The Impact of Water Scarcity on Economic Growth and Human Development in Morocco: A Comparative Analysis Using VAR Models

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Abstract: The global water scarcity crisis, exacerbated by climate change, has not spared Morocco, which has experienced a significant decline in its water resources, leading to a notable deterioration in their condition. This growing scarcity of water resources has had a substantial impact on the country's economy and social development. To better understand the implications of this situation, our study builds upon existing research that has highlighted the importance of water for development. By combining a comparative analysis of eight African and Middle Eastern countries, including Morocco, with an in-depth study of the Moroccan case, we explore the impact of access to safe drinking water and sanitation services on economic growth and human development. We use gross domestic product per capita (GDP per capita) and the Human Development Index (HDI) as outcome indicators to assess the influence of several water-related development variables over a 15-year period from 2005 to 2020. To achieve this, we adopted an econometric approach based on the estimation of Vector AutoRegression (VAR) models. Specifically, we employed a panel VAR model for a comparative analysis of multiple countries, including Morocco. This specification allows us to capture cross-country heterogeneity while accounting for the time-varying nature of the variables. Additionally, we estimated a country-specific VAR model for Morocco to identify the unique characteristics of the Moroccan context and situate it within an international perspective.

Our results highlight the crucial role of safe drinking water in stimulating productivity and economic development. Overall, our study suggests that improving water-related indices is more about quality than quantity. The model indicates that increases in water quantity do not significantly contribute to improved economic well-being. This places greater emphasis on qualitative variables, such as water quality, access to sanitation, and efficient water management practices. These findings shed new light on the importance of investing in water access to promote sustainable development, stimulate economic growth, reduce poverty, and improve public health. By prioritizing investments in water infrastructure, sanitation services, and water conservation measures, countries can mitigate the adverse effects of water scarcity and ensure a more equitable and sustainable future for their populations.

Keywords: Access to safe drinking water- Sanitation- GDP per capita- Human Development Index (HDI - Vector AutoRegression (VAR).

1. INTRODUCTION

The works of Georgescu-Roegen (1971) and the seminal report "The Limits to Growth" (Meadows et al., 1972) were the spearhead that ostensibly ushered in a new era marked by significant attention to the environmental impacts of economic growth. Whether we like it or not, the combined effects of global warming and population growth have caused proven damage. Moreover, societies' dependence on water exerts significant pressure on our water resources. Consequently, the water crisis, which is approaching a critical threshold, is considered one of the most critical global risks to society, questioning our practices and the governance of this vital sector.

The World Bank sounded the alarm in a 1995 press release, stating that the wars of this century were largely linked to oil; but the wars of the next century would be linked to water. UNESCO also made forecasts indicating a high probability of an imminent water crisis, based on a short-term timeframe (UNESCO, 1999, p17). Moreover, recent hydrological projections of the planet's freshwater resources have signaled a potentially emerging global threat: the decline of freshwater reserves relative to the world's growing demand for water (Falkenmark *et al.* 1997; Revenga *et al.* 2000; Vörösmarty *et al.* 2000).

According to some estimates, humanity has already appropriated more than half of the world's available water resources, and combating water scarcity is the defining challenge of this century (Postel et al., 1996; Falkenmark, 1997; Vorosmarty *et al.*, 2000). Alarm bells are ringing, and the hypothesis of potential water stress is looming large worldwide. Looking to the future, it is worth noting that numerous projections concern the future scarcity of water. However, it is difficult to predict future water availability (Gleick 2003).

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This difficulty in estimation lies in the precise role that economic growth plays in determining water use.

Moreover, the deficit in access to water and sanitation services represents a significant societal burden, weighing heavily on collective health (Hutton & Chase, 2016). Waterborne risks pose a major health challenge, going beyond the prevention of diarrhea. In fact, they can induce a variety of deficiencies, particularly parasitic diseases, waterborne diseases, and diseases linked to water quality (Mara et al., 2010).

To this end, investments in the water and sanitation sector are urgently needed to improve global health, especially in low and middle-income countries, particularly since a large number of waterborne diseases are preventable (Prüss, A. *et al*., 2002).

From an economic perspective, water is not only a resource affected by growth but also a crucial factor that can stimulate it, as access to safe drinking water improves population health and productivity, and increases labor force participation, which in turn fosters economic growth (Banerjee & Morella, 2011; Günther & Fink, 2011; Hutton & Chase, 2016).

With this in mind, this paper seeks to examine the impact of access to safe drinking water and sanitation services on Morocco's economic growth, given that, like other countries, Morocco has also experienced a significant decline in its water resources due to the global water scarcity situation (Jalil, M. 2023). Effectively, through this paper, we aim to contribute to the collective reflection on the following question: What is the impact of access to safe drinking water and sanitation on economic growth and human development in Africa and the Middle East, particularly in Morocco?

Our study is structured around four main axes. First, we will conduct a review of the existing literature on the impact of access to safe drinking water on economic growth and human development. Second, we will present the methodology used, including the data used and the econometric models estimated. The results of our analyses will then be presented and discussed in relation to previous work and current issues.

