

The economics of the environmental footprint and green hydrogen as a Tool for sustainable development in Iraq(an analytical study)

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Abstract

The research aims to identify the concept and basics of the environmental footprint and to study the relationship between the use of green hydrogen and reducing the negative environmental impact, as the environmental footprint and green hydrogen are considered contemporary indicators in identifying ecosystems and preserving the environment, and it is an indicator for measuring the impact of pressures that Renewable environmental resources are exposed to environmental activities as a result of various human activities in the world or a region (production or consumption). The rate of an individual's ecological footprint increases with the greater the pressures resulting from the activities he practices. Biocapacity represents the amount provided by productive areas (marine and terrestrial). From materials and services sufficient for human subsistence, and the resulting waste and environmental pollutants, measured in global hectares per capita. The study concluded that green hydrogen is considered the fuel of the future and has a significant impact on achieving sustainable development, reducing the environmental footprint, and minimizing the costs of environmental degradation and erosion. The study recommended the use of green biofuels instead of fossil fuels to reduce carbon dioxide emissions and increase environmental allocations and investments in Iraq by decision-makers for rational environmental policies.

Keywords: environmental footprint , Green Hydrogen , Sustainable Development.

Introduction

The ecological footprint and green hydrogen contribute to achieving sustainable green development by linking its three dimensions: environmental, economic, and social. It is a tool and a means to reduce energy and resource waste, carbon emissions, and waste, thus achieving sustainable development goals. Development models for the traditional agricultural sector often ignore environmental safety. The environment, while its goal is to maximize profits and

minimize costs, is critical. The agricultural sector has a huge carbon footprint and simultaneously plays a dual role in economic impact, as it is the primary driver of creating green jobs, decent livelihoods, and mitigating climate change.

Research Problem

The research problem stems from the increasing severity of environmental pollution and the high environmental

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footprint resulting from the use of fossil energy sources, and the resulting negative environmental impacts, such as the spread of greenhouse gases, global warming, ecosystem degradation, and water and air pollution. The question arises: to what extent can green hydrogen reduce the harmful environmental footprint in Iraq?

Importance of the Research

The research is of great importance in contributing to reducing the negative environmental impact in Iraq by identifying the ecological footprint and green hydrogen through developing scientific and environmental solutions. It also plays an effective role in supporting low-carbon or zero-carbon agricultural economies. To raise awareness of the need to switch to using green hydrogen and reduce the environmental footprint of renewable and clean energy sources.

Research Objective

The research aims to:

1. Identify the concept and fundamentals of the environmental footprint.
2. Study the relationship between the use of green hydrogen and reducing environmental impact.
3. Identify the experiences and applied studies of some countries.

Research Hypothesis

The research is based on the hypothesis that the use of green hydrogen as an energy alternative contributes positively to reducing environmental pollution and achieving development and environmental sustainability. Green hydrogen also reduces the environmental footprint in Iraq.

Research Method

The descriptive theoretical approach was adopted, drawing on the tools and concepts of economic theory, in addition to the quantitative analytical approach using the Panel model.

Previous studies

- Researcher Kulionis (2013) conducted research on the relationship between renewable energy, carbon dioxide emissions, and economic growth in Denmark. The Kranger causality test was conducted to examine the relationship between renewable energy consumption and carbon emissions, as well as whether there is a relationship between GDP and energy consumption. Vector autoregression was used to determine the causal relationship between the selected variables. The Cranger causality test is the most common method for determining causal validity in energy consumption, economic growth, and pollution models.

- The researcher (Mikhnoet, 2021) conducted a study on the green economy and its role in sustainable development and improving efficiency. This study addressed its principles and foundations that affect urban expansion in industrial activities and increase human impact and environmental degradation. It aims to reduce environmental risks to the economic growth process. A comparative analysis was conducted between developed and developing countries. Then, the focus was on the external factor. Negative as taxes The losses resulting from the negative impact on the resulting economic indicators were also analyzed and it was proven that there was a significant decline in the level of per capita GDP with the widespread development of the economy.

- In a study (Nashur, 2022), a study was conducted on a balanced economic environment to achieve the components of a green economy and sustainable

development in Iraq. The environmental erosion of global economies requires a reconsideration of countries' economic concepts by reformulating the balance between development and the environment through green growth. He recommended the need to focus on environmental and economic indicators.

