The Effects of Technological Innovation on Sustainable Development in Morocco: Does the Transition to Social Innovation Matter?

[1] EL AIDI Abir, [1] MOUSSANE Aboutayeb, [2]TARBALOUTI Essaid

[1] Phd student in Economics, Department of Economics, Cadi Ayyad University, Marrakesh, Morocco.

[2] Professor and researcher, Department of Economics, Cadi Ayyad University, Marrakesh, Morocco.

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ABSTRACT

Technological innovation currently is one of the crucial factors influencing economic growth and contributing to development. However, our primary aim by presenting this paper is not solely the economic progress ensured by innovation, but rather to study the impact of technological innovation on the three pillars of sustainable development (economic, social and environmental). This means that we will examine the repercussions at an economic, social, and environmental level. To do so, we have worked with a time series covering the period from 1990 to 2021 in Morocco, estimated by the ARDL model to figure out short-term and long-term results. Our findings were as follows: concerning the relationship between technological innovation and the economic pillar, it is seen to be positive in the short term and tends to become slightly negative in the long term. Regarding the relationship between technological innovation and the environmental pillar, a positive impact is clear, meaning that an increase in technological innovation levels reduces environmental damage. However, in the long term, this trend may reverse as it tends to become less positive or even negative.

Finally, the relationship between technological innovation and the social pillar is characterized as non-significant.

Keywords: Technological innovation, Economic growth, Environmental improvement, Human development, Social innovation.

INTRODUCTION

Innovation is a key driver of economic growth, and advances in science and technology are frequent. Economic growth has generally improved living conditions, but climate change, erosion of fertile soils, overfishing, eutrophication, and pollution of aquatic environments threaten the survival of billions of people worldwide as well as the well-being of future generations. It is therefore crucial to adopt more sustainable development models, which increase incomes while ensuring widespread access to essential needs such as drinking water and electricity, while minimizing environmental impacts.

Social innovation should not be seen as an end in itself, but rather as a means of improving quality and productivity. As Damon (2009) points out, "social policies are implicated in the innovation process." He identified several social protection innovations implemented in different countries to adapt social protection systems to new economic realities and improve the management of new social risks and becoming increasingly important and an integral part of national policy agendas to meet contemporary's social challenges.

However, technological innovation plays a crucial role in achieving sustainable growth. Researchers, particularly in economic fields, have focused on the intricate relationships between technological innovation and sustainable development. The Brundtland Report (1987) was the first to discuss the links between technological innovation and sustainability. Nonetheless, measuring these relationships poses a challenge, as sustainable development encompasses various subfields. From an economic standpoint, classical economists including Solow (1956) and contemporary figures such as Romer (1995) argue that technological advancements drive economic growth by enhancing production efficiency and spurring innovation. From a social perspective, the United Nations Development Program (UNDP) maintains that technological innovation is crucial for human development. Studies like Romer's (1995) contend that technological innovation promotes human and economic development, consequently improving the well-being of society.

The environmental aspect is a complex issue. While many authors argue for the importance of technological innovation in addressing environmental problems. Empirical studies, such as Fal et al (2006) research, demonstrate that the relationship between technology and the environment is highly dependent on a country's level of development. The potential impact of technological innovation on the environment can vary from positive to negative, depending on the context. Consequently, although technological innovation can contribute to environmental progress, its actual impact will depend on a variety of factors, including the level of development and the policies in place.

The key question will therefore be presented as follows: does a middle-income country such as Morocco have the necessary conditions to enable technological innovation to promote the country's sustainable development and respond adequately to economic, social and environmental problems?

To answer this question, our article makes a significant contribution to the debate. Firstly, it takes a fresh look at the interaction between technological innovation and sustainable development. Secondly, it focuses primarily on the case of a developing country, specifically Morocco. Thirdly, we use a time series to examine both short- and long-term impacts. Our main objective is to analyze the impact of technological innovation on each of the three pillars of sustainable development. To do so, we use the Autoregressive Distributed Lag (ARDL) model proposed by Pesaran et al (2001) which is based on a cointegrated stationary series model. We chose this model because of its advantage, namely its ability to analyze both the short and long term, which is in line with the objectives of our study. The time frame we have selected for this analysis covers the period between 1990 and 2021.

This paper is structured as follows: In Section II, we begin by summarizing existing research on the essential role of technological innovation in the three dimensions of sustainable development. Then, in the same section, we review the empirical literature, with particular emphasis on similar studies already carried out. In addition, we introduce the econometric model used and the variables examined. In Section III, we proceed to analyze the time series of each variable, explaining in a detailed manner the methodology of our estimation model and identifying the data sources employed. Section IV presents the results from our econometric analysis, followed by an in-depth discussion of the results and their interpretations, highlighting the potential contributions of social innovations as a sustainable solution for each of the pillars of sustainable development. Finally, in section V, we draw a conclusion based on the observations and findings set out above.

LITERATURE REVIEW

Theoretical Literature Review

In the economic pillar of sustainable development, technological innovation is the key to stimulate long-term economic growth. Technological advances make it possible to increase production efficiency, create new sectors of activity and improve business competitiveness. These innovations boost productivity and create wealth, generating economic opportunities for individuals and societies. This leads us to invoke the fundamental proposition of growth theory that, to maintain a positive growth rate in per capita product over the long term, there must be continuous advances in technological knowledge in the form of new goods, new markets or new processes. This proposition can be demonstrated using the neoclassical growth model developed by Solow (1956), which shows that without technological progress, diminishing returns would eventually put an end to economic growth. The central idea is that capital accumulation can stimulate economic growth in the short term, but to achieve a long-term growth, the process depends primarily on technological innovation.

In this context, Mankiw, Phelps & Romer (1995) have lent their support to this approach by including human and physical capital in the capital view, but it should be noted that the model, as conceived, fails to explain the persistent differences between the growth rates of different countries, as it considers as exogenous the rate of technological progress that uniquely determines each country's growth rate.

The initial challenge is to base a theory of sustainable growth on exogenous technology, but this depends on economic decisions as much as on capital accumulation. Several attempts to endogenize technology were made before the recent emergence of endogenous growth models. However, all these efforts came up against the problem of managing increasing returns in a dynamic general balance framework.

In this respect, Arrow (1962) postulated that growth was an involuntary consequence of the experience of producing new capital goods, which led to a phenomenon known as learning-by-doing. However, Arrow's (1962) model was not fully exploited, as it was based on a fixed capital/labor ratio and a fixed (vintage-specific) labor requirement. This meant that, in the long term, output growth was limited by labor growth and was therefore independent of saving behavior, as in the Swan model (2023).

From another point of view, this does not rule out the fact that endogenous growth has a sustainable approach. This theory, whose origins can be traced back to Romer (1986), sees growth as a cumulative phenomenon. At the root of this cumulative phenomenon are economic agents, who accumulate various forms of capital, including experience and know-how, education and professional training, public infrastructure, etc. According to this theory, growth creates wealth, which in turn generates more income to finance investment in human capital. This translates into training that provides a more skilled workforce capable of innovation.

In line with this, Schumpeter (2000) re-emphasizes the importance of innovation, pointing out that the cyclical nature of the economy is not due to social transformations, demographic changes or currency fluctuations. It originates in innovation. Schumpeter (2000) defines innovation as "new objects of consumption, new methods of production and transportation, new markets, new types of industrial organization". To simplify this definition further, we can say that: innovation is the economic application of an invention, for example, the discovery of pressure enabled its force to be used in steam engines. However, the relationship between innovation and societal transformation is not unidirectional. In this respect, we can debate Schumpeter's idea in the framework of an analysis due to the rebound effect, which can be defined in a wide sense as "the increase in consumption linked to the reduction of limits to the use of a technology, these limits being monetary, temporal, social, physical, linked to effort, danger, organization...". (F Schneider 2001)

Yet this can lead to a higher consumption, including the direct accounting of the increase in demand for the same type of good due to the reduction in costs associated with increased efficiency. The effects of technological innovations are not only limited to the direct effects as Schumpeter described them, but also include the rebound or income effect: savings may enable a consumer to purchase other types of goods, leading to a further increase in the use of materials and energy. It thus includes modifications to the general equilibrium and transformational effects when the effects on social organization are taken into consideration.