2. LITERATURE REVIEW

Looking at the evolution of the international economy over decades, it becomes clear that this is not the first time economists have studied the link between economic growth and access to water. We can cite several works: (Dalhuisen et al., (2003); Portnov & Isaac, (2008); Rock, MT (1998); Gleick, P. (2003); Shafik, N., & Bandyopadhyay, S. (1992); Barbier (2004); S.El Khanji, J Hudson (2016); Hertel, T., & Liu, J. (2019); Bai, Hefei, et al. (2021) ... These works show that water availability is a crucial factor for economic growth.

When we talk about the relationship between water and economic growth, the instinctive thought that comes to mind is the impact of growth on water resources. Indeed, growth is accompanied by increased industrialization, growing urbanization, and an exponential increase in water demand. This is why most studies in this field have focused on the impact of growth on water resources. However, our study takes the opposite approach by exploring the other side of this relationship: How does access to clean water stimulate economic growth? In fact, we have particularly considered domestic water use. In addition, there are considerations related to the quality of this resource.

2.1. Access to Safe Water and Economic Growth: Literature Review

Barbier (2004) examined the potential effect of water scarcity on economic growth through theoretical and empirical analyses. To do so, he employed a panel data approach to test his theory on a set of developed and developing countries. This approach is based on examining the impact of the water use rate on the economy, assuming in his growth model that "water" is considered an integral input in the production process. Barbier's model suggests that the water use rate ensures that GDP per capita is maximized. However, the relationship between growth and the water use rate is likely to be more complex for those who lack water

Still, within the framework of the relationship between economic growth and water resources, Shafik and Bandyopadhyay (1992) studied in their paper "Economic Development and Environmental Quality: An Econometric Analysis" the relationship between economic growth and environmental quality, meticulously examining aspects of environmental transformation at various income levels. The authors find that water availability is positively correlated with economic growth. This means that countries with a greater quantity of water per capita experience faster economic growth.

Our choice of the variables "proportion of the population using a safely managed drinking water service" and "proportion of the population using a safely managed sanitation service" stems from the variable "access to urban water supply and sanitation" used by Shafik and Bandyopadhyay (1992) in their study. Indeed, our two variables are closely linked to this variable, which is a direct measure of access to these services.

It is not only about scarcity. There is also the issue of deteriorating water quality (Baechler, L. 2012). In fact, the problem of water access is more qualitative than quantitative, as the more we consume, the more we discharge. Consequently, pollution is the major flaw in this evidence. This massive influx of wastewater is catastrophic for the aquatic environment and will require much more costly treatments to make land reserves usable.

It is within this framework that the article by S. El Khanji and J. Hudson (2016) entitled "Water utilization and water quality in endogenous economic growth" [1] is situated. These authors worked on the effect of water quality on endogenous economic growth. To do so, they imitated the methodology of Barbier (2004) who integrated the water use ratio into his model.

It has been demonstrated that the impact of water quality on economic growth outweighs the quantity of water, meaning that water quality is much more significant when discussing its effect on economic growth.

Table 1. Results of statistical analyses on the correlation between the Human Development Index (HDI) and various indicators related to water access and sanitation.

Main categories	Predictor variables	All countries	Country HDI rank classification: Low	Medium	High	Very high
Access	Drinking water coverage	0.3500***	0.1573***	0.1151***	-	0.9952***
	Sanitation coverage	0.1963***	-	0.0925***	0.0952**	0.4957***
Hydroclimatology	Interannual variability	-	-	-	-	−1.8383**
	Seasonal variability	−4.4917***	−2.532***	-	-	-
Storage	Dam capacity per capita	-	-	-	-	-
	Reservoir density	-	-	-	-	-
Overall	Number of observations	151	31	37	51	52
	Significance	<0.0001	0.0013	<0.0001	0.0129	<0.0001
	R^2	0.831	0.3787	0.5631	0.1197	0.3501

Note. Shaded color intensities indicate the significance of regression coefficients. Red colors are negative correlations, blue is positive. Green indicates the number of observations and the strength of R^2. $^{**}p = 0.05$ $^{***}p = 0.001$.

Source: Amorocho-Daza, H., van der Zaag, P., & Sušnik, J. 2023).

Ultimately, the model results undoubtedly prove that water quality is a parameter as revealing as it is promising, to the point of outweighing quantity. As proof, water quality is significant in the regressions for both dependent variables. Unlike quantity, which is only significant in one model.

Indeed, our study converges with that of S. El Khanji and J. Hudson (2016), both in terms of the analysis of the impact of water use on economic growth, and in terms of integrating the dimension of water quality. For our study, we used two variables: (1) the proportion of the population using safely managed drinking water services, and (2) the proportion of the population using safely managed sanitation services. These two variables give an idea of the quality of water. Indeed, access to safe drinking water protects the population from waterborne diseases, such as diarrhea, cholera, and typhoid fever (World Health Organization, 2019).

Still within the framework of water quality and its impact on economic growth, the study by Desbureaux, S., Damania, R., Rodella, AS, Russ, J., and Zaveri, E. (2019), in their article entitled "The impact of water quality on GDP growth: Evidence from around the world," studied the impact of water quality on GDP growth. To do so, the authors relied on a revealing indicator of water quality, namely the Biochemical Oxygen Demand (BOD). [1] They used a fixed effects panel model. Using a panel of 17 countries for a period spanning from 1990 to 2014. The results showed that river pollution leads to a decrease in the economic growth of downstream regions, with these regions losing between 1.4% and 2.5% of economic growth.

