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Circular Economy Strategy In Colombia: An Analysis Using A Multiple Linear Regression Model

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Abstract: One of the fundamental pillars to put sustainable development into practice are the principles of circular economy applied to production processes. In Colombia, in 2018, the National Circular Economy Strategy was established in order to promote efficiency in the use of materials, water and energy, taking into account the recovery capacity of ecosystems and the circular use of flows of materials. In this work, the prioritized lines in this strategy and their relationship with the country's gas emission were analyzed to determine an applied multiple linear regression model.

Keywords: circular economy, sustainable development, sustainability

1. INTRODUCTION

When defining the word sustainable development, (Cantú Martínez, 2013) refers to the great controversy that growth with care for the environment implies. That is to say, one cannot speak of economic development, generation of industries, technology, communications and think that each of these factors will not have any type of effect on the environment. Although on many occasions the impact of large developments has been attenuated by the resilience of both humans and nature, there have been events that have been of great environmental disaster. From each one of them and from the study of the damage caused to the environment, different world-wide debates have been emerging with different agreements and publications as shown in Figure 1.

With them it was finally possible to reach consensus such as the adoption of the sustainable development goals (SDG) formulated to eradicate poverty, protect the planet and ensure prosperity for all as part of a new sustainable development agenda (UN, 2015).

In the investigation of (Bustillo-García & Martines-Dávila, 2008), the authors begin their dissertation with the question: What really should be sustained? Question that leads to reflection about why sustainable development is concerned and the premise of sustaining the human race and with it a congruent rational dynamic based on the rescue of the biota.

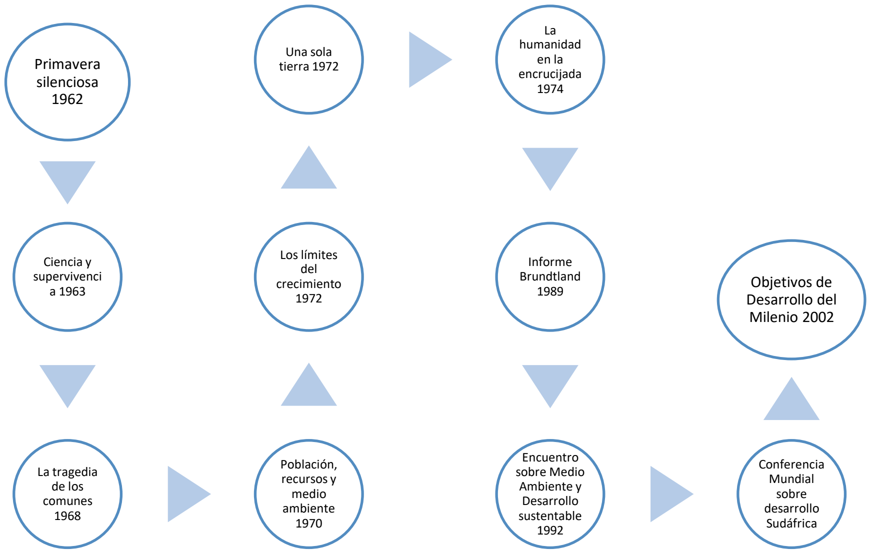

Figure 1. Reports and agreements from the 70's to the year 2002

Three approaches to sustainable development stand out (Figure 2): the first, economistic, the second, environmentalist, in favor of the conservation of natural resources; and the third focused on the binomial society-nature. The economistic approach is anthropocentric, that is, it only analyzes nature based on the well-being of man and is generally considered a linear model. The second environmentalist approach considers the scarcity of natural resources and incorporates an entropic perspective for production and the dynamic balance of the environment. And the third approach is based on a connection between society and nature, which is established by structural and functional relationships in which there are complex restrictions for development.