The challenge we face at this point is not efficiency, but the growth economy, where ever more money, time and space are devoted to increasing consumption. Instead of continuing to innovate for growth. To ensure an ecological and social well-being we require a "frugal innovation", where our brainpower is used to produce better and less, rather than better and always more.

In the environmental dimension, the work of Nordhaus (2019) is worth noting. According to him, the concentration of greenhouse gases in the atmosphere is the main environmental concern, and he has extensively studied the economics of climate change. He argues that climate change is the ultimate challenge for economics, as it has profound implications for markets, public policy and people's daily lives.

In the same connection, the author Daly (2014) promotes an understanding of economic development that goes beyond simple growth in Gross Domestic Product. He emphasizes the need to take into account the planet's ecological limits and social implications. This perspective encourages economists and policymakers to broaden their vision of progress by integrating environmental and social dimensions into their development policies, such as putting forward concepts such as pricing the depletion of natural resources, environmental taxation and reforming the financial system to encourage more sustainable practices.

Technological innovation plays a significant role in advancing sustainable development's social pillar. It allows for greater access to education, healthcare, and information, therefore improving people's quality of life. Social networks, and other communication platforms stemming from technological innovation, enable collaboration, knowledge sharing... Innovation can be a key factor in addressing multifaceted societal challenges, such as providing access to potable water, affordable healthcare, and reducing poverty. This is in complete line with the contribution of Sen & Corbridge (2002), in where the authors explain that development is not simply reduced to economic growth or the accumulation of material goods, but must be understood as the expansion of people's choices and opportunities. They advocate that measuring development not only be based on income, but also on the ability of individuals to pursue their goals and live with dignity.

The sharing economy would not be able to exist without the initial financial capacity of those behind it (for example, public funding for coworking or the acquisition of a car-sharing fleet). The impact of sustainable development on technological innovation and vice versa can be explained through a bidirectional relationship. Sustainable development and technological innovation are closely linked, and one can influence the other in several ways Environmental externalities were defined by Boudeville et al. (1973) as a consequence of an agent's decisions that affects other agents in ways other than the market.

The entrepreneur maximizes his profit under the constraint of production costs, which translates, in a competitive situation, into choosing the quality produced so as to equalize the marginal cost with the selling price. According to this approach, environmental pressures are seen on the one hand as "constraints" likely to threaten the sustainability of organizations. In fact, the various sources of environmental pressure will force polluting companies to respect the environment; if they fail to react, they will consequently lose their image and hence their legitimacy. However, the introduction of an environmental policy will push companies to integrate the environmental dimension into their economic activity by carrying out depollution actions.

A large number of economic researchers (Schmidheiny et al. (1992), Landry (1990), Sala (1992) and Robins

(1992)) have taken an interest in promoting the implementation of environmental strategies centered on the principles of sustainable development.

Their work has shown that this development is generally understood as the result of three requirements. The first is economic viability, which some interpret as sustained and sustainable economic growth. The second is environmental viability, which is expressed in terms of protecting the environment and the balances on which the maintenance of the biosphere depends, as well as maintaining resource-producing ecosystems for human activities and establishing a healthy environment for inhabitants. The third and final requirement is social equity, both within and between generations.

This approach is often referred to as win-win-win (Zaccaï (2004)), since environmental regulation is beneficial firstly for the environment, since it leads to a reduction in pollution levels. Secondly, it is socially beneficial, guaranteeing a cleaner, safer, healthier environment and a better quality of life for present and future generations. Thirdly, it promotes economic activity by encouraging producers to adopt cleaner production methods, thus opening up opportunities for clean investment, wealth and job creation, and the promotion of environmental markets.

Sustainable development can stimulate technological innovation by creating economic incentives, influencing market demand, and encouraging compliance with environmental standards. In turn, technological innovation can contribute to sustainable development by providing more efficient, environmentally-friendly solutions. This creates a synergistic relationship between sustainable development and technological innovation.

To better illustrate the bi-directional relationship between sustainable development and innovation, the following diagram summarizes the process, which then forms an impact circuit

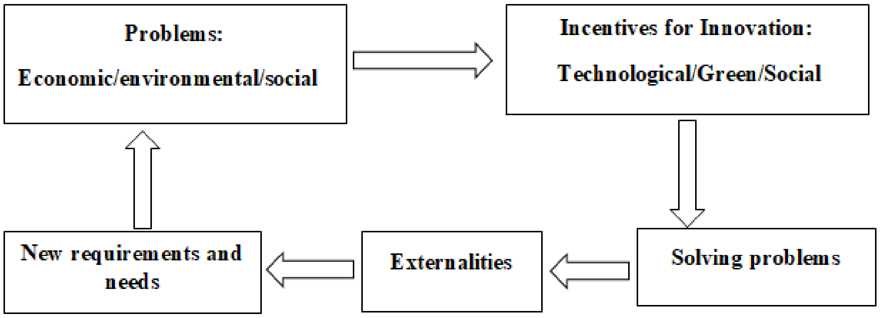

Figure 1: Explanation of the relationship between sustainable development and technological innovation

Source: Created by the Author

Whether economic, environmental or social. Innovations represent the most relevant solution to the problems, yet the solutions generated by innovation can present externalities that are either positive or negative. Which leads to new needs and new requirements, sometimes even exogenous, due to changes in society, thus to deal with the new problems and requirements we're going to have to use innovations once again. This means that the impacts between innovation and sustainable development are characterized as bidirectional, forming a circuit of continuous evolution.

Empirical Literature Review on Sustainable Development and Technological Innovation

Infrastructure, Industrial Growth, and Technological Innovation

Based on a study conducted by Fan, Ismail, and Reza (2018) on Bangladesh's infrastructure, technological innovation, and industrial growth from 1974 to 2016, critical challenges were identified. Despite modest rankings in technological readiness and innovation, these advancements did not yield the expected impact on industrial growth. Bangladesh lags not only globally but also within South Asia, ranking 111th out of 137 countries in terms of infrastructure. The study proposes that adopting green technologies in environmentally damaging sectors could enhance environmental quality, though challenges and costs hinder this in a developing country. The study is also showing a positive correlation between infrastructure and industrial growth. Technological innovation, however, negatively affects industrial growth in the long run. In the short term, both infrastructure and technological innovation positively impact industrial growth. Granger's VECM causality test reveals bidirectional causality between industrial growth and infrastructure, as well as between infrastructure and technological innovation. Unidirectional causality from industrial growth to technological innovation is also found. These findings, consistent with the ARDL approach. The authors advocate the need for a policy of technological innovation and infrastructure that promotes overall economic growth.

Economic growth, human capital, and technological innovation

The link between economic growth, human capital, and technological innovation is central to numerous recent studies. For instance, Traoré et al. (2021), in a recent study conducted in Mali, examined the impact of human capital and technology on economic growth over the period 1986-2020 using the Auto Regressive Distributed Lag (ARDL) model.