2.2. Access to Safe Water and Human Development: Literature Review

Janez Sušnik and Pieter van der Zaag (2017), in their article titled "Correlation and causation between the UN Human Development Index and national and personal wealth and resource exploitation," explored the correlation and causality between the HDI and certain national economic, water, and energy variables. Based on time series data, the objective was to first detect the existence of a correlation between the variables, then analyze the causality, if a correlation existed. Focusing on the 3 variables related to the water ecosystem[1], the study shows that the variable "access to drinking water" recorded the strongest correlation with the HDI (r^2 = 0.67).

In the same vein, Amorocho-Daza, H., van der Zaag, P., & Sušnik, J. (2023), in their article titled "Access to Water-Related Services Strongly Modulates Human Development," empirically analyzed the impact of a number of water-related factors on human development. This exploration is exhaustive in the sense that it combined three dimensions: namely, access to drinking water and sanitation services (Sušnik & van der Zaag, 2017), water storage (Grey & Sadoff, 2007), and hydroclimatology (Brown & Lall, 2006). The HDI is the variable to be explained (UNDP, 1990). In order to complete this study, the authors used an approach based on the correlation and causality between water ecosystem indicators and human development. This study covers the period from 2000 to 2017.

This 18-year study reveals that variables related to access to safe water and sanitation are the factors that have the most impact on the Human Development Index, with a correlation coefficient of (ρ = 0.84). These results are in perfect harmony with previous studies (Fukuda et al., 2019; Sušnik & van der Zaag, 2017). However, this positive result was offset by the strong negative correlation of seasonal variability on the HDI (ρ = -0.7). Nevertheless, the study did not show any correlation between indicators related to water storage and the HDI (Brown & Lall, 2006; Brown *et al.*, 2013). It should be emphasized that the conclusions of these works have led us to formulate the hypothesis that access to water and sanitation has a significantly positive impact on Morocco's HDI. Moreover, we converge in the use of variables related to water and at the level of the HDI variable.

In addition to correlation analysis, a causality analysis was conducted, the results of which support those advanced by Sušnik & van der Zaag (2017), namely the existence of an interdependence between access to water and sanitation services and the Human Development Index. These conclusions are in perfect agreement with the literature advocating for the existence of a causal chain between water and sanitation services and socioeconomic development (Libanio, 2021).

Our theoretical model is based on the hypothesis that access to safe drinking water has a positive impact on the HDI and on Morocco's growth. Indeed, access to clean water improves workers' health, increasing their energy and productivity. This translates into effective participation in economic activity and a decrease in absences due to waterborne diseases; in other words, a population with access to safely managed drinking water services is less likely to be absent from work or school due to water-related illnesses.

In short, the existing literature has shown that water has proven itself as a factor that modulates human development, particularly economic growth. Moreover, this literature review has provided us with a solid framework to test the impact of access to safe drinking water and sanitation services on the HDI and on economic growth in Morocco. Thus, we have been able to select relevant variables to build a robust econometric model to test this hypothesis both in Morocco and in other countries during the period from 2005 to 2020.

3. RESEARCH METHODOLOGY

3.1. Empirical Model

Following a review of studies examining the impact of access to safe water and sanitation services on economic growth and human development, this section aims to assess the water situation and its impact on several socioeconomic indicators in a selection of African and Middle Eastern countries, including Morocco. We use Gross Domestic Product per capita (GDP per capita) and the Human Development Index (HDI) as outcome indicators to examine the impact of several water-related development variables on these indicators in a panel of eight countries over the period 2005-2020.

A Panel Vector Autoregression (PVAR) approach is employed using a system of equations and the Generalized Method of Moments (GMM) following Holtz-Eakin *et al.* (1988) and Abrigo and Love (2016). While the VAR structure allows us to capture the endogeneity of macroeconomic variables, the panel framework enables us to control for unobserved heterogeneity across countries. It also contributes to increased efficiency by reducing the potential bias caused by low degrees of freedom in country-level VAR models (Jawadi *et al*., 2016).

The following section presents in detail the data and estimation strategy used in the analysis, as well as the results obtained.

3.2. Data/Sources and Descriptive Statistics

Our data is annual from 2005 to 2020 and covers eight countries in Africa and the MENA region, namely Morocco, Egypt, Algeria, Senegal, Tunisia, Ethiopia, Iraq, and Chad. The selection of these countries was based on similarities in their water ecosystems. Indeed, the latest OECD report states that the countries selected in this model share a significant lack of water resources, as well as standardized growth rates over the past 10 years.

The variables included in the model are GDP per capita (gdpcap), the Human Development Index (HDI), the proportion of the population using improved drinking water sources (ppeaupo), the proportion of the population using improved sanitation facilities (ppassai), the level of spatial extent of water-related ecosystems (ecosyseau), and finally, the amount of official development assistance related to water and sanitation (MTdev). GDP data is obtained from the World Bank database, while other variables are from the United Nations database (UNWater). Annual data on the Human Development Index is sourced from the United Nations Development Programme (UNDP) platform.