- (ZHANG, ET, AI, 2022) conducted a research on sustainable productivity, renewable energy, and environmental degradation: recent evidence from ASEAN countries. The research hypothesis stated that there is a statistically significant positive relationship between GDP and both renewable energy production and consumption in Egypt, investigating environmental degradation and reducing emissions. The researcher recommended the need for research and development to create new economic fields. Related to the fields of solar and wind energy technology, providing permanent job opportunities and improving the environment.

- In a study (2023, XIE, LI et al.) they analyzed the control effect of carbon emissions on urban economic indicators based on the concept of a green economy in light of sustainable development. The study addressed carbon emissions on the urban economy in a province in China and discussed the high carbon emissions of factories and companies that have a negative impact on the environment.

These concepts are among the most important contemporary environmental indicators today. The ecological footprint is an indicator of the impact of pressures on renewable resources and ecosystems resulting from human activities in the world or a region (production and consumption). The rate of an individual's ecological footprint increases as the pressures resulting from their activities increase. Biocapacity represents the amount of materials and services that

productive areas (land or sea) provide for human and other living organisms, as well as the waste and pollutants they produce. It is measured in global hectares and is calculated by dividing the area of productive land (biocapacity) by the population in a given area (Hussein and Mahdi, 2022). The carbon footprint refers to the total amount of carbon dioxide emissions. Which results directly or indirectly from a specific economic activity. It is a term derived from the ecological footprint (Yang and others, 2014: 132). It is a measure of environmental impacts in terms of greenhouse gas emissions released into the atmosphere resulting from various uses. Carbon is represented by any amount of carbon dioxide that is released as a result of burning fossil fuels such as gas, oil and coal. It is one of the ways human activities affect the environment in terms of greenhouse gas emissions, represented by methane, carbon dioxide, and nitrogen oxides. The combustion of fossil fuels such as natural gas, coal, and oil releases these gases into the atmosphere. Fertilizers, chemicals, and other industrial processes resulting from smokestacks, factories, and the use of machinery, equipment, and industrial processes are also considered.

Green hydrogen results from using electrical energy generated from renewable energy sources such as the sun, wind, and hydropower to split water into two molecules: a hydrogen molecule and an oxygen molecule. In this case, the hydrogen production process is carbon-free and free of any pollutants. It is capable of storing chemical energy and is environmentally friendly. It can be used directly or converted into so-called derivatives. Such as ammonia, synthetic methane, and sustainable fuels, the scope of work includes various types of hydrogen serving sectors such as energy, industry, and agriculture, supporting the decarbonization of emission-intensive

sectors such as capital-intensive industries. It is a type of fuel resulting from a chemical process that uses an electric current resulting from renewable sources that separates oxygen from hydrogen in water. It is an integrated concept with the environmental footprint, and thus it becomes energy produced without emitting carbon dioxide into the atmosphere, which causes global warming. It is a very effective gas and is considered an alternative to oil. It is not available freely and is considered a highly reactive element that is considered a source. For clean energy and as an economic engine, there are four types of hydrogen, each with its own production method (Abdul Hamid, 2022):

- 1- Gray hydrogen is extracted from natural gas at a high rate.
- 2- Blue hydrogen is extracted from gas with a medium carbon capture rate.
- 3- Green hydrogen is extracted from water using renewable electricity and electrolysis.
- 4- Black hydrogen is extracted from petroleum and coal

Environmental and Carbon Footprint Basics

Carbon footprint policies can control agricultural management through agricultural assessment to mitigate greenhouse gas emissions and thus reduce climate change and the climate burden. A key focus should be on increasing production and efficiency while reducing chlorocarbons. Soil has been shown to be of great importance in reducing conventional energy use and saving. Clean energy and thus understanding the role of low-carbon agriculture in providing clean energy (Ozlu, et al., 2022, pp. 14-35). Among the main determinants that

contribute to the increased carbon footprint associated with field crop production are various agricultural processes such as harvesting, tillage, pesticide spraying, and the gain or loss of carbon in the soil from various agricultural systems, as well as the decomposition of crop residues, processing, and storage. Fertilizers used in grain production contribute the largest proportion of the carbon footprint, averaging 65% of total direct and indirect emissions. Volatilization resulting from the use of nitrogen fertilizers in agricultural fields also contributes to total emissions. The use of inorganic fertilizers also leads to land degradation, making agriculture unsustainable in the long term. (Liu, and others, 2016:2) In order to measure environmental damage and address the challenges of sustainable development in Iraq, it is necessary to clarify the green GDP index, which is an indicator of economic development and takes into account the environmental damage of growth on the country's GDP. It is obtained by subtracting the costs of environmental degradation and carbon dioxide from the GDP. It also helps manufacturers Economic policies focus on understanding economic activities, accurately assessing environmental impacts, and then implementing effective environmental policies that direct resources toward sustainable activities. Green GDP takes a broad approach by integrating economic expansion with environmental sustainability and views the conservation of natural resources, biodiversity, and carbon reduction as essential to achieving material prosperity. Creating a balance between economic growth and environmental sustainability, the Green GDP works to provide clearer and more accurate pictures of the true state of the economy by calculating the costs of environmental degradation. It also urges decision-makers and policymakers to realize that economic progress should not be at the expense of the environment, thus

promoting the optimal use of resources and the adoption of sustainable practices (Bhaskar, and others, 2023:2).