The study explores the links between economic growth, human capital and technological innovation using the ARDL model. The results show that education spending, health spending and Gross Enrolment Ratio (GER) have a positive effect on economic growth in both the short and long term, underlining the importance of human capital in the country's economic development. On the other hand, research and development (R&D) expenditure and investment show significant negative effects on economic growth. These findings highlight the need to mobilize considerable resources in favor of R&D to stimulate innovation and, consequently, foster increased economic growth in Mali. The authors thus suggest policy implications, stressing that the Malian government should direct its efforts towards strengthening R&D to support the country's economic growth.

Industrial activities, technological innovation and environmental problems

Given the worsening environmental conditions due to various factors, especially human activities, particularly industrial, many researchers are investigating the dynamic relationship between technological innovation and CO2 emissions. To illustrate, York, Rosa, and Dietz (2003) they conducted a study to investigate the determinants impacting CO2 emissions in various nations from 1975 to 2000. The results of the analysis show the complexity of the relationships between industrial activities, technological innovation and environmental problems, based on the STIRPAT model. Population emerges as a major factor influencing CO2 emissions and energy footprint, with significant elasticity, indicating that demographic changes are proportionally linked to variations in these impacts. Urbanization, as an indicator of modernization, is associated with a monotonic increase in both impact measures studied, suggesting that modernization processes can contribute to increasing environmental pressures. Furthermore, the structure of the economy, measured by the share of the industrial sector, shows a positive association with environmental impacts, underlining the crucial role of industrial activities in generating these impacts. The results diverge when it comes to wealth, indicating that there is no conclusive evidence of an environmental Kuznets curve for total CO2 emissions or energy footprint.

In Morocco, the results generally support the existence of an inverted-U relationship between economic growth and carbon emissions, as well as a linear relationship between CO2 and energy consumption. The existence of a long-term Kuznets curve is the result of various environmental policies. However, the impact of energy remains relatively high due to dependence on fossil fuels (Aboutayeb et al., 2022).

In the light of our analysis of the theoretical and empirical literature concerning our research topic, our study aims to establish a link between technological innovation and the three pillars of sustainable development in a middle-income country, in this case Morocco. To this end, we formulate the following hypotheses:

Hypothesis 1: Technological innovation has a positive and favorable impact on the three pillars of sustainable development.

Hypothesis 2: Technological innovation does not have the same impact on the different pillars of sustainable development.

DATA AND METHODOLOGY

Data

As mentioned above, the aim of this article is to examine the ability of technological innovation to simultaneously affect economic growth, human development and environmental quality in the case of Morocco over the period 1990-2021:

Technological innovation (TI): Several measures can be used to define technological innovation, such as R&D expenditure, the global innovation index, the total number of patents, the global innovation index, the total number of patent applications, the number of scientific articles published per 1,000 inhabitants of a country. Gill (2013) and Crespo & Crespo (2016). The total number of patents is therefore our measure of technological innovation.

Gross Domestic Product (GDP): the total value of final goods and services produced on a country's territory over a given period. Many authors have used GDP as a measure of economic growth, including Barro (1991) and Acemoglu (2005). GDP represents our estimation variable for the economic component.

CO2 Emissions: CO2 emissions, which are the release of this gas into the atmosphere, can originate from natural sources or be anthropogenic (related to human activities). This variable's importance as an environmental measure is recognized by Stern (2007), Nordhaus (2019), and numerous other influential authors interested in environmental issues. CO2 emissions serve as our variable for measuring environmental impact.

The human development index (HDI): is a composite statistical index used to assess a country's level of human development. The HDI is measured using three main criteria: gross domestic product (GDP) per capita, life expectancy, and education level. This index, developed through the contributions of Anand & Sen (1994), has become a reference for measuring human development in global economies, as demonstrated in the works of Grammy & Assane (1997) and Sachs (2010), among many economists. The HDI serves as our measurement variable to determine social impact.

Table 1 offers a detailed presentation of the description and sources of each variable integrated in our study. This enables us to examine the relationship between technological innovation and sustainable development in a middle-income country such as Morocco, in order to provide an appropriate response to economic, social, and environmental problems.

Table 1: Description and source of variables

Abbreviation	Description	Source
CO2	CO2 emissions in metric tons	The World Development Indicators, date:05/04/2023

GDP	Gross domestic product	The World Development Indicators, date:05/04/2023
TI	Total number of patent applications from residents and non-residents (Moroccan)	The World Development Indicators, date:05/04/2023
HDI	Human development index	The United Nations Development Program, date:05/04/2023

Source: Issued by the Author

Time series analysis is intended to understand how the four variables - CO2 emissions, GDP per capita growth, human development index and total number of patent applications - have evolved over time. The aim is to identify the trends, cycles and key events that have influenced these developments.

From a visual point of view, it appears that there has been an overall growth in CO2 emissions over the period studied, despite periodic fluctuations. Economic events such as the Covid-19 pandemic in 2020 had a significant impact on this trend.

As for the time series of annual changes in GDP per capita growth in Morocco, it helps us to understand how this growth has evolved over time, and to identify the trends, cycles and key events that have influenced it. Analysis of this series reveals both increases and decreases in this indicator over the period examined, with a notable impact from the Covid-19 pandemic in 2020. In addition, Morocco's human development index shows significant linear growth between 1990 and 2021, largely thanks to the efforts made by public authorities in this area. Finally, the total number of patent applications (both resident and non-resident) in Morocco demonstrates significant quadratic growth over the period 1990 to 2021.

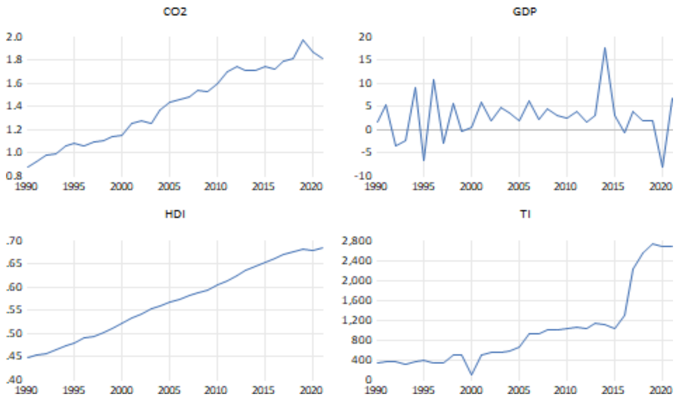

Figure 2: Time series of CO2, GDP, HDI and TI

Source: Author's calculations

We used a set of descriptive statistics tools to calculate values that are well known to experts, to get an idea of the distribution over time.

Take the example of the CO2 emission series. The average annual CO2 emission in Morocco over the period 1990-2021 is 1.41 tons per capita. This means that, on average, 1.41 in tons were emitted per capita each year over this period. With a minimum emission value of 0.87 tons per capita and a maximum value of 1.96 tons per capita. The Skewness index, Kurtosis and Jarque-Bera test were used to test the normality of the series.

Table 2 : Descriptive statistics

	CO2	**GDP**	**HDI**	**TI**
Mean	1.412399	2.715220	0.568813	970.0625
Median	1.445762	2.660032	0.570000	785.0000
Maximum	1.968907	17.46920	0.683000	2730.000
Minimum	0.875022	-8.172741	0.447000	104.0000
Std. Dev.	0.324948	4.836025	0.077623	770.7624
Skewness	-.031820	.385183	-.012818	1.305928
Kurtosis	1.631327	4.845348	1.700261	3.547667
Jarque-Bera	2.503087	5.331698	2.253306	9.495647
Probability	0.286063	0.069540	0.324116	0.008671
Sum	45.19676	86.88703	18.20200	31042.00
Sum Sq. Dev.	3.273337	725.0012	0.186783	18416316
Observations	32	32	32	32

Source: Author's calculations

The Pearson correlation coefficient between the series in question can take values between -1 and 1. A value closer to -1 and 1 shows a linear link between the two series examined. And a value close to 0 shows no link. From the results obtained in the correlation matrix of our model, it is clear that there are significant links between several pairs of variables. We observe a significant correlation between the Human Development Index (HDI) and CO2 emissions, between CO2 emissions and the total number of patents, and between the total number of patents and the Human Development Index. These results suggest the existence of potential relationships between these data series.