Our model integrates variables that capture both the quantity and quality of water, in line with the recommendations of the WHO and UNICEF. Indeed, by including these two SDG indicators (indicator 6.1.1 on access to safely managed drinking water services and 6.2.1 on access to safely managed sanitation services), we consider not only the availability of water but also its quality and safety. This approach is consistent with the broader definition of water access, which emphasizes the health and environmental dimensions. Indeed, it is clear that the term "safely managed" in relation to WASH services has been strongly emphasized, presenting a dimension related to public health[1].

We summarize all definitions and data sources in Table **2**.

To enhance significance and robustness, we log-transformed both the "GDP per capita" and "amount of official development assistance for water and sanitation."

The choice of these variables is well-documented in the literature. The studies cited in the literature review provide a strong rationale for the inclusion of these variables in the econometric model.

[1] Information available in the report: WHO strategy on water, sanitation and hygiene 2018-2025.

Table 2. Studied Variables.

Variables	Nature of the Variable	Source
GDP per capita (GDPcap) [a1]	Explained variable	World Bank
Human Development Index (HDI)	Explained variable	United Nations Development Programme (UNDP) platform).
Proportion of population using improved drinking water sources (V1)	Explanatory variable	the United Nations database (UNWater)[2]
Proportion of the population using safely managed sanitation services (V2)	Explanatory variable	the United Nations database (UNWater).
000000the level of spatial extent of water-related ecosystems (ecosyseau)	Explanatory variable	the United Nations database (UNWater).
The amount of official development assistance related to water and sanitation (MTdev). (V4)	Explanatory variable	AQUASTAT data.

3.3. Estimation Framework

To investigate the impact of several water ecosystem parameters on GDP per capita and the HDI in Morocco, we opt for a Vector Autoregressive (VAR) model. We use Gross Domestic Product per capita (GDP per capita) and the Human Development Index (HDI) as outcome indicators (endogenous variables) to examine the impact of several water-related development variables on these indicators in Morocco over the period 2005-2020.

Vector Autoregressive (VAR) models of time series have emerged in the macroeconomic literature as an alternative to multivariate simultaneous equations models (Sims, 1980). All variables in a VAR system are generally treated as endogenous, although identification restrictions based on theoretical models or statistical procedures can be imposed to disentangle the impact of exogenous shocks on the system. With the introduction of VAR in the context of panel data (Holtz-Eakin, Newey, and Rosen, 1988), panel VAR (PVAR) models have been used in numerous applications across all fields. In our case, we use this approach to estimate the impact of exogenous variables on GDP per capita and subsequently on the Human Development Index. We consider a homogeneous PVAR model with k variables of order p with panel-specific fixed effects, represented by the following system of linear equations:

$$Y_{it} = A_0 + Y_{it-1}A_1 + Y_{it-2}A_2 +$$

$$... + Y_{it-p+1}A_{p-1} + Y_{it-p}A_p + X_{it}B + u_i + e_{it}$$

$$i \in \{1,2,...,8\}, t \in \{1,2,...,16\}$$

Where Y_{it} is a (1xk) vector of dependent variables; X_{it} is a (1xl) vector of exogenous covariates; and $u_i\ et\ e_{it}$ are (1xk) vectors of fixed effects specific to the dependent variable and errors, respectively. The (kxk) matrices A_1, A_2, ..., A_(p-1), A(p) and the (lxk) matrix B are parameters to be estimated.

Formally, the two equations of the model are:

$$lgdpcap = a_0 + a_1 dppeaupo +$$

$$a_2 dppassai + a_3 ecosyseau + a_4 lMTdev + u_i + e_t$$

$$IDH = b_0 + b_1 dppeaupo + b_2 dppassai$$

$$+ b_3 ecosyseau + b_4 lMTdev + \Omega_i + \pi_t$$

The parameters above can be jointly estimated with fixed effects, or alternatively, independently of fixed effects after some transformations, using ordinary least squares (OLS) equation by equation. In our case, we opt for a fixed effects model, assuming that the errors are not serially correlated. Panel VAR analysis relies on the choice of the optimal lag order both in the specification of the panel VAR and in the moment condition.

A. Descriptive statistics

Table **3** below presents the descriptive statistics for the study variables.

B. Unit Root and Stationarity Test

Before describing the methodological approach and the model used, it is necessary to verify whether the variables are stationary or not. Most economic variables exhibit strong trends, such as GDP, consumption, or the general price level. These are non-stationary. To work with longitudinal data in a PVAR model, these data must maintain a constant distribution over time (stationarity), and since our data is presented in both a time and individual dimension, it is necessary to verify this hypothesis. The presence of a unit root in macroeconomic data has serious consequences, at least potentially. If a structural variable, such as GDP per capita in our case, is truly I(1)[3], then shocks that affect this variable cause permanent effects (Greene, 2011). Unit root tests therefore allow us to detect the existence of non-stationarity for a given variable. To empirically test the stationarity of our variables, we use the LLC test (Levin, Lin, and Chu, 2002). Table 4 presents the results of the two tests.

The stationarity tests show that all the variables in our series are stationary except for two: the proportion of the

[2] In addition to our literature review, the choice of these variables is justified by the fact that they are part of the SDGs for 2030.