Table (1): Shows GDP, environmental degradation costs, and green GDP in Iraq (2005-2024)

Years	GDP (million dinars)	environmental degradation costs	Green GDP (million dinar)
2005	29585788	81280	29504508
2006	53235358	88110	53147248
2007	73533598	85130	73448468
2008	95587954	82960	95504994
2009	111455813	76650	111379163
2010	157026061	88140	156937921
2011	130643200	94200	130549000
2012	162064565	108550	161956015
2013	217327107	113040	217214067
2014	254225490	129000	254096490
2015	273587529	139100	273448429
2016	266332655	134040	266198615
2017	194680971	133170	194547801
2018	196924141	142230	196781911
2019	225722375	155080	225567295
2020	268918874	163150	268755724
2021	276157867	174560	275983307
2022	219768798	143493	219625305
2023	301439533	153487	301286046
2024	383064152	120282	382943869

Source: Ministry of Planning / Central Statistical Organization, various issues.

It is noted from the table that the total costs of environmental degradation amounted to (2,405,65) million Iraqi dinars. The highest value was (174,560) million Iraqi dinars in 2021 and the lowest value was (76,650) million Iraqi dinars in 2009. The average value was (120,282.63) million Iraqi dinars, with a growth rate of (3.9%).

For the same period, this increase in the growth rate is due to several reasons, including those related to natural factors of

climate change, drought, desertification, high temperatures, and lack of rain, which led to a decrease in cultivated areas and a lack of vegetation and afforestation, and those related to human factors resulting from population growth and an increase in the number of compounds resulting from carbon dioxide gas.

Due to the dependence of most sectors on energy sources with high carbon emissions and the lack of dependence on renewable and clean energy sources, (Muhammad,

2023) As for the total green domestic product, which results from deducting the costs of environmental degradation from the total domestic product, it amounted to approximately (3888876187) million Iraqi dinars, while its highest value was (382943869) million Iraqi dinars in 2024 and its lowest value was (29504508) million Iraqi dinars in 2005. This may be due to the increase in carbon dioxide resulting from natural and environmental disasters and the use of various types of weapons in wars in this year. As for the average, it reached 194,443,809 million Iraqi dinars. With a growth rate of (9.4%). Despite the improvement and increase in the growth rate of the green gross domestic product. (Al-Sayed, 2023), there is a continuous increase in the emission of carbon dioxide. The carbon produced by the combustion of fuel in factories and vehicle exhausts. When comparing the GDP with the green GDP, we find that they follow the same trend of rising and falling.

Methods for calculating the ecological footprint and the carbon footprint.

The ecological footprint is measured by the global hectare per capita and is calculated using the following equation: Area of productive land \times Biocapacity divided by number of Population

As for the carbon footprint: The carbon footprint of food systems is an important research area in responding to climate change and is a key method for measuring carbon emissions in agricultural production. Studying the carbon footprint of food systems helps us accurately understand the characteristics and fundamentals of carbon emissions in agricultural production and provides a scientific basis for formulating strategies and implementation pathways. Reducing carbon emissions from agricultural

activities (Hassan, 2022) is of great importance in achieving green agricultural development, as the carbon footprint is measured from a sustainable food perspective. The agricultural carbon footprint is measured in light of food chains, crops, poultry farming, food processing and consumption, taking into account the daily lives of rural residents. Carbon footprint calculations have recently become in high demand, and many methods, tools, and methodologies have been developed to calculate them. The carbon footprint model for agricultural production depends on calculating the greenhouse gas emissions of agricultural products throughout their production period. The agricultural carbon footprint can be calculated through the following equations (Bakdi, 2020):

The carbon footprint of field crops = 16.4 tons of carbon dioxide (CO₂) per hectare of crop area.

The carbon footprint of burning agricultural residues = 4.1 kg of carbon dioxide per kilogram of residue burned.