Table 3: Pearson correlation test

	CO2	**GDP**	**HDI**	**TI**
CO2	1	0.0810186	0.988980	0.844050
GDP	0.081018	1	0.098715	-.050169

HDI	0.988980	0.098715	1	0.855329
TI	0.844050	- .050169	0.855329	1

Source: Author's calculations

METHODOLOGICAL APPROACH

In order to better define our study, and based on our findings from the empirical literature and the nature of our series, which is a time series, we feel that the ARDL model is best suited to providing more in-depth answers to our problem:

Auto Regressive Distributed Lag/ARDL models are dynamic models. They have the particularity of taking account of temporal dynamics (adjustment lag, anticipations, etc.) in the explanation of a variable (in time series), thus improving forecasts and the effectiveness of policies (decisions, actions implemented, etc.), unlike the simple (non-dynamic) model whose instantaneous explanation (immediate effect or not spread over time) only restores part of the variation in the variable to be explained.

The ARDL estimation method we use consists of two essential stages. The first phase consists of an initial test to demonstrate the existence of a long-term relationship between the variables included in our model. We then proceed to estimate the short- and long-term parameters in a subsequent phase. However, various factors, including the degree of stationarity of the variables, influence this procedure. In order to analyze time series data with different levels of integration (I (1) and I (0)), Pesaran et al. (2001) recommended the use of the ARDL model to assess cointegration as an alternative to the Engle-Granger model.

For further time series analysis, it is imperative to check the stationarity of the variables, which determines whether they are I (0) or I (1) and ensures that none of them are integrated at second order, I (2). In our study, we will check the stationarity of the variables using the Dickey-Fuller augmented unit root test (ADF) with a threshold of 5%. This approach will then enable us to select the appropriate values for the maximum delays using the SIC information criterion. Finally, diagnostic tests will be conducted to confirm the suitability of our model. These validation tests will assess the reliability and robustness of our results, including the Jarque-Bera test for error normality, the Breusch-Pagan-Godfrey test for error homogeneity, the Lagrange Multiplier (LM) test and Ramsey's RESET test for correct model specification.

In fact, on the basis of the theoretical growth model and the available data, we used an ARDL model to analyze the relationship between per capita economic growth (dependent variable) and three explanatory variables: technological innovation (TI variable), CO2 emissions (CO2 variable) and the human development index (HDI variable) over a period extending from 1990 to 2021. The objective was to determine the impact of technological innovation on each pillar of economic development, taking into account the other pillars of development. To do this, we specified three distinct models: model (1), model (2) and model (3), as follows:

Model 1: $\mathrm{GDP} = \mathrm{f}\,(\mathrm{TI}, \mathrm{CO2}, \mathrm{HDI})$ (1)

Model 2: $\mathrm{CO2} = \mathrm{f}\,(\mathrm{TI}, \mathrm{GDP}, \mathrm{HDI})$ (2)

Model 3: $\mathrm{HDI} = \mathrm{f}\,(\mathrm{TI}, \mathrm{CO2}, \mathrm{GDP})$ (3)

To estimate the three equations of models 1, 2 and 3, we then formulate the following ARDL model to identify the directions of the short- and long-term causal relationships between technological innovation (TI), gross domestic product per capita (GDP), carbon emissions per capita (CO2), and human development (HDI) and the conditional error correction version of the ARDL model for the three equations is represented as follows:

Model 1:

$$\Delta GDP_t = \beta_0 + \sum_{q}^{p} \beta_1 \Delta GDP_{t-1} + \sum_{q}^{p} \beta_2 \Delta TI_{t-1} + \sum_{q}^{p} \beta_3 \Delta CO2_{t-1} + \sum_{q}^{p} \beta_4 \Delta HDI_{t-1} + \alpha_1 GDP_{t-1} + \alpha_2 TI_{t-1} + \alpha_3 C02_{t-1} + \alpha_4 HDI_{t-1} + \mu_t \; (4)$$

Model 2:

$$\Delta CO2_t = \beta_0 + \sum_{q}^{p} \beta_1 \Delta C02_{t-1} + \sum_{q}^{p} \beta_2 \Delta TI_{t-1} + \sum_{q}^{p} \beta_3 \Delta GDP_{t-1} + \sum_{q}^{p} \beta_4 \Delta HDI_{t-1} + \alpha_1 GCO2_{t-1} + \alpha_2 TI_{t-1} + \alpha_3 GDP_{t-1} + \alpha_4 HDI_{t-1} + \mu_t \; (5)$$

Model 3:

$$\Delta HDI_t = \beta_0 + \sum_{q}^{p} \beta_1 \Delta HDI_{t-1} + \sum_{q}^{p} \beta_2 \Delta TI_{t-1} + \sum_{q}^{p} \beta_3 \Delta CO2_{t-1} + \sum_{q}^{p} \beta_4 \Delta GDP_{t-1} + \alpha_1 HDI_{t-1} + \alpha_2 TI_{t-1} + \alpha_3 C02_{t-1} + \alpha_4 GDP_{t-1} + \mu_t \; (6)$$

Where Δ stands for the first difference operator applied to the respective variable. The term μ corresponds to the disturbance term, assumed to be uncorrelated and with zero mean. The coefficient β0 represents the deterministic drift parameter. The coefficients β1, β2, β3, β4 and β5 respectively represent the elasticities of each pillar with respect to technological innovation and the other determinants. Importantly, β1, β2, β3, β4 and β5 are all non-zero, indicating the existence of cointegration. This cointegration is established using a non-standard F-test, originally developed by Pesaran et al. (2001) and adapted by Narayan (2005) for small samples.

EMPIRICAL RESULTS AND DISCUSSION

Estimating the unit root test is a necessary step before analyzing time series cointegration. In line with the recommendations of Enders, & Granger (1998), we used the standard ADF (Augmented Dickey-Fuller) test developed by Dickey and Fuller in 1979 to assess the stationarity of variables (Dickey & Fuller 1979).

In this study, we performed the unit root test to determine the order of integration of variables using two alternative specifications. First, we tested model 2, then model 3 (see Table 1). The results of the unit root test, presented in Table 1, indicate that all variables are stationary, either at the first difference level, or at the level.

Specifically, the test reveals that three of the variables are non-stationary at I (0), with the exception of GDP per capita growth, which is stationary at I (0). By contrast, when we examine the first I (1) differences, all three variables become stationary. These results indicate that, with or without constant and trend, some variables are stationary at level I (0), while others become stationary at level I (1). Table 4 details the results of the ADF unit root tests, at a significance level of 5%.

Table 4: ADF unit root test results

ADF unit root test results at 5% threshold						
Variables	Model	In level		First difference		
		t-statistic	P-value	t-statistic	P-value	Order of integration
GDP	Trend and Constant	-7.810433	0.0000	-7.646215	0.0000	I (0)
	Constant	7.898887	0.0000	7.686132	0.0000	I (0)
CO2	Trend and Constant	-2.587432	0.2880	-5.878782	0.0002	I (1)
	Constant	-1.184245	0.6684	-5.876120	0.0000	I (1)
HDI	Trend and Constant	-1.941706	0.6073	-3.755294	0.0337	I (1)
	Constant	-0.967313	0.7518	-3.704986	0.0092	I (1)
TI	Trend and Constant	-1.240848	0.8838	-4.517108	0.0059	I (1)
	Constant	0.769766	0.9918	-4.259888	0.0023	I (1)

Source: Author's calculations

Model 1: Impact of technological innovation on the economic pillar

The results of our optimal model, evaluated according to the SIC criterion, indicate that the ARDL model with the optimal lags (1, 0, 2, 2) is the most appropriate. These figures represent the number of lags for each variable: 1 for GDP, 0 for HDI, 2 for CO2 and 2 for TI (technological innovation). For our analysis, we focused on the TI variable and its lags (see Table 5).