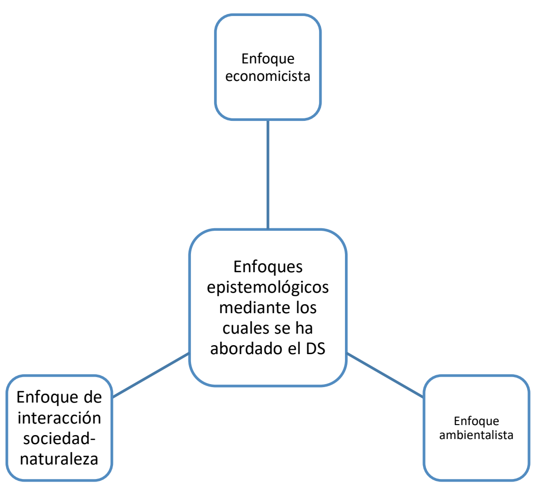

Figure 2. Approaches with which sustainable development has been approached

The circular economy and sustainable development

Paradoxically, sustainable development has been approached as an objective with different industrial models and from a linear perspective (Prieto-Sandoval et al., 2017). Even many of the efforts to solve environmental problems tend to be reduced to corrective or end-of-pipe and technological modernization that can buy time, but cannot by itself buy sustainability.

The Circular Economy (CE) paradigm is presented as the alternative to this linear model because it aims to generate economic prosperity, protect the environment and prevent pollution, thus facilitating sustainable development (Prieto-Sandoval et al., 2017).

In Colombia, a baseline was established for creative, innovative and sustainable industries, under the guiding motto of Pact No. IV "for sustainability: producing while conserving and conserving by producing", of the National Development Plan (Bello, 2020; PND, 2018). With this guideline, the gradual implementation of circular and orange economies was promoted as a way to innovate towards an economic system that would contribute to sustainable development. Then, in 2018, the National Circular Economy Strategy – ENEC was created in order to promote efficiency in the use of materials, water and energy, taking into account the recovery capacity of ecosystems and the circular use of material flows. (Ministry of the Environment and Sustainable Development, 2019).

The ENEC defines the circular economy as: Production and consumption systems that promote efficiency in the use of materials, water and energy and that take into account the recovery capacity of ecosystems and the circular use of material flows. Thus harmonizing Colombian development strategies with the Sustainable Development Goals, contributing to goals 6, 7, 8, 9, 11, 12, 13, 14, 15 and 17 (Figure 3).

Figure 3. Sustainable Development Goals. Source: (Contreras, 2013)

For its measurement and control, the ENEC recognizes several indicators proposed by the Organization for Economic Cooperation and Development - OECD to examine the progress of countries in the framework of environmental performance evaluations, such as : intensity in the consumption of materials and energy intensity, carbon dioxide (CO_2) emissions per inhabitant, the rate of use of waste or the rate of recycling, the ecological footprint per inhabitant per hectare, the percentage of reuse of water and the percentage of biomass use (OECD & ECLAC, 2014).

The objective of this study was to analyze the prioritized lines in the National Circular Economy Strategy and their relationship with the country's gas emission to determine those with the highest incidence and affect through an applied multiple linear regression model.

2. METHODOLOGY

The study carried out is exploratory, descriptive and longitudinal. For its realization, the information published by DANE in the Fourth and Fifth Circular Economy Reports was taken into account, which presents the information of 16 indicators categorized in the National Circular Economy Strategy grouped into six large groups (see Figure 4): i) Flows of industrial materials and mass consumption products – RAE – RESPEL, Steel and used tires; ii) Container and Packaging Materials, iii) Biomass Flows; iv) Water Flows; v) Energy flows and; vi) Construction materials. This classification thus allows the understanding and analysis of the circular economic model, and its relationship and impact with the environment and natural resources.