Typical and hypothetical data covering the research were used, based on three dependent variables: (production value, environmental degradation costs and environmental footprint, and environmental investments) to understand the mutual and integrated impact of these variables on environmental performance and achieving sustainable development.

Table (2) Standard Model Description
Variable Type Code Description

Productivity	Value	(PP)	Produced
	(tons/hectare)		
Environmental	Degradation	Costs	(TE)
	(million dinars)		

variable	Type	The symbol	Description
Productivityvalue	continued	PP	/hectare) Productivity tons)
costsofenvironmental degradation	continued	TE	)milliondinars(
Environmental investments	continued	IE	)milliondinars(
the share of agricultural work	independent	AW	Totalnumber of workersdividedby the totalnumber of cultivatedacres
Mechanicaltechnology	independent	MT	Mechanicaltechnologyagriculturalmethods)thousandhorsepower) includeagriculturalsoilpreparationoperations , fertilizersspreadingmachines , pesticidesprayingmachines , harvestingmachines , inadditiontotraditionalormodernirrigationmachines.
Chemicaltechnology	independent	CT	technologyChemical) thousand tons(includeschemicalpesticidesgrowthregulators , agriculturalfertilizersand
Government support	independent	GS	Itis a governmentsubsidypaidtofarmersandagribusinesscompa niestoincreasetheirincomeandmanage the supply ofagriculturalcommodities
Cultivatedarea	independent	CT	Totalcultivatedarea) hectares(
Localprices	independent	GS	Priceper tonin US dollars
population	independent	CA	) million people (Totalpopulation
Worldprices	independent	LP	Priceper tonin US dollars
exchangerate	independent	PO	Number of localcurrencyunitsequivalenttoonedollar

This research will estimate three functions:

A. The production function: This function shows that the value of production, as a dependent variable, is affected by or responds to changes in four independent variables: the share of agricultural labor per dunum (AW), mechanical technology (M), chemical technology (CT),

government support (GS), and the random error term (Ui), meaning that

$$RP_{it} = F(AW_{it}, MT_{it}, CT_{it}, AS_{it}) + U_{it} \quad i = 1,2,3$$

B. Environmental Degradation Cost Function: This function shows that the environmental degradation cost function as a dependent variable is affected or responds to changes in three independent variables: green GDP, harvested area, local

prices, in addition to the random error (V), meaning that

$$TE_{it} = F(\widehat{WP}_{it}, CA_{it}, LP_{it}) + V_{it}$$

C. Environmental investment function: This function is shown as a dependent variable that is affected or responds to changes that occur in four independent variables: foreign investments, population, global prices, exchange rate, in addition to the random error term (W), meaning that:

$$IE_{it} = F(\widehat{WS}_{it}, PO_{it}, IP_{it}, ER_{it}) + W_{it}$$

Using the Panel Dynamic Ordinary Least Squares (PDOLS) model

In this research, the dynamic ordinary least squares (PDOLS) method, developed in part by Kao & Chiang, 2000 and Mark & Sul, 2003, was applied to characterize the value of productivity, the costs of environmental degradation, the ecological footprint, and long-term environmental investments. This procedure relies on the dynamic ordinary least squares method.

In the time series developed by (Saikkonen, 1991) and then generalized by (Stock & Watson, 1993) and has several advantages, namely that it works on direct estimates in the position of the mixture of static variables at level $I(0)$ or the first difference $I(1)$, and it also works on efficient estimators, and it can be used well in samples, in addition to the fact that it avoids the problem of overlapping independent variables and the random The application of the PDOLS technique includes four main steps:

Step 1: The cross-sectional dependence of the data is tested to verify the extent to which the data are cross-sectionally dependent. Therefore, appropriate tests for stationarity (unit root tests) are used. The most commonly used tests for cross-

sectional dependence of panel data are: Breusch-Pagan error term variable.

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1. Breusch-Pagan LM (Breusch & Pagan, 1980) 2. Pesaran Scaled LM (Pesaran, 2004) 3. Bias-Corrected Scaled LM (Baltagi, *et al.*, 2012) 4. (Chudik & Pesaran, 2015)

Step 2: When the null hypothesis of cross-sectional dependence of the data is accepted, the first generation of stationarity tests is used, which include tests such as (Dickey & Fuller, 1979), Fisher-PP, Z-test of (Hadri, 2000), (Levin, Lin & Chu, 2002) (LLC), (Breitung, 2002) and (IPS). However, in the case of accepting the hypothesis of cross-sectional dependence, the second generation of unit root tests is used, which provides more accurate information than using the first generation tests. Among these tests is the cross-sectionally augmented Dickey-Fuller test (PESCADF) (Pesaran, 2003).