[3] [1] A series is said to be I(1) when it is integrated of order 1.

population using drinking water services (ppeaupo) and the proportion of the population using sanitation services (ppassai). The next step is therefore to determine whether the first difference of these variables will maintain the same non-stationary trend. The results show that these two variables become stationary after the first difference, and therefore we add them to the estimation in D1.

Table 4. Stationarity test.

Stat			LLC[4] Test (5% level)	
	T	t ajusté	Niveau	D1
Ppeaupo	0.7097	1.4688	0.9291	0.0077
Ppassai	-0.2445	0.2163	0.5856	0.00
Ecosyseau	-5.8996	-4.0359	0.00	.
lMTdev	-5.1912	-2.0445	0.0205	.
Lgdpcap	-5.8840	-3.3705	0.0004	.
Idh	-6.0264	-5.3344	0.00	.

Source: Developed by myself.
Note: The null hypothesis is that each series contains a unit root against the alternative hypothesis that each series is stationary. If the p-value is less than 5%, the null hypothesis is rejected: there is no unit root. The" indicate that the variable is stationary and requires no lag.

C. Cointegration Test

Cointegration analysis allows us to clearly identify the true relationship between two variables by searching for the existence of a cointegration vector and eliminating its effect, if any. Panel data analysis requires testing for potential cointegration among variables. Indeed, the risk of estimating "spurious" relationships and misinterpreting the results is very high. Table **5** presents the results of the cointegration tests between the outcome variables (GDP per capita and HDI) and all explanatory variables. The modified non-adjusted DF[5] test statistic is used for interpretation.

Table 5. Cointegration Test.

	PIB/h (log)		IDH	
	ADF (5%)	pvalue	ADF (5%)	pvalue
dppeaupo (retardé)	-5.6897	0.00	1.3191	0.0936
dppassai (retardé)	-5.5138	0.00	1.2662	0.10
Ecosyseau	-5.10	0.00	1.3006	0.0967
lMTdev	-5.00	0.00	0.9477	0.1716

Source: Developed by myself.

The results ²show that the variables are not cointegrated. Therefore, we can proceed with the VAR analysis without any corrections to the initial model.

[4] Levin, Lin et Chu. 2002
[5] Dickey-Fuller (1979)

4. EMPIRICAL RESULTS

4.1. Results of the Moroccan Case Study (VAR Model)

To better understand the specific characteristics of the Moroccan economy, we will conduct an individual analysis of the Moroccan case. We will use a VAR (vector auto-regressive) approach to determine the results for Morocco.

A vector autoregressive process of order (p), denoted VAR(p), is a multivariate generalization of AR(p) processes. The dimension of this process represents the number of variables studied that make up this vector process, for which we seek to establish linear relationships between the variables (Lütkepohl, 2006). Assuming that all variables in our VAR model are endogenous and tend to vary with each other over time, a general VAR model with two variables Y and X with p lags is given by:

$$Y_t = \alpha_0 + \sum_{i=1}^{p} \varphi_{1i} X_{t-i} + \sum_{i=1}^{p} \varphi_{1i} Y_{t-i} + \mu_{1t}$$

$$X_t = \rho_0 + \sum_{i=1}^{p} \varphi_{2i} X_{t-i} + \sum_{i=1}^{p} \varphi_{2i} Y_{t-i} + \mu_{2t}$$

With;

Yt: the value of variable Y at time t

Y_{t-1}: the value of variable Y at time t minus a lag of i (where i ranges from 1 to p

X_t: The value of variable X at time t

X_{t-i}: The value of variable X at time t minus a lag of i (where i ranges from 1 to p)

φ: The vector of coefficients explaining the endogenous variables.

α_0 et ρ_0 are constants.

μ_{1t} et μ_{2t} are the error terms.

Essential Conditions for the Model's Error Terms

$Cov(\mu_{1t} ; \mu_{2t}) = \sigma \neq 0$. This hypothesis states that the errors are autocorrelated and the variables interact with each other

$Cov(\mu_{1t} ; \mu_{2t-1}) = 0$. A shock to one equation does not allow to predict future shocks

We now incorporate the variables of our study into the general model. Since we are interested in the influence of variables related to the water ecosystem in Morocco on the two variables of interest (HDI and GDP per capita), we use these variables as explanatory variables to estimate how an exogenous shock to one or more of these variables affects the latter. Dickey-Fuller (DF)[6](1979) and Phillips-Perron[7] (1988) stationarity tests show that all variables are I(1) except for the logarithm of GDP per capital.

[6] Dickey-Fuller (DF) tests allow us to identify the stationary or non-stationary nature of a time series by determining a deterministic or stochastic trend.
[7] This test is based on a non-parametric correction of the Dickey-Fuller statistics to account for heteroscedastic errors.

Table **6** and **7** present the results of the analysis for GDP per capita and HDI, respectively. The results are similar to those found for the panel of eight countries studied in the previous section. Indeed, the variable that most affects the two variables of interest is "the proportion of the population using drinking water services (ppeaupo)", thus reinforcing our previous idea about the impact of micro variables on macroeconomic aggregates of certain countries.

Table 6. VAR Analysis Results for Morocco (GDP per capita).