We estimated three parameters linked to the TI variable to assess the impact of technological innovation on the economic development pillar (TI variable, first lag and second lag). The parameter for the TI variable is estimated at 0.007, with a significance of 0.0884 (below 10%). The first and second lags have estimated parameters of 0.00703 and -0.0087 respectively, with respective significances of 0.0216 and 0.0507. These results highlight the significant impact of technological innovation on the economic development pillar.

Table 5: ARDL (1) model estimation with optimal delays (1, 0, 2 ,2)

Variable	Coefficient	Standard deviation	t-Statistic	P-value
GDP (-1)	-0.622420	0.158840	-3.918534	0.0008
CO2	20.85508	15.61434	1.335636	0.1960
CO2 (-1)	-50.48792	18.26360	-2.764402	0.0116
CO2 (-2)	52.97737	17.46403	3.033514	0.0063
HDI	-18.12380	87.24361	-0.207738	0.8374
TI	-0.007027	0.003933	-1.786693	0.0884
TI (-1)	0.007035	0.005522	1.274051	0.0216
TI (-2)	-0.008793	0.004243	-2.072248	0.0507
C	-9.137039	22.04456	-0.414481	0.6827

Source: Author's calculations

As regards the impact of technological innovation on the economic development pillar, the results show both short-term and long-term effects. In the short term, the coefficients of the first and second lags are significant at the 5% level. The first lag has a positive coefficient, while the second lag has a negative coefficient, suggesting an immediate positive effect of technological innovation on economic development followed by a delayed negative effect.

However, in the long term, the impact of technological innovation on the economic development pillar is very weak and negative (see Table 6). The coefficient of 0.007 means that a one-unit increase in technological innovation (TI) leads on average to a 0.007-unit increase in the economic pillar (GDP), all else being equal. This suggests a significant positive impact of technological innovation on economic development.

The first lag of the TI variable indicates a significant positive effect with a one-period lag, meaning that the impact of technological innovation on economic development occurs slightly with a time lag, but remains positive. In contrast, the second lag of the TI variable has a significant negative coefficient, indicating a negative effect with a two-period lag. However, it is important to note that this negative effect is less significant than the immediate positive effect (coefficient of the TI variable) and the positive effect with a one-period lag (coefficient of the first lag).

Table 6: Long-term and short-term ARDL (1) coefficients

Variable	Coefficient	Standard deviation	t-Statistic	P-value
Long-term coefficients				
CO2	14.38870	12.99018	1.107660	0.2805
HDI	-11.17084	53.87962	-0.207330	0.8377

TI	-0.005414	0.001237	-4.377016	0.0003
C	-5.631735	13.50873	-0.416896	0.6810
Short-term coefficients				
D (CO2)	20.85508	11.07818	1.882536	0.0737
D (CO2(-1))	-52.97737	10.88701	-4.866109	0.0001
D (TI)	-0.007027	0.003237	-2.170942	0.0415
D (TI (-1))	0.008793	0.003151	2.790913	0.0110
CointEq(-1)*	-1.622420	0.139597	-11.62218	0.0000

Source: Author's calculations

The diagnostic tests of the model are presented in the following results. They include the F-bound test to check the long-term impact of all the variables included in the model on the dependent variable, the Jarque-Bera test to assess the normality of the errors, and the Breusch-Pagan-Godfrey test to examine the homogeneity of the errors.

The error histogram almost follows a normal distribution, a result confirmed by the Jarque-Bera test. The errors show no significant autocorrelation for delays, as indicated by their fit within the confidence interval. Moreover, the heteroskedasticity test is satisfactory at a threshold of 5%.

However, the test for the existence of integration relationships between variables is rejected, as the F-bound test statistic exceeds the confidence interval at a threshold of 5% (F=22.69, well above the upper bound of 3.67).

Finally, Ramsey's RESET specification test indicates that the estimated model is free of serial correlations, inadequate functional form specifications, non-normal errors and heteroscedasticity at a threshold of 5%. All these diagnostic checks are summarized in Table 7.

Table 7: Model 1 diagnostic tests

Test	Null hypothesis	T-statistic	P-value	Conclusion
Jarque-Bera	Residues are normally distributed	0.8135	0.6658	Non-rejection of Ho because the P-value is insignificant, so the model residuals are normally distributed.
Breusch-Godfrey	The absence of autocorrelation	1.983	0.1650	Non-rejection of Ho because the P-value is non-significant,

(LM test)				suggesting that the residuals are uncorrelated.
Breusch-Pagan-Godfrey	Homoscedasticity	1.1385	0.3792	Non-rejection of Ho because the P-value is non-significant, which means the absence of heteroscedasticity.
Ramsey Reset	The model is correctly specified	0.9530	0.3520	Non-rejection of Ho because P-value is insignificant, suggesting correct model specification

Source: Author's calculations

Model 2: Impact of technological innovation on the environmental pillar

The results of the model estimation indicate that the optimal model, according to the SIC criterion, is the ARDL model with optimal lags of (1, 3, 3, 4). More precisely, the number 1 corresponds to the number of lags of the variable CO2, the number 3 to that of the variable GDP, the number 4 to the variable HDI, and finally, the number 4 represents the lag of the variable TI of technological innovation.

The parameter associated with the TI variable is 0.001 with a significance of 0.0333, which is less than 0.05, demonstrating the significance of the impact of technological innovation on the environmental development pillar. It should be noted that the parameters associated with the lags (first, second, third and fourth) vary, with significances above 0.05 for the second and third lags, while below 0.05 for the first and fourth lags (see Table 8). These results reveal that technological innovation has a significant impact on the environmental development pillar, albeit with a lag of more than three years.

Table 8: Estimation of ARDL model (2) with optimal delays (1, 3, 3 ,4)

Variable	**Coefficient**	**Standard deviation**	**t-Statistic**	**P-value**
CO2 (-1)	0.643489	0.191001	3.369026	**0.0050**
GDP	0.000343	0.002634	0.130352	0.8983
GDP (-1)	0.000941	0.003443	0.273272	0.7889
GDP (-2)	-0.006673	0.003790	-1.760586	0.1018
GDP (-3)	-0.008025	0.003371	-2.380430	**0.0333**
HDI	12.02577	4.609702	2.608795	**0.0216**
HDI (-1)	-13.19106	6.562357	-2.010110	**0.0656**
HDI (-2)	-9.289674	7.524919	-1.234521	0.2389
HDI (-3)	13.06383	5.544200	2.356306	**0.0348**
TI	**0.000143**	6.02E-05	2.380788	**0.0333**

TI (-1)	-0.000237	8.07E-05	-2.936964	**0.0116**
TI (-2)	0.000102	5.98E-05	1.702004	0.1125
TI (-3)	1.90E-05	7.18E-05	0.264902	0.7952
TI (-4)	-0.000187	6.38E-05	-2.933088	**0.0116**
C	-0.768052	0.358474	-2.142559	**0.0517**

Source: Author's calculations

To assess the impact of technological innovation on the environmental development pillar, both in the short and long term, the results reveal the following observations:

In the short term, the coefficients associated with the TI variable are all positive and statistically significant at the 5% level, except for the t-1 lag (see Table 9). This suggests a very weak positive effect of technological innovation on the environmental development pillar. Nevertheless, the long-term impact of technological innovation on the environmental pillar is not statistically significant, as evidenced by the negative coefficient of -0.0004 with a significance of 0.1996, thus exceeding the traditional 0.05 threshold. This non-significance indicates a certain uncertainty as to the long-term impact of technological innovation on CO2 emissions.