Step 3: If some or all of the variables are non-stationary, cointegration is tested using error tests resulting from the estimation of the Panel model and the group statistics of Pedroni (2004), the Kao test (Kao & Chiang, 2000), or the Johansen test (Johansen, 1991).

Step 4: The dynamic ordinary least squares (PDOLS) method is used to identify the long-run factors that affect the value of productivity, environmental degradation costs, and environmental investments. Formally, the research model is defined as follows:

$$\Delta(Y_t) = \lambda Y_{t-1} + \sum_{i=1}^{k-1} \alpha \Delta Y_{t-i} + \beta X_t + \varepsilon_t \quad (4)$$

where Δ is the first difference parameter, Y_t is the dependent variable, λ is the dependent variable parameter, α is the dependent variable parameter in previous periods, β is the vector of independent variable parameters, X_t is the vector of independent variables, and ε_t is the random error term.

$$Y_t = \alpha_0 + \beta X_t + \sum_{i=-k}^k \Phi X_{t-i} + \varepsilon_t \quad (5)$$

where β is the vector of long-run coefficients, $X_{(t-i)^*}$ is the vector of stationary independent variables at first difference $I(1)$. Lead-Lags (k) have been added to the set of independent variables with $I(1)$ to eliminate the problems of endogeneity and autocorrelation between the independent variables.

Analysis and Interpretation of Results

1. Descriptive Statistics

Table (3) Descriptive Statistics for Research Variables

Descriptive statistics :1

Variables	standard deviation	greatest value	Less value	average
(P) Production)tons /hectare(	2,652,218	8,277,041	9,467	2,865
ironmental Degradation Costs Env (TE) million dinars	4,894,988	14,771,851	9,392	4,610
Environmental Investments () IE million dinars ()	12,408	57,064	3.50	8,037
Share agricultural labour per dunum (A W) worker/dunum (	2.73	9.92	0.44	2.14
Mechanical Technology (MT) thousand hp ()	2,433	7,404	132	3,320
Chemical Technology (CT)) thousand tons (	432	1,874	227	683
Government support (GS)) thousand dollars (	6,404	4,008	32,120	13,940

Cultivated area (CA) hectares	708,950	3,786,020	21,529	860,884
Local Price (LP) USD/ton	147.8	653.3	62.3	312.2
Population (PO) inhabitants	26,854,440	97,323,601	13,200,000	42,012,403
International Prices (IP) (USD / ton)	58	303	116	203
Exchange Rate (ER) local currency/dollar	668.0	1962.0	3.28	520.70

source: Prepared by the researcher.

dependent variable for each of the research functions.

2: Connections

Table (4) shows Pearson correlations between the independent variables and the

Table (4) Simple correlations between the variables of the research functions

Dependent variables			Independent variables	function
IE	TE	T		
		0.321 **	AW	Productivity value
		-0.532 **	MT	
		0.635 **	CT	
		-0.135	AS	
	0.210 **		CA	Costs of environmental degradation and ecological footprint
	-0.007		LP	
0.753 **			PO	Environmental investments
0.146			IP	
-0.166			ER	

** , *The correlation is significant at the 1% and 5% significance levels, respectively.

The results of the correlations between the variables of each research function indicate the following:

There is a positive relationship between the share of agricultural labor per dunum (AW) and the productivity value (P) at a significance level of 1%. Increasing the number of workers employed in agriculture leads to increased productivity, and vice versa. Mechanical technology (MT) had a negative relationship with productivity at a significance level of 1%.—

The increase in mechanical technology used in agriculture leads to a decline in the value of productivity. This result may seem contrary to economic logic and may be due to farmers' ignorance or perhaps the misuse of mechanical technology, which may lead to a decline in production instead of an increase in the country. As for chemical technology (CT), it is associated with a strong positive relationship with productivity at a significance level (1%).

Increased chemical technology used in agriculture leads to increased production, and vice versa. Agricultural subsidies (AS) appear to have little to no relationship with productivity, due to the lack of government support for agriculture in general or its poor allocation to non-agricultural sectors (Al-Dakari, 2021).

There is a positive relationship between the area planted with agricultural crops (CA) and the costs of environmental degradation and the ecological footprint (TE) at a significance level (1%). Increasing the cultivated geographical area leads to higher productivity and vice versa. The price of agricultural crops in local markets (LP) has a strong relationship with environmental costs.