		Coefficient	Erreur-Type	z	p>z
Lgdcap	Ppeaupo	9.81	4.28	2.29	0.022*
	Ppassai	7.33	3.6	2.02	0.043*
	Ecosys	0.00	0.009	-0.53	0.599
	lMTDEV	0.014	0.03	0.645	0.645

Source: Developed by myself.
Note: * indicates that the results are significant at the 5% level.

Table 7. VAR Analysis Results for Morocco (HDI)

		Coefficient	Erreur-Type	z	p>z
IDH	Ppeaupo	0.60	0.25	-2.38	0.017*
	Ppassai	0.10	0.29	0.726	0.726
	Ecosys	0.00	0.00	0.101	0.101
	lMTDEV	-0.007	0.002	0.808	0.808

Source: Developed by myself.
Note: * indicates that the results are significant at the 5% level.

Granger Causality Test for Morocco

Tables **8** and **9** present the results of the Granger causality test for GDP per capita and HDI, respectively. Since the VAR analysis showed that the variables that most influence our two variables of interest are "the proportion of the population using drinking water services (ppeaupo)" and "the proportion of the population using sanitation services (ppassai)", we are interested in the causal relationship between these and GDP per capita and HDI. The test results confirm those found in Tables **6** and **7**. Indeed, the tests have shown the presence of a mutual influence relationship between the variables.

Table 8. Granger Causality Test (GDP per capita).

		chi2	prob chi2
	Ppeaupoo	5.24	0.022**
	Ppassai	4.09	0.043**
		chi2	prob chi2
Ppeaupo	Lgdpcap	1.877	0.0173**
Ppassai	Lgdpcap	17.149	0.00*

Source: Developed by myself.
Note: * and ** indicate significance at the 1% and 5% levels, respectively.

Table 9. Granger Causality Test (HDI)

		chi2	prob chi2
Idh	ppeaupoo	5.65	0.017**
	ppassai	3.17	0.072**
		chi2	prob chi2
ppeaupo	Idh	16.85	0.00**
ppassai	Idh	0.21	0.640

Source: élaboré par nos soins.
Note: * and ** indicate significance at the 1% and 5% levels, respectively.

4.2. Empirical Results of the PVAR Model

To generalize our findings beyond Morocco, we used a panel VAR model for eight African and Middle Eastern countries. Our results confirm our Moroccan-specific conclusions First, we present the impact of the different predefined explanatory variables on GDP per capita and then on the HDI. Table **10** presents the results of the analysis for both variables of interest. The results show that the variable "level of spatial extent of water-related ecosystems (ecosyseau)" has no effect on either GDP per capita or HDI. For the Human Development Index, it is the proportion of the population using drinking water services that has the greatest impact.

Table 10. Résultats du choc systémique sur le PIB/h et l'IDH.

Variables de réponse	Variables de chocs			
	lMTdev	dppeaupo	dppassai	ecosyseau
Idh	0.005**	0.12*	0.09**	-1.76
Lgdpcap	0.54*	0.02*	0.013*	-5.16

Source: Developed by myself.
***Note:** * and ** indicate significance at the 1% and 5% levels, respectively.*

Indeed, this impact can be explained by the fact that access to safe drinking water reduces morbidity rates associated with limited access to a potable water source. And since the HDI is a variable that is affected by life expectancy, the reduction in mortality rates helps to increase this index. The same explanation can be advanced for the variable "proportion of the population using sanitation services". On the contrary, for GDP per capita, the results show that it is the variable "amount of official development assistance related to water and sanitation (MTdev)" that most affects this index, with a 54% increase in the amount of official development assistance related to water and sanitation leading to a 1% increase in GDP per capita. It should be noted that these results reflect the eight countries in the study, and an individual analysis could show divergent results compared to the panel studied.

But certainly, the lesson to be learned in this context is that one way to improve economic (GDP per capita) and social (HDI) well-being in countries where access to water is limited is to invest in this area so that this resource becomes a non-exclusive public good again. Based on our results, it is undeniable that improving access to safe drinking water systematically increases life expectancy, which also helps to improve the Human Development Index.

Panel Granger Causality Test

In order to deepen our analysis and determine whether the model variables exert a causal influence on each other, and to better understand the nature of these relationships and identify the directions of causality, we will apply the Granger causality test. This test will allow us to answer key questions such as: Does X influence Y? or Does Y influence X? By definition, Granger causality means that: causes in the Granger sense if the current and past information of helps to improve the forecast of the variable given the past of this definition is based on the dynamic relationship between the variables. For our case, it would be useful to know the causal relationships existing between our explained variables and the other explanatory variables. Table **11** presents the results of the Granger causality analysis for the HDI, while Table **12** presents those for GDP per capita.

Table 11. Granger Causality Test for HDI.

		chi2	Prob > chi2
IDH	lMTdev	6.07	0.014
	dppeaupo	24.7	0.00
	dppassai	23.5	0.00
	ecosyseau	0.4	0.527
lMTdev	IDH	5.69	0.017
	dppeaupo	44.05	0.00
	dppassai	125.72	0.00
	ecosyseau	38.63	0.00
Dppeaupo	IDH	12.2	0.00
	lMTdev	2.15	0.142
	dppassai	71.15	0.00
	ecosyseau	29.5	0.00
Dppassai	IDH	8.38	0.004
	lMTdev	0.288	0.591
	dppeaupo	70.9	0.00
	ecosyseau	31.5	0.00
Ecosyseau	IDH	246.4	0.00
	lMTdev	218.46	0.00
	dppeaupo	64.5	0.00
	dppassai	1.34	0.246

Source: Developed by myself.