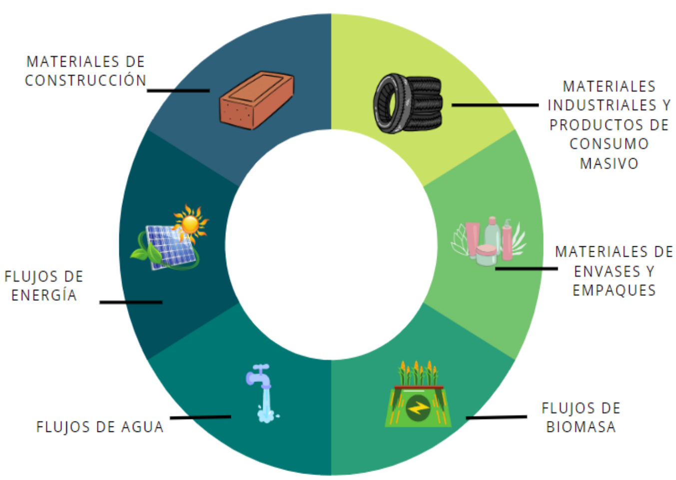

Figure 4. Category prioritized lines for the National Development Plan in the National Circular Economy Strategy - ENEC 2018. Source: Own elaboration with information from the ENEC

For the analysis of results, the environmental accounting accounts of DANE were first identified, taken into account in the National Circular Economy Strategy for the measurement and control of information. However, the information has been compiled to date in five reports between the years 2020 and 2021, there are some information gaps and not all the prioritized categories are fully covered.

Second, the accounting account variables were classified into two classes: issuer variables and absorption variables; thus making reference to the variables that most affect greenhouse gas emissions in the country since their flow into the atmosphere contributes to climate change by increasing the temperature of the planet, due to its ability to absorb and send infrared radiation from the land surface. The second class of variables are those whose natural action, such as capture through photosynthesis by plants, or those that, due to human action, are expected to contribute to reducing the environmental impact, such as wastewater treatment, recycling, renewable energy. renewable among others.

Once the emission and absorption variables were known, a statistical analysis was carried out to determine the relationship of each of them with the dependent variable GHG Emissions to find those with the highest positive correlation (emitters) and those with the lowest correlation (absorbers) to finally find a model of the accounts prioritized in the National Circular Economy Strategy, which would be the most relevant.

2.1. Data

The time series of the environmental accounts compiled in the DANE circular economy reports are found for some variables since 1995, however, for the most part there is only complete information for the period between 2012 and 2019. The Table 1 contains the names, description and unit of measurement of the "emitter" variables and Table 2 of the "absorption" variables.

Table 1. Variables Emitters of the study

Variable	**Description**	**Unit**
Emitting	Water Use Total Water Consumption economy	Cubic meters
GDP	Gross Domestic Product	Billions
Emissions	GHG Emissions total economy	Gigagrams CO2eq
HogGasnat	Natural gas consumption households	Terajoules
HogGasolmotor	Gasoline consumption motor households	Terajoules
HogLPG	Liquefied Gas Consumption of Petroleum (LPG) l households	Terajoules
HogLena	Firewood consumption households	Terajoules
HogElectr	Electricity consumption households	Terajoules
HogConsEnergPercap Ener	consumption per capita	Terajoules
ConsumptionEnerEm pr	Intermediate consumption of energy products economy	Terajoules

	(terajoules)	
OfferEnerFos	Supply of primary energy, fossil	Terajoules
AreaBosqModif	Area modified by type of forest cover	Hectares
ExtracMadNoSost Unsustainable	extraction, extraction and use of wood resources in natural forest	Cubic meters (m3)
ResidHogares	Waste generated households	Tons
ResidIndustria	Waste generated Ind ustria	Tonnes
FlowResEnvironment	flows into the environment	Tonnes
SupplyWaste	Supply of waste and residual products (Includes imports)	Tonnes

Source: Prepared by the authors with information from DANE (2022).