There is a very strong statistically significant positive relationship between population (PO) and the costs of environmental degradation and the ecological footprint at a significance level of (1%). Population increase will lead to an increase in the ecological footprint and may lead to an increase in the costs of environmental degradation. Its international price (IP) has little impact on its import to developing countries. The growing need for a crop, whether to meet the population increase or to meet the environmental degradation.

Or to cover the decline in productivity, the government will increase imports even in light of rising global food prices, as food is a commodity essential to sustaining life and has low price elasticity. The exchange rate of the US dollar against local currencies (ER) also has a significant relationship with crop imports and increased investment.

3. Cross-sectional and unit root dependence tests:

The results in Table (4) indicate that there is cross-sectional dependence at a significance level of 1% for the data and each of the research variables. This indicates that any shock to any of the determinants of productivity, environmental costs, and environmental investment will lead to radical changes in Iraq. This stems from the fact that crops are among the most important food commodities (Bakhta, 2019) Price or quantity shocks in the production of this commodity could threaten food security for many countries around the world. In light of this result, unit root tests will be used for second-generation panel data, as shown in of the research functions.

Table (5) Results of the cross-sectional dependence test for the variables

Bias-corrected scaled LM	Pesaran scaled LM	Breusch-Pagan LM	Variables
11,736 **	11,696 **	33,324 **	Productivity(P)
7,011 **	7,071 **	20,770 **	CostsofEnvironmental(TE) Degradation
9.055 **	9.115 **	25,766 **	(IE) EnvironmentalInvestments
4.277 **	4.327 **	23,622 **	share of workAl- M Zari'i(AW)
8,780 **	8,730 **	22,553 **	MechanicalTechnology(MT)
8.619 **	8,569 **	22,259 **	ChemicalTechnology(CT)
17,061 **	17,111 **	45,312 **	Governmentsupport(GS)
2.116 *	2.157 *	7.332 *	CultivatedArea(CA)
13,027 **	13,087 **	35,430 **	LocalPrices)LP(
20.375 **	20,435 **	52,081 **	Population(PO)
30,459 **	30,519 **	77,000 **	InternationalPrices (IP(
12,151 **	12,221 **	32,737 **	ExchangeRate(ER)

Table (6) Second generation unit root test (PESCADF) for time series of research variables

Degree of stillness	PESCADF Constant + Trend	PESCADF Constant	the condition	Variables
I(0)	-3.121 ***	-2.233 *	Level	Productionvalue
	--	--	Firstdifferen	

			ce	
I(0)	-3.248 ***	-3.075 ***	Level	Costs of (TE)EnvironmentalDegradation
	--	--	Firstdifferen ce	
I(1)	-1.571	-1.445	Level	EnvironmentalInvestmen(IE)
	-6.686 ***	-6.415 ***	Firstdifferen ce	
I(0)	-2.867 **	-1.381	Level	The share of the dunum of workAgricultural (AW)
	--	--	Firstdifferen ce	
I(0)	-2.735 **	-0.812	Level	(MechanicalTechnologyMT)
	--	--	Firstdifferen ce	
I(1)	-1.852	-1.774	Level	ChemicalTechnology (CT)
	-5.334 ***	-5.012 ***	Firstdifferen ce	
I(1)	-0.445	-0.760	Level	Governmentsupport(GS)
	-15.521 ***	-22.431 ***	Firstdifferen ce	
I(1)	-2.429	-1.330	Level	CultivatedArea(CA)
	-4.743 ***	-4.833 ***	Firstdifferen ce	
I(1)	-1.428	-1.537	Level	Pri calLo (LP(ces
	-3.828 ***	-3.852 ***	Firstdifferen ce	
I(1)	-1.389	-3.532 ***	Level	Population(PO)
	-4.020 ***	-2.314 *	Firstdifferen ce	
I(0)	-3.114 **	-3.153 **	Level	InternationalPrices) IP(
	--	--	Firstdifferen	

			ce	
I(1)	-2.428	-2.353 **	Level	angeExchRate(ER)
	-4.246 ***	-2.327 **	Firstdifference	

*** , **The timeseriesarestationaryat 1% and 5% significancelevels , respectively.**

The results of the second-generation unit root test (PESCADF) indicate that the variables: productivity (P), environmental degradation costs (TE), farm labor per dunum (AW), mechanical technology (MT), and world price (IP) were stationary at level I(0), while the variables: environmental investments (RI), chemical technology (CT), government subsidies (GS), cultivated area (CA), domestic prices (LP), population (PO), and exchange rate (ER) appeared stationary at first difference I(1).