The results of the Granger causality test converge with those found in the PVAR analysis. Indeed, all variables have a causal structure with respect to the HDI, except for the variable 'ecosyseau'. This stipulates that improving the Human Development Index remains dependent on variables that are supposed to affect individuals.

Table 12. Granger Causality Test for GDP per capital.

		chi2	Prob > chi2
Lgdpcap	lMTdev	5.21	0.022
	dppeaupo	126.56	0.00
	dppassai	158.53	0.00
	ecosyseau	20.49	0.00
lMTdev	lgdpcp	16.27	0.00
	dppeaupo	144.53	0.00
	dppassai	170.4	0.00
	ecosyseau	30.04	0.00
dppeaupo	lgdpcap	17.08	0.00
	lMTdev	4.8	0.028
	dppassai	161.14	0.00
	ecosyseau	20.3	0.00
dppassai	lgdpcap	11.35	0.001
	lMTdev	2.46	0.117
	dppeaupo	158.74	0.00
	ecosyseau	18.74	0.00
Ecosyseau	lgdpcap	45.42	0.00
	lMTdev	1.85	0.17
	dppeaupo	149.15	0.00
	dppassai	97.42	0.00

Source: Developed by myself.

In the case of GDP per capita, the Granger causality test indicates that all variables, with the exception of "ecosyseau", have a causal relationship with GDP per capita. The consistency of this result across a large number of countries with similar characteristics suggests that quantitative inputs alone do not suffice to enhance the economic and social well-being of the population. Consequently, there is greater scope for individual-level adjustment variables, as improvements in well-being continue to depend on the living conditions of disadvantaged citizens and regions

5. ANALYSIS AND DISCUSSION

Firstly, to limit the scope to the Moroccan case only, we employed a VAR (Vector AutoRegressive) model approach (Lütkepohl, 2006) to determine the results solely for Morocco as the country of study.

When visualizing the results, we initially observe that our empirical findings suggest that the variable "level of spatial extent of water-related ecosystems (ecosyseau)" has no effect on either GDP per capita or the HDI.

For the Human Development Index, it is the proportion of the population using drinking water services that has the greatest impact. These results can be explained by the fact that access to safe drinking water reduces morbidity rates from diseases caused by limited access to a safe water source. And since the HDI is a variable that is affected by life expectancy, reducing mortality rates increases the percentages of this index. The same explanation can be advanced for the variable "proportion of the population using sanitation services[8].

This result is in perfect harmony with (Janez Sušnik & Pieter van der Zaag 2017), who explored the correlation between the Human Development Index and a set of variables including water, and they found that it is the variable "access to safe drinking water" that recorded the strongest correlation with the HDI (*i.e.*, $r^2 = 0.67$).

Our results also converge with those found by (Amorocho-Daza, H., van der Zaag, P., & Sušnik, J. 2023; Fukuda et al., 2019; Libanio, 2021; Kumar, M. et al. 2008), who demonstrated that variables related to access to safe water and sanitation are the factors that have the greatest impact on the Human Development Index at a rate of ($\rho = 0.84$).

Moreover, considering that human health[9] is an integral part of the calculation of the HDI (UNDP 2014), our results add to a large body of evidence supporting the idea that access to safe water and sanitation is a major factor for human health (Prüss, A., Kay, D. Fewtrell, L. and Bartram, J. 2002; Prüss-Ustün, A. et al in 2014; Lewin, S. et al 2007; Esrey, S. A. et al. 1991). Indeed, the literature is unanimous on the idea that human health is dependent on access to safe, clean water free from harmful substances and adequate sanitation services. Otherwise, humanity would face major health challenges, including high mortality rates and diseases such as (diarrhea, trachoma, cholera, schistosomiasis...).

On the contrary, for GDP per capita, the results show that it is the variable "amount of official development assistance for water and sanitation (ODA)" that has the greatest impact on this index. This result is in line with theoretical expectations and underlines the crucial importance of basic infrastructure for economic development. Several mechanisms can explain this relationship, such as improving population health, reducing absenteeism at work, and facilitating the development of key economic sectors. It is important to note that this effect is robust to different model specifications and that it stands out from the impact of other explanatory variables. These results have important implications for public policy, highlighting the need to prioritize investments in the water and sanitation sector.

In total, these conclusions suggest that improving water-related indices is achieved through quality rather than quantity (El Khanji, S. and Hudson, J. 2016). It appears in the model that quantitative inputs[10] do not contribute to improving economic well-being. This leaves more room for qualitative variables. While one might expect the extent of aquatic ecosystems to play a key role in economic development, our results suggest that it is rather the quality of water that is decisive. Indeed, variables related to access to a safe drinking water service and sanitation (variables related to water quality) have a significant impact on GDP per capita and the HDI, while the variable related to the extent of aquatic ecosystems does not show a significant correlation. This finding is in line with the work of El Khanji and Hudson (2016), who highlight the fact that the effect of water quality outweighs quantity.