Table 2. Absorbent Variables of the study

Variable	**Description**	**Unit of measurement**
%Water vert	Percentage of wastewater discharged and treated by industrial establishments	%
PdnEnerrenovables	Renewable energy supply	Terajoules
Recycling	Recycling	Tons
RateRecycling	Rate of recycling and new use	Ratio
Absorc	Absorptions	(Gg of CO2 eq)
PdnMatReciclaje	Recycling material production	Tonnes
ConsumMatRecic	Recycling material consumption	Tonnes
ResidSoliUtiliza	Solid waste used in recycling and	Tonnes
EmissionsCol	GHG emissions	(Gg of CO2 eq)
ImptosAmbient	Environmental taxes	Billions of pesos[1]

Source: Prepared by the authors with information from DANE (2022)

2.2. The Model

The model to be used in the research that relates multiple variables to each other is called Multiple Linear Regression (MLR) (equation 1). Where the parameters β_1, β_2, …,β_n are known as the regression coefficients.

$$\hat{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \qquad \text{(Eq. 1)}$$

The RLM model measures the amount (+/-) that the dependent variable $\hat{Y}$ when the first independent variable X increases by one unit, maintaining constant other coefficients, and the same with the other regression coefficients, as long as the other independent variables remain constant, in what is known as elasticity of the dependent variable with respect to the independent (Martínez, 2012).

In the case of this study, the GHG Emissions variable will be modeled as the dependent variable and the regressor variables will be correlated positively (emitters) and negatively (absorption).

3. RESULTS

The study carried out is exploratory, descriptive and longitudinal. For its realization, the information published by DANE in the Fourth and Fifth Circular Economy Reports was taken into account, which

3.1. ENEC Data

3.1.1. Emitter Variables

Año Variable	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
UsoAgua	66789203	64210722	63565454	64494226	64539222	64833817	72199955
PIB	711415	747939	781589	804692	821489	832656	854008
EmisionesCol	22550650	21359383	25778861	24607929	24826333	26921062	29352851
HogGasnat	13	13	12	11	11	12	13
HogGasolmotor	21	20	26	28	28	31	24
HogGLP	5	5	4	8	6	6	5
HogLena	28	28	25	21	21	19	21
HogElectr	33	35	34	32	33	33	37
HogConsEnergPercap	2615004	2619867	2433176	2269819	2322355	2478632	2390321
ConsumoEnerEmpr	2187433	2201878	1975088	1763974	1830892	1970178	1925116
OfertaEnerFos	4964837	5018311	5033625	4894066	4734938	4657883	4574057
AreaBosqModif	1764499	2065445	1406574	1983766	1525686	1553874	2206280

ExtracMadNoSost	8041830	7756167	8360562	8908194	8461506	8594131	7808643
ResidHogares	8862000	8374542	9034750	9572328	10544501	10693136	11632368
ResidIndustria	10985171	9903264	12997108	11488045	11129165	12180508	13202178
FlujoResAmbiente	526761	502611	386077	218974	2683 28	352076	252819
OfertaResiduos	20310199	18934945	22603545	21787570	22370704	23577289	25625507

3.1.2. Absorption variables

Año Variable	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
%water vert	79	79	83	85	82	79	81
PdnEnerrenovables	415438	404735	417612	414802	411837	443155	447649
recycling	1780	1789	1666	1861	1901	2164	2357
Rate recyclingl	8	9	11	9	7	11	11
Absorc	19640	20791	21791	22227	22694	22833	23776
PdnMatReciclaje	1780	1789	1666	1861	1901	2164	2357
ConsumMatRecic	571	561	511	548	585	684	796
ResidSoliUtiliza	1548668	1697281	2415508	2037885	1656826	2533939	2897100
EmisionesCol	22550650	21359383	25778861	24607929	24826333	26921062	29352851
ImptosAmbient	170	182	216	207	726	612	827

3.2. Correlation analysis of emission variables versus GHG Emissions

Figure 5 contains the correlations of the emission variables listed in the methodology with information available in the 2012-2018 period. The positive correlation coefficient close to 1 would in this case be dark blue, while being a negative relationship close to -1 it turns red. The "x" on some correlations indicate that the correlation in this case is not significant since the value "p" does not meet the condition of being less than 0.05, therefore, it allows rejecting the null hypothesis of the correlation.