In light of these results, the research functions can be estimated using the dynamic ordinary least squares method for panel data after verifying the existence of a cointegration relationship between the variables of each research function.

4. Cointegration Test:

The existence of a cointegration relationship between the variables of the function means that these variables move together and simultaneously over the long run. Changes in one of the variables,

On average, changes in other variables occur over time. Based on the results of the Kao test for cointegration between the variables of each of the three functions of the analysis, we note that all results were significant, which indicates the following:

- The existence of a long-term equilibrium relationship between the value of productivity on the one hand, and the share of agricultural labor per dunum, mechanical technology, chemical technology, and agricultural support on the other hand.

- There is a long-term equilibrium relationship between the costs of environmental degradation, on the one hand, and both farmed area and local prices, on the other hand, in Iraq.

- There is a long-term equilibrium relationship between the costs of environmental degradation and environmental investments, on the one hand, and population, world prices, and the exchange rate in Iraq, on the other hand.

Table(7): Kao's test for cointegration

Kao Residual Cointegration Test		
Null Hypothesis: No integration		
Prob.	t-Statistic	function
0.015	-1.848 *	productivityfunction
0.000	-3.126 **	Environmentaldegradationcostfunctionandecologicalfootprint
0.000	-6.473 **	EnvironmentalInvestmentFunction

Estimating the search functions:

Based on the previous results, the long-run relationship for each of the three search functions will be estimated. Several methods allow for these estimations, depending on the characteristics of the data and the results of previous tests. In this case, we will use the dynamic ordinary least squares (PDOLS) method. One

advantage of this method is that it can be applied to both static data and non-static data.

and non-stationary (Neal, 2013), which allows us to include all the previously mentioned independent variables in these functions, in light of the results of the unit root test shown in Table (5).

A. Estimating the productivity value function:

Table (8): displays the results of applying the (PDOLS) method to estimate the productivity value function in the long run.

Dependent Variable: RP				
Method: Panel Dynamic Ordinary Least Squares (PDOLS)				
Prob.	t-Statistic	Std. Error	Coefficient	Variable
0.004	3.6850**	135259.3	498428.8	AW
0.000	6.3311**	47.08018	297.0714	MT

0.001	4.5482**	10094.44	45922.35	$\Delta(\text{CT})$
0.413	-0.8501	241.8322	-205.5815	$\Delta(\text{GS})$
	82.072**	F-Test	0.77	R-squared
	0.000	Prob.	0.74	Adjusted R-squared

*significance level of (1%). Increasing one worker per dunum planted with the crop will lead to an increase in its productivity in the long term (498,428) tons. This may be due to the application of the text of the second stage of the Yield Law, which is the economically optimal stage. Based on this result, this variable is the most important determinant. For crop productivity. There is also a highly significant positive effect of mechanical technology on productivity at a significance level of (1%), as increasing mechanical technology by (1000) horsepower in planting a certain crop will lead to an increase in crop productivity in the long term by approximately (297) tons. As for the effect of chemical technology on productivity, there is also a significant positive effect on productivity at a significance level of (1%), as increasing technology It will lead to an increase in productivity in the long run by (45922) tons. The results showed that there is no significant effect of government support on

productivity in the long run, and this may be attributed to the general decline in agricultural support, as the average annual government support did not exceed (10,850,000) dollars on average. Through the (F) test, the productivity value function is considered relatively significant in the long run at a significance level of (1%).

It shows that the function variables explain 74% of the productivity value.

B. Estimating the Environmental Degradation Cost Function and the Ecological Footprint

Table (8) displays the results of applying the PDOLS method to estimate the long-term environmental degradation cost function in Iraq (Al-Janabi, 2022).

Table (8): Results of the (PDOLS) method for estimating the long-term relationship of the environmental degradation cost function

Table (9): shows that there is a significant

Dependent Variable: TE				
Method: Panel Dynamic Ordinary Least Squares (PDOLS)				
Prob.	t-Statistic	Std. Error	Coefficient	Variable
0.000	198.841**	0.00130	0.27887	\widehat{WP}
0.000	102.458**	0.00858	0.88864	$\Delta(CA)$
0.047	2.1355*	17.0105	35.3426	$\Delta(LP)$
	19275.79**	F-Test	0.96	R-squared
	0.000	Prob.	0.95	Adjusted R-squared

** , *There is a significant effect at the significance level of 1% and 5%, respectively

positive effect of productivity on crop supply at a significance level of (1%). Increasing crop productivity by one ton will lead to an increase in crop supply in the long run by (0.278) tons. There is also a significant positive effect of the area planted with agricultural crops on crop supply at a significance level of (1%). Increasing the area planted with one hectare of agricultural crops This will lead to an increase in crop supply in the long term and reduce the costs of environmental degradation by 0.888 tons. As for the impact of crop prices in the countries' local markets, a significant positive effect of the

local price on crop supply was also demonstrated at a significance level of 5%. A one-dollar increase in the local price per ton will lead to an increase in crop supply in the long term by 35.34 tons in Iraq.