Today, numerous debates revolve around improving water ecosystems in developing countries. These discussions generally focus on financing support mechanisms rather than on how these investments should be targeted and implemented to ensure that the proportions directly affecting individuals increase. In order to broaden the scope of the analysis beyond the Moroccan case and to generalize our results, we employed a panel VAR model approach, covering eight countries in Africa and the Middle East, including Morocco. The results obtained for this panel of countries confirm the conclusions established for the Moroccan case.

Indeed, the variable that most significantly affects both GDP per capita and the HDI is the "proportion of the population using drinking water services (ppeaupo)". This reinforces our earlier idea regarding the impact of micro-level variables on macroeconomic aggregates in certain countries. This postulate finds its theoretical foundation in studies that have explored the link between access to safe drinking water and human health. These studies support the hypothesis that access to safe drinking water leads to a reduction in diarrheal and other waterborne diseases, which can improve human health. Better health is likely to stimulate economic growth by increasing labor force participation and productivity (Banerjee & Morella, 2011; Cheng et al., 2012; Günther & Fink, 2011; Hutton & Chase, 2016; UNDP, 2006). Our results are similar to those found by Barbier (2004) who found, through his study on the effect of water scarcity on economic growth, that growth is negatively affected by the government's appropriation of production to provide water, but positively influenced by the contribution of increased water use to capital productivity. Cross-country estimates confirm this relationship and suggest that, for most economies, current water use rates do not impose any constraints on growth rates. Nevertheless, even in water-scarce countries, there seems to be no evidence that increasing production to provide water leads to significant diminishing returns, resulting in a decline in per capita income. Furthermore, our estimates converge with those suggested by Shafik and Bandyopadhyay (1992). They state that access rates to safe drinking water and urban sanitation improve with increasing per capita income, unlike other environmental indicators which deterio-

[8] Diarrhea remains a significant cause of mortality. According to the World Health Organization (WHO), improving water supply, sanitation, and hygiene would prevent 361,000 deaths of children under 5 years of age each year

[9] Given that it is through health that we can measure life expectancy.

[10] Non-significant impact of the variable "extent of the ecosystem"

rate as incomes increase. In addition, our conclusions join those found by El Khanji and Houdson (2016).

CONCLUSION

The contribution of water and its importance as a renewable energy source have proven valuable in recent years, especially in the context of drought and climate change. It is undeniable that more frequent and sustained access to water can improve the quality and life expectancy of citizens.

The aim of this paper was to empirically verify the aforementioned claims in the Moroccan context and for a range of countries with limited and underutilized water (and clean water) resources. By adopting a comparative perspective, we contribute to strengthening the external validity of our results and making them more relevant for the development of international public policies.

To assess the impact of water resources on development, we estimated the impact of exogenous variables on GDP per capita and then on the Human Development Index over a 15-year period (2005-2020). To better understand the impact of water resources on development, we combined an individual analysis of Morocco with a comparative panel analysis. Our methodology consisted of two steps. First, we conducted an individual analysis of Morocco using a VAR model to isolate the effects specific to this country. Second, we expanded our analysis to a panel of countries, using a panel VAR model, to identify the common determinants of economic and human development in a context of water scarcity.

Our results, both at the panel level and for the specific case of Morocco, highlight the central role of access to safe drinking water in human development. While public development assistance plays an important role in stimulating economic growth, it is the proportion of the population benefiting from drinking water services that appears to be the main determinant of the HDI. These results confirm the importance of public policies aimed at improving access to safe drinking water to improve the living conditions of the Moroccan population.

In summary, water is an indispensable element, both for economic growth and human development. To this end, it is undeniable that Morocco must continue its significant investment in water infrastructure, promote policies aimed at good management of this highly coveted resource, and also act on water quality, acknowledging the challenges arising from exposure to unsafe water.

Like any study, ours has its limitations. First, Morocco and other countries with similar water situations lack in-depth research on the impact of access to water on economic development. In this regard, it should be noted that the scarcity of research in this area is a barrier to the implementation of effective policies. Moreover, we consider that in addition to quality of life, education levels, and per capita income, there are other indicators that explain the HDI, including access to safe drinking water. In this sense, we have faced a scarcity of literature on this subject. However, the impact of access to water on human health has been extensively studied, as the HDI is a variable that is affected by life expectancy.

Next, the water issue is a problem that affects an entire country, but it affects the most vulnerable individuals to water scarcity shocks more (Devoto, Florencia et al. 2012). The type of data used in this work reflects the characteristics (averages) of a country, which limits the analysis to a more generalized and extended scope, whereas the ideal in the context of public policies is to target the region or communities most vulnerable to a phenomenon (in our case, water).

Previously, our objective was to undertake this study over a longer time period, but we were faced with the constraint of data availability. Finally, for the Moroccan case, a regional analysis would be more practical and could lead to conclusions that are completely different from those found in the general context of the country. In addition, and after exploring the impact of domestic water on economic development, it would be relevant to undertake other studies that analyze the impact of industrial or agricultural water on the same area; or to integrate more robust indicators of water quality and re-examine the impact on human development. Furthermore, the study of hydroclimatology and its impact on economic development would be a promising research opportunity for Morocco.

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