Since the variable of interest is Emissions, those with a blue correlation were analyzed, that is, GDP, Waste generated by households and Waste generated by Industry.

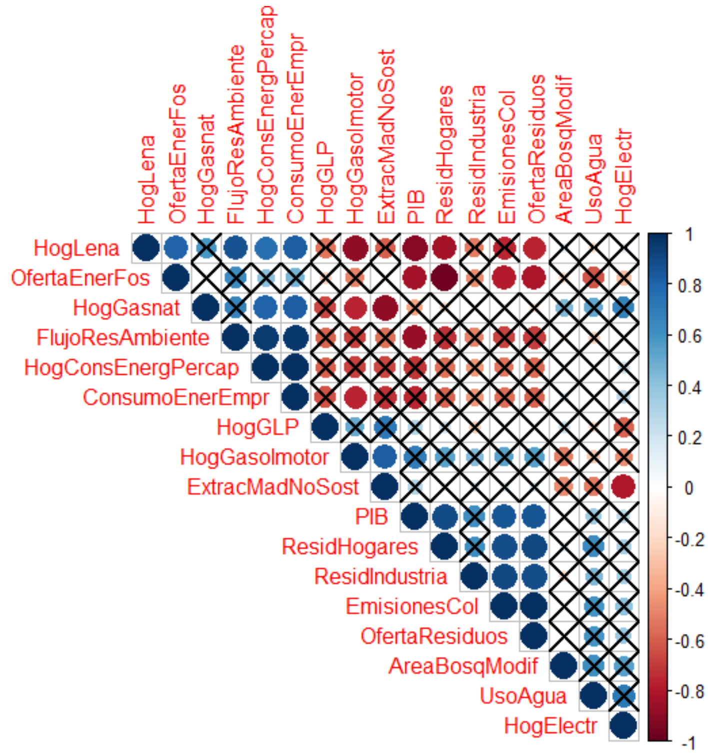

Figure 5. Matrix of variable correlations emitters Vs GHG Emissions. Source: Own elaboration in R

On the other hand, Figure 5 shows the correlations of the absorption variables listed in the methodology with information available in the period 2012-2018. The positive correlation coefficient close to 1 would in this case be dark blue, while being a negative relationship close to -1 it turns red. The "x" on some correlations indicate that the correlation in this case is not significant since the P-value does not meet the condition of being less than 0.05, therefore, it allows rejecting the null hypothesis of the correlation.

In this case, those with the highest correlation can be interpreted as the actions with the greatest force to counteract GHG emissions and that can be included in a regression model in a negative way, which are: Solid waste used in recycling and reuse and natural absorptions (Figure 6).