Through the F test, the supply function is considered significant in the long run at a significance level of 1%, as it indicates that the variables in the function explain 95% of the costs of environmental degradation in Iraq.

C. Estimating the Environmental Investment Function:

Table (10) Results of the PDOLS method for estimating the long-run relationship of the environmental investment function.

Dependent Variable: IE				
Method: Panel Dynamic Ordinary Least Squares (PDOLS)				
Prob.	t-Statistic	Std. Error	Coefficient	Variable
0.000	-25.1520**	0.00008	-0.00235	\widehat{WS}
0.000	19.6886**	0.00113	0.02242	$\Delta(PO)$
0.047	-2.62376*	3.11875	-10.6059	IP
0.000	-26.5199**	3.92883	-120.715	$\Delta(ER)$
	3097.10**	F-Test	0.88	R-squared
	0.000	Prob.	0.87	Adjusted R-squared

** , *There is a significant effect at the significance level of 1% and 5%, respectively.

The results of Table (10) show that there is a negative effect of crop supply on investment at the significance level of (1%). An increase in crop supply by one ton will lead to a decline in crop imports in the long run, which reduces environmental investments. There is a positive effect of population size on investments at the significance level of (1%). An increase in the population by one million people corresponds to increased demand for crops in the long term and increased environmental investments. As for the impact of crop prices in the global market, there is a negative impact of the global price on crop imports at a significant level (5%). An increase in the global price of one

Conclusions

- 1- The environmental footprint increases as the pressures resulting from these activities

dollar per ton will lead to a decline in crop imports in the long term, which leads to a reduction in investments (Abdul Hamid, 2022) regarding the price. The dollar exchange rate against local currencies in countries. An increase in the dollar exchange rate by one unit of the local currency will be met with a decrease in crop imports in the long run, which reduces investments. Through the F test, the environmental investments function is significant in the long run at a significance level of (1%), as it shows that the function variables explain (87%) of environmental investments. This increases these Investments in Iraq.

increase, as the rate of human consumption exceeds nature's production capacity.

- 2- It became clear that with the increase in the critical environmental limit, the environmental footprint increases. That is, the more humans consume resources than their renewal rate, the greater the environmental footprint, which constitutes a cause for environmental danger.
- 3- It has become clear that the costs of environmental degradation are an accounting tool that makes sustainable development a measurable element by measuring human consumption of its vital space. In comparison, the environmental footprint can be used by individuals and businesses to achieve sustainable development.
- 4- It became clear that the environmental balance deficit (ecological environmental standard) is the rate of human consumption exceeding nature's capacity to produce. The standard of the rate of human consumption has become exceeding nature's capacity to produce, as it is represented in calculating the area and productivity of land and sea necessary to produce the resources that humans produce to absorb the waste they leave behind.
- 5- Green hydrogen is considered a strategic option to reduce the environmental footprint. Technical and information technology advancements are essential to reduce environmental costs, make green hydrogen more competitive, and activate the role of environmental taxes in Iraq.
- 6- With the severity of climate change and challenges, this type of sustainable solution must be implemented broadly and quickly.

It can be the fuel of the future, achieving environmental sustainability and cleanliness.

Recommendations

1. The need to develop advanced mechanisms and models for collecting, reviewing, and auditing data related to ecological footprint calculations by environmental policymakers and making them available at the local and global levels.
2. The concepts of ecological and carbon footprints and green hydrogen should be widely integrated into development plans and policies.
- 3- The need to develop a scientific modeling tool to assess how policies addressing water and energy supply and demand affect carbon emissions.
- 4- The need to understand the impact of climate change on the organic carbon of different soils and determine the expected impact of climate change on the comparative range of soil inputs and degradation.
- 5-Focus on investing in green hydrogen, which is an alternative energy source that reduces emissions and environmental pollution, thus improving environmental sustainability.
- 6- Work to create or formulate integrated policies that include comprehensive environmental policies and work to achieve development and environmental sustainability.

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