit, marketing and processing*;

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