As for the coefficients of the lags of the TI variable, they reveal that the effects of technological innovation are exceedingly small and propagate over time. The coefficients associated with all three lags are positive, suggesting a positive relationship between technological innovation and CO2 emissions at these different lags. However, the significance of these effects varies, indicating that these relationships are not uniformly significant at all lags.

Table 9: Long- and short-term ARDL (2) coefficients

Variable	Coefficient	Standard deviation	t-Statistic	P-value
Long-term coefficients				
GDP	-0.037627	0.031269	-1.203350	0.2503
HDI	7.317763	2.435184	3.005015	0.0101
TI	-0.000449	0.000332	-1.351309	**0.1996**
C	-2.154355	0.926742	-2.324654	0.0369
Short-term coefficients				
D(GDP)	0.000343	0.001753	0.195814	0.8478
D (GDP (-1))	0.014699	0.002998	4.902991	0.0003
D (GDP (-2))	0.008025	0.002155	3.724063	0.0026

D (HDI)	12.02577	3.358055	3.581171	0.0034
D (HDI (-1))	-3.774157	3.387103	-1.114273	0.2853
D (HDI (-2))	-13.06383	3.923161	-3.329925	0.0054
D (TI)	**0.000143**	5.02E-05	2.856663	**0.0135**
D (TI (-1))	6.62E-05	4.39E-05	1.508167	**0.1554**
D (TI (-2))	**0.000168**	3.90E-05	4.306476	**0.0009**
D (TI (-3))	**0.000187**	5.03E-05	3.721463	**0.0026**
CointEq (-1)*	-0.356511	0.098774	-3.609366	0.0032

Source: Author's calculations

In summary, the results indicate a potential relationship between technological innovation and CO2 emissions, suggesting that technological innovation could help reduce emissions, and this result is confirmed by the study of Hatzigeorgiou, Polatidis, & Haralambopoulos (2011) which shows that the efficient use of innovative technologies reduces energy intensity which in turn leads to lower carbon emissions during the production process and vice versa,

As Jaffe, Newell, Stavins (2003) point out, technological innovations bring two main externalities: the first is positive and the second is negative. State policies are therefore called upon to take advantage of the positive externalities and promote them further, promising an adapted framework to stimulate these benefits, while on the other hand being able to absorb the negative impacts that can accompany such innovations, namely environmental degradation.

The results of the model's diagnostic tests are presented below. They include the F-bound test, which checks that all variables included in the model have a long-term impact on the dependent variable, the Jarque-Bera test to assess error normality, the Breusch-Pagan-Godfrey test to test error homogeneity, and Ramsey's RESET specification test.

The error histogram shows a distribution that approximately follows a normal distribution, and this observation is corroborated by the Jarque-Bera test. Furthermore, the results show that the error autocorrelation for the different delays lies within the confidence interval, suggesting the absence of error autocorrelation. The homoscedasticity test is also accepted at the 5% threshold, indicating error homogeneity.

On the other hand, the test to determine the existence of integration relationships between variables is rejected, as the F-bound test statistic lies outside the confidence interval at the 5% threshold (F=5.21, well exceeding the upper bound of 3.67 at the 5% threshold). Finally, Ramsey's RESET specification test attests that the estimated model is free of serial correlations, inappropriate functional form specifications, errors not conforming to a normal distribution and heteroscedasticity at the 5% threshold.

All the results of the diagnostic tests are presented in Table 10 for easier reading.

Table 10: Model 2 diagnostic tests

Test	**Null hypothesis**	**T-statistic**	**P-value**	**Conclusion**
Jarque-Bera	The residues are normally distributed	0.8417	0.6564	Non-rejection of Ho because the P-value is non-significant, so the model residuals are normally distributed.
Breusch-Godfrey (LM test)	The absence of autocorrelation	0.0400	0.9609	Non-rejection of Ho because the P-value is non-significant, suggesting that the residuals are uncorrelated.
Breusch-Pagan-Godfrey	Homoscedasticity	1.6454	0.1885	Non-rejection of Ho because the P-value is non-significant, which means the absence of heteroscedasticity.
Ramsey Reset	The model is correctly specified	0.1815	0.8589	Non-rejection of Ho because the P-value is non-significant, which suggests the correct specification of the model

Source: Author's calculations

Model 3: Impact of technological innovation on the social pillar

The results of the model estimation reveal that the optimal model, according to the SIC criterion, is the ARDL model with optimal lags of (1, 0, 0, 1). Here, "1" represents the number of lags for the HDI variable, "0" for the GDP variable, "0" for the HDI variable, and "1" for the lag of the TI variable of technological innovation (see Table 11).

The parameter associated with the TI variable has an extremely value of 0.0007, with a significance of 0.0015, which is less than 0.05. It is therefore essential to note that the impact of technological innovation on the social development pillar is statistically significant at the 5% level.

Table 11: ARDL (3) model estimation with optimal lags (1, 0, 0.1)

Variable	Coefficient	Standard deviation	t-Statistic	P-value
HDI (-1)	1.021544	0.042600	23.98004	0.0000
GDP	0.000261	8.06E-05	3.241409	0.0034
CO2	0.014885	0.008383	1.775690	0.0880
CO2 (-1)	-0.013589	0.009046	-1.502304	0.1455
TI	-3.70E-06	1.04E-06	-3.565487	0.0015
C	-0.003877	0.010874	-0.356507	0.7245

Source: Author's calculations

To assess the impact of technological innovation on the social development pillar, both in the short and long term, the results indicate that the coefficient associated with the TI variable is extremely low, reaching only 0.0007. This suggests that technological innovation has a very limited effect on social development, as measured by the Human Development Index (HDI). This suggests that technological innovation has a very limited effect on social development, as measured by the Human Development Index (HDI). What's more, the significance of this coefficient is 0.91, well above the traditional 0.05 threshold. In other words, the result has no statistical significance, meaning that there is insufficient evidence to assert that technological innovation has an impact on social development as modeled here.

The coefficient on the first lag of the TI variable is also very low, with a negative value of -0.01312, but fails to reach statistical significance at the 5% level. This suggests that the analysis reveals no significant effect of technological innovation with a one-period lag on social development, as measured by the HDI.

The coefficients remain both small and insignificant, suggesting that there may be other factors or variables not included in the model that exert a stronger influence on social development. It is also plausible that the impact of technological innovation on social development is indirect, requiring further analysis that takes considers other variables and their interactions.

According to the results of our ARDL model, it seems that technological innovation (variable TI) does not have a significant impact on the social pillar measured by the Human Development Index (HDI).

Table 12: Long-term and short-term ARDL (3) coefficients

Variable	**Coefficient**	**Standard deviation**	**t- Statistic**	**P-value**
Long-term coefficients				
GDP	-0.012127	0.024814	-0.488724	0.6293
CO2	-0.060134	0.559431	-0.107491	0.9153
TI	0.000172	0.000324	0.529845	0.6009
C	0.179935	0.179762	1.000961	0.3264
Short-term coefficients				
D (CO2)	0.014885	0.006644	2.240470	0.0342
CointEq(-1)*	0.021544	0.001156	18.64084	0.0000

Source: Author's calculations

The model's diagnostic tests are described in the following results. They include the F-bound test to assess the long-term impact of all variables included in the model on the dependent variable, the Jarque-Bera test to assess the normality of the errors, and the Breusch-Pagan-Godfrey test to examine the homogeneity of the errors. The error histogram approaches the normal distribution, a result confirmed by the Jarque-Bera test. Moreover, the autocorrelation of errors for lags respects the confidence interval, suggesting the absence of autocorrelation. In addition, the homoscedasticity test is satisfied at the 5% threshold. However, the test for the existence of integration relationships between model variables is rejected, as the F-bound test statistic far exceeds the confidence interval at the 5% level (F = 81.07, well above the upper bound of 3.67).