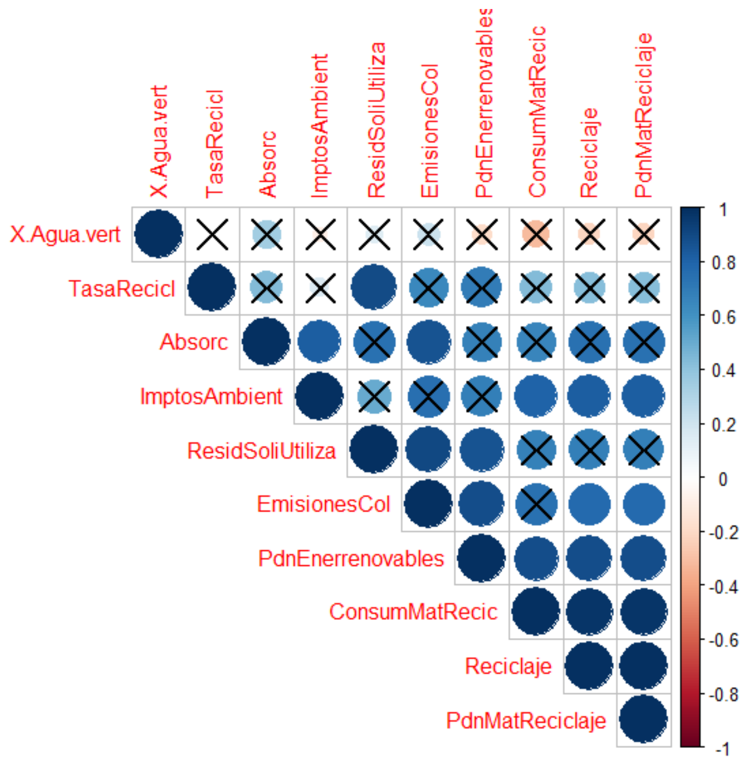

Figure 6. Matrix of variable correlations absorption Vs GHG Emissions. Source: Own elaboration in R

Taking into account the previous result, a regression model is found in R only with the variables: GDP, Waste generated by households, Waste generated by Industry, Solid waste used in recycling and new use and natural absorptions.

Summary of model[b]

Model	R	R squared	Adjusted R squared	Standard error of estimate	Estadísticos de cambio				
					Change in R squared	Change in F	gl1	gl2	Sig. Change in F
1	1,000[a]	1,000	1,000	51012,612	1,000	3278,392	5	a	1,013

a. Predictors: (Constant), Absorc, ResidIndustria, ResidHogares, ResidSoliUtiliza, GDP

b. Dependent variable: EmissionsCol

ANOVA[a]

Model		Sum of Squares	gl	Quadratic Mean	F	Sig.
1	Regression	42656577267189,170	5	8531315453437,834	3278,392	,013[b]

	Remainder	2602286615,698	1	2602286615,698		
	Total	42659179553804,870	a			

a. .Dependent variable: EmissionsCol
b. Predictors: (Constant), Absorc, ResidIndustria, ResidHogares, ResidSoliUtiliza, GDP

Model		Non-standardized		Standardized coefficients		
		B	Desv. Error	Beta	t	Sig.
1	(Constante)	-479504,127	615793,859		-,779	,579
	GDP	-1,110	5,120	-,021	-,217	,864
	ResidHogares	,998	,043	,439	23,399	,027
	ResidIndustria	,921	,040	,406	23,200	,027
	ResidSoliUtiliza	1,105	,101	,213	10,941	,058
	Absorc	160,108	180,239	,083	,888	,538

RLM:

$$\widehat{\text{Emisiones Colombia}} = -(479504.127e^{-16} + 1.110\text{PIB} - 0.998\text{ResidHogares} - 0.921\text{ResidIndustria} - 1.105\text{ResidSoliUtiliza} - 160.108\text{Absorc})$$

Since the Rsquared of the model is 0.9996, close to one, it can be established that the model explains all the variability of the response data around its mean. From the linear regression model found, it is possible to identify that the most prevalent emissions in Colombia are the Gross Domestic Product and the contributions of solid waste generated in homes and in industry, which have as mitigating or absorbing, the various activities of reuse of this waste, such as recycling, and the absorption of CO2 that ecosystems carry out in the national territory. No evidence was found of other elements that could directly and significantly affect the balance of emissions in Colombia.

4. CONCLUSIONS

There is a theoretical contradiction in the economic development of a society and at the same time the conservation of natural resources. That is why the documents analyzed make a dissertation and compilation of the different theories that have analyzed this axiom, separating the different approaches that have emerged throughout history into an economistic one with an anthropocentric axis and another ecologist, in the which incorporates an entropic perspective for the production and balance of the environment. On the other hand, in Colombia there is no record of evidence that demonstrates an optimal and wide application of the concept of circular economy throughout the national territory, particularly in the industrial and residential sectors of the country.

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