Ramsey's RESET specification test demonstrates that the estimated model does not suffer from serial correlations, functional form misspecification, non-normal errors or heteroscedasticity at the 5% threshold. All diagnostic checks on the model are presented in Table 13.

Table 13: Model diagnostic tests (3)

Test	**Null hypothesis**	**T-statistic**	**P-value**	**Conclusion**
Jarque-Bera	The residues are normally distributed	1.2370	0.5387	Non-rejection of Ho because the P-value is non-significant, so the model residuals are normally distributed.
Breusch-Godfrey (LM test)	The absence of autocorrelation	0.1975	0.8589	Non-rejection of Ho because the P-value is non-significant, suggesting that the residuals are uncorrelated.
Breusch-Pagan-Godfrey	Homoscedasticity	1.1145	0.3780	Non-rejection of Ho because the P-value is non-significant, which means the absence of heteroscedasticity.
Ramsey Reset	The model is correctly specified	0.1626	0.8721	Non-rejection of Ho because the P-value is non-significant, which suggests the correct specification of the model

Source: Author's calculations

Discussion of Results and Future Prospects in the Field of Social Innovation

In this discussion section we will take a closer look at the findings of our study on the impact of technological innovation on sustainable development. Our goal is to investigate how technological advancements can aid in achieving sustainability objectives while acknowledging potential obstacles and implications for future policies. We will examine the result of this intricate relationships between technological advancement and the sustainable development pillars of the environment, economy and society as summarized in the diagram above, while also elucidating the various dimensions of innovation. Ultimately, this discourse endeavors to reveal potential avenues for maximizing technological innovation to foster sustainable and equitable development.

The relationship between technological innovation and the economic pillar

Regarding the relationship between the economic sphere and technological innovation, we have demonstrated that there is an immediate positive effect, followed by another positive effect with a one-period lag, and finally, there could be a negative effect with a two-period lag, although it is less pronounced than the positive effects. Technological innovation contributes positively to economic development, although there may be lags and fluctuations in this effect over time.

In the short term, it is reasonable to anticipate a positive influence of technological innovation on the economic sector. Advancements can result in increased productivity, decreased production expenses, and augmented economic expansion. Businesses that implement innovative technologies can improve their competitiveness and inaugurate novel markets, subsequently encouraging economic activity. These conclusions are bolstered by various economic scholars, such as Solow (1956), Romer (1995), Schumpeter (2000), among others. However, over the long term, innovation has a slightly negative impact on the economic pillar, which can be explained by factors such as creative destruction. New technologies can make existing industries and jobs obsolete, resulting in economic disruption and inequality. Additionally, as technological innovation advances, marginal returns may decrease, making the additional economic benefits of innovation less significant after a certain period. Yet the relationship between technological innovation and growth may not always be positive, as Tyler Cowen (2011) discusses in his book "The Great Stagnation". Modern societies may face economic stagnation due to the absence of groundbreaking innovations unlike those of the past, and recent innovations may have a limited impact on overall productivity.

To clarify the second part of this impact, a first aspect that may explain the diminishing impact of technological innovation on long-term growth is the principle evoked by Schumpeter: creative destruction, i.e. a new good may not add to old goods, but rather replace them. The innovator, who is the winner, puts his competitors in the losing position by eliminating them from the market. As Aghion and Howitt (1992) show, there is a negative externality that can be damaging to well-being and employment. A second aspect of the Schumpeterian vision is neglected: the exhaustion of the innovator's rent. The dynamics of innovation presented by Schumpeter and taken up by industrial economics are as follows.

Initially, the innovator invests to obtain a new product. This investment in research represents a fixed cost, the scale of which is, a priori, independent of sales volume. This new product temporarily monopolizes the market. There are various reasons for this: the product may be protected by a patent, or it may take some time to imitate it. His monopoly position allows the innovator to set a price above marginal cost. I1 thus obtains a rent. This will enable him to amortize his fixed research costs. There can be no research without imperfect competition. However, in Schumpeter's vision, this monopoly position can only be temporary, even if the lifespan of the good is long. In practice, the legal duration of patents is limited, and the possibility of circumventing them is never completely closed.

Moreover, if these effects of creative destruction are not accompanied by a successful transition to new sectors, this could contribute to negative long-term results. Since the benefits may initially accrue to certain companies and individuals, creating economic inequalities, if these inequalities persist or worsen, this may have negative implications for social stability and economic growth.

Long-Term Dynamics of Technological Innovation and Environmental Impact

Our study demonstrates that technological innovation has a positive short-term impact on the environmental pillar. This supports the notion that innovations can promote sustainable practices. For instance, the implementation of clean technologies can curtail greenhouse gas emissions and pollutants. Innovation can enhance energy conservation and environmental efficacy, as Schiederig, Tietze & Herstatt (2012) have argued. On the other hand, Schor, J. B. (2013) as well as Gowdy, J. M. (2007) showed that this impact can be reversed in view of the overconsumption that can cause the depreciation of natural resources.

Entrepreneurial actions should be focused on green innovations to contribute towards environmental improvement and consider current ecological circumstances in CSR strategies of firms globally, including Morocco. However, to achieve such an objective, we believe that the contribution of all economic actors is needed at the same time, investments in technological innovation and research and development are not enough, the parties benefiting from these innovations must in turn show some adaptation and initiative within this framework, sustainability will therefore be the result of the combined efforts of all economic actors.

However, in the long term, the positive impact of technological innovation on the environment is no longer noticeable and appears to be having a negative effect. To explain this outcome, we suggest the following potential reasons: Within the framework of the Moroccan economy, it was previously heavily reliant on the agricultural sector. Subsequently, it diversified and began investing in the secondary and tertiary sectors. Our analysis of graphs on the official World Bank website indicates a correlation between the rise of CO2 emissions and the expansion of the service sector. This can be explained by: As the Moroccan state shifts its focus from agriculture toward other sectors, CO2 emissions increase. This negative externality arises from the correlation between service utilization and transportation usage, ultimately leading to environmental damage. Additionally, renewable energy consumption in Morocco further exacerbates the issue, as observed through the graphs presented by the World Bank. The low consumption of renewable energies in Morocco explains the non-sustainability of their positive environmental impact.

The relationship between technological innovation and the social pillar

The insignificant relationship between technological innovation and the social pillar in our study can be attributed to the complexity of social interactions. The impact of innovation on social well-being depends on various factors, such as government policies, access to education and healthcare, and the equitable distribution of innovation benefits.

According to Omri's (2020) study on technological innovation's effects on HDI, per capita CO2 emissions have a negative impact on human development in all country panels. Specifically, a 1% increase in carbon emissions results in a decrease of around 0.33%, 0.2%, and 0.23% in low, middle, and high-income countries, respectively. This finding aligns with the analysis by Constant and Raffin (2016), which examines the relationship between environmental quality and life expectancy, revealing that environmental conditions can significantly impact people's longevity.

Economic support for this result comes from Brynjolfsson & McAfee's (2014) contribution, in which they discuss the major transformations that digital technology is bringing to the economy and society. The authors discuss both the opportunities and challenges presented by this technological revolution. They caution against the widening economic and social inequalities that may arise from automation and technological innovation.

According to our study, technological innovation only has a positive impact on economic growth and the environmental pillar, and this is limited to the short term, whereas our initial objective is sustainability. For this reason, we propose the following perspectives and paths that could achieve a harmonious and positive balance between the three pillars of sustainable development, always based on the use of technological innovations, but what kind of innovation? The comparison of social innovation with technological innovation highlights another important characteristic of social innovation: its continuity. Unlike radical technological innovation, which occurs in clusters and makes a break with the past, social innovation represents a continuous, incremental innovation, linked to its territory and working to improve what already exists. "The new development model characterizing today's society and economy is therefore based on continuous innovation. This hypothesis is reinforced by the need for innovation at the present time; innovation is seen as a remedy for the systemic economic, social, environmental and cultural crisis facing Western societies" (Bouchard 2011).

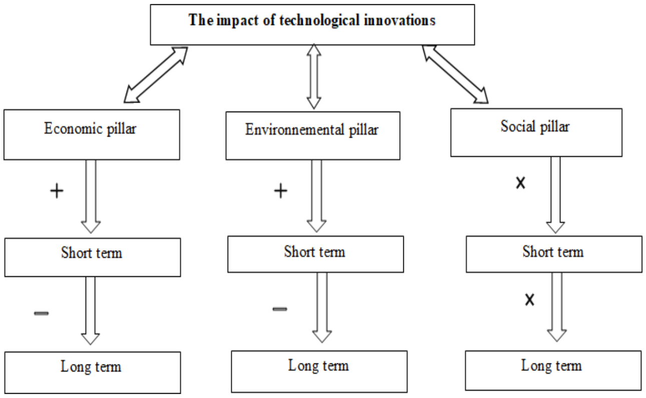

Figure 3: Diagram of empirical results

Where: (+: means positive impact; -: means negative impact and X means non-significant impact)

Source: created by the Author

Social innovations have become a powerful engine for achieving sustainable development by harmoniously integrating economic, social and environmental dimensions. They embody an innovative way of tackling social problems while generating significant economic and environmental value. For example, the adoption of clean energies, such as solar and wind power, is both a social and environmental innovation, as it meets basic electricity needs, improving people's quality of life by ensuring more reliable access to energy, particularly in regions where the access to electricity is limited.

Moving on from technological innovation to social innovation is a more relevant solution in the context of sustainability. Technological innovation certainly precedes by far the term social innovation, which is emerging as a new-entrant in the world's economies. And yet, thinking about money, laws, marriage, the modern state, education or health systems, these are all examples of social innovations that have played a decisive role in the evolution of modern societies. Meaning that social innovation and technological innovation are similar in many respects. Both by nature and necessity; even if there are important similarities between technological and social innovation. Firstly, all innovation involves a non-linear process that calls on the commitment of several players in a problem-solving approach, a corollary of the existence of external pressure. Secondly, the process leads to the definition of an approach, the design of a new or alternative product or service. And finally, in order to turn the new solution into an innovation, it must be diffused and, above all, be adopted by users or promoters.

This practice also promotes inclusion by creating economic opportunities through job creation in the installation and maintenance of energy infrastructures, or through the development of local entrepreneurship in the renewable energy sector. In turn, the renewable energy sector can encourage the development of local entrepreneurship. As such, encouraging the adoption of environmentally-friendly farming methods can help conserve natural resources, while boosting food security and improving farmers' incomes. The economic benefits are obvious: more sustainable agriculture is often more profitable in the long term, while offering protection against market fluctuations. Moroccan companies can therefore direct their technological innovations to this category of practices. For example, the use of drones and satellites for agricultural monitoring Stehr (2015) enables more efficient management of water and fertilizers, reducing waste. Drones equipped with infrared cameras and satellites can monitor crop condition and water requirements in real time. By analyzing thermal images and reflectance data, farmers can identify areas where plants need water and those where irrigation is not required. This enables more targeted use of irrigation water, avoiding wastage of precious water. Additionally, they can quickly spot crop health problems, such as disease or pests, by flying over fields at regular intervals. So, by reducing the overuse of water and fertilizers, this technological approach lowers the environmental impact of agriculture. Less water is drawn from local sources, which can help preserve water quality and aquatic ecosystems. In addition, reduced fertilizer uses limits nutrient pollution of groundwater and watercourses, which is good for the environment. On the economic front, increased efficiency in agriculture due to drone and satellite monitoring can lead to savings for farmers, contributing to the economic pillar of sustainable development.

Social innovations demonstrate their ability to address economic, social and environmental issues in a global way, creating synergies that support sustainable development.

As an example, ride-sharing applications broaden access to mobility by enabling passengers to share rides with drivers heading in the same direction, offering an affordable transport option to a bigger number of people. Car-sharing applications help to reduce the number of vehicles on the road, which can alleviate traffic congestion, improve air quality and cut journey times, all of which have a positive impact on the quality of life of city residents. This helps to optimize the use of resources, notably fuel and road infrastructure. Passengers benefit from reduced transport costs thanks to shared fuel costs, which can free up resources for other needs. Drivers can also recover some of their vehicle-related expenses.

We assume that the adoption of these forms of innovation contributes directly to the achievement of sustainable development objectives, as they address the three fundamental pillars of sustainable development: economic, environmental and social. Social innovation aims to solve social problems while promoting inclusion, equity and improved quality of life in communities. Through cooperatives, social enterprises and collaborative projects, it strengthens the social fabric by creating economic opportunities for marginalized groups, improving access to basic services such as education and health, and promoting values of solidarity and community cohesion. These advances strengthen the social pillar of sustainable development by reducing poverty, inequality and social exclusion.

What is particularly powerful is the synergy between these two forms of innovation. Collective social innovation projects can incorporate green practices and technologies, creating significant added value by combining social and environmental dimensions, these projects reinforce the three pillars of sustainable development in an integrated way. What's more, they contribute to more resilient economies by creating local jobs, boosting food security through sustainable agricultural practices, and improving quality of life.

CONCLUSION

The study we conducted on the impact of technological innovation on the three pillars of sustainable development - economic, social, and environmental - revealed significant findings worth close examination. Our objective was to understand how technological innovation, as an engine for economic growth, could shape the future of sustainable development in Morocco. Our findings highlight several important trends.

First, regarding the relationship between technological innovation and the economic sector, our results indicate a positive impact in the short term. This suggests that technological innovation can stimulate economic growth in a relatively brief timeframe. However, it is noteworthy that this relationship tends to become slightly negative in the long term. This reversal could be attributed to factors such as market saturation or adverse effects of innovation.

In terms of the environmental pillar, our study shows a positive impact of technological innovation. An increase in technological innovation levels appears to reduce short-term environmental damages. However, it is important to note that this trend may reverse in the long term, indicating a need for more in-depth sustainability measures to sustain these environmental benefits.

Regarding the social pillar, our findings suggest a non-significant relationship between technological innovation and social development. This implies that the impact of technological innovation on the social aspects of sustainable development is complex and may depend on various factors.

Overall, our study demonstrates that technological innovation has a crucial role to play in sustainable development in Morocco. However, it is important to recognize that the effects of technological innovation are nuanced and depend on the specific pillar of sustainable development being examined, as well as the time period under consideration. To maximize the benefits of technological innovation, long-term sustainability policies and strategies must be carefully developed to mitigate potentially negative effects and ensure balanced and inclusive development. Our initial hypotheses, including the assumption that technological innovation would have a positive impact on the three pillars of sustainable development, have been confirmed to some extent.

However, a thorough analysis is required to fully comprehend the intricacies and long-term implications. In this regard, we have enriched this study with the introduction of social innovation as a new perspective that leads to the realization of sustainable development, as it has a positive impact on the three pillars of sustainable economic, social and environmental development.

Our study paves the way for future research aimed at gaining a better understanding of the underlying mechanisms of technological innovation and developing more targeted policies for sustainable and balanced development.

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