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ARIMAX Model to Forecast Grain Production under Rainfall Instabilities in Brazilian Semi-Arid Region

By José de Jesus Sousa Lemos & Filomena Nádia Rodrigues Bezerra

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GJHSS-E Classification: JEL Code: O13, Q13, Q16

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José de Jesus Sousa Lemos [α] & Filomena Nádia Rodrigues Bezerra [σ]

Abstract- The state of Ceará has most of its area in Brazil's semi-arid region. Initially, the research segmented Ceará's annual rainfall into 6 periods: very rainy, rainy, normal-humid, normal-dry, drought and very drought. This segmentation was based on the annual rainfall in the state between 1901 and 2020. The research estimated the average rainfall and instability of both the annual rainfall in the state during the period and those estimated for the periods in which the rainfall was segmented. The research then developed forecast models for harvested areas, yields, production values and average annual grain prices between 1947 and 2020, the years in which this information is available. To make these forecasts, the research used the ARIMAX model, which is an extension of the Box-Jenkins model, with the addition of an exogenous variable. The exogenous variable included in the model was the annual rainfall observed between 1947 and 2020, assuming that this variable influences these forecasts. The results showed that the state's rainfall has a high level of instability and that the adjusted models proved to be parsimonious and robust from a statistical point of view.

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I. Introduction

The Brazilian semi-arid region is not homogeneous in terms of landscape, availability of natural resources or floral cover. The convergence that exists in the immense area that makes it up is climatic instability, reflected in the poor distribution of rainfall, both from a spatial and temporal point of view. Also common among the mosaics found in this Brazilian ecosystem are agricultural activities, especially those producing food such as rice, beans, manioc and corn, which are practiced mainly by family farmers on a rainfed basis, as well as extensive livestock farming, both of which are high-risk activities. These activities have very low yields, even when compared to those observed in the Northeast, which is not part of the Semi-Arid.

There is no doubt that the Brazilian semi-arid region is one of the most vulnerable ecosystems due to the instability of the rainfall regime, which leads to the systematic occurrence of droughts and, often, the incidence of floods (Assad & Pinto 2008; CEDEPLAR & FIOCRUZ, 2009). The adverse climate conditions in the semi-arid region turn its population into potential migrants. These migrations to other cities and/or other states tend to aggravate social problems that already exist in urban areas of cities of all sizes, especially in large cities, by the so-called "climate refugees".

Due to these aspects related to climate instability and the lack of more consistent policies for the Semi-Arid population to live with climate adversity, the social and economic indicators prevailing in the populations that survive in the municipalities located in the Semi-Arid are quite critical (Marengo et al., 2011; Lemos, 2015, 2020).

In Brazil, there are differences between what is Semi-arid from a technical point of view, which is measured only by the aridity index (AI), and that defined by the Federal Government, which uses other definition criteria in addition to the AI. It is worth noting that municipalities officially recognized by the Federal Government as belonging to the semi-arid region receive differentiated treatment in public policies.

According to the latest revision of the Semi-Arid Map, carried out by the Deliberative Council of the Northeast Development Superintendence (CONDEL/ SUDENE) at a meeting held in December 2021, the Brazilian Semi-Arid now has 1,427 municipalities. In the new delimitation, Ceará now has 171 of its 184 municipalities (97%) recognized as part of this ecosystem (SUDENE, 2017, 2021).

Agricultural activities in any ecosystem depend directly on edaphoclimatic factors and therefore become more sensitive to climatic fluctuations. In the semi-arid region of Ceará, this is very evident, given that the technological advances that allow cultivation with water difficulties have not yet reached the vast majority of Ceará's farmers. For this reason, favorable climatic conditions are still considered the defining factors for obtaining good levels of productivity, production and income in agricultural activities. This is evidence of the vulnerability of the agricultural sector to the climatic instability that permeates the reality of the rural population whose main productive activity is agriculture, both crop cultivation and domestic animal husbandry (Deschênes & Greenstone, 2007; Fisher et al., 2009; Alemaw & Simalenga, 2015; Mallari, 2016).

Therefore, the exercise of trying to predict what is likely to happen in the state's grain crops, even knowing that rainfall, being a natural phenomenon, is totally unpredictable, could be useful for both farmers and those promoting public policies aimed at the production of these items in Ceará.

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The general objective of this study is to assess how the instability associated with rainfall influences the forecast of grain production in the semi-arid region of Ceará, from 1947 to 2020.

Specifically, the research aims to: a) classify the rainfall in the state of Ceará between 1901 and 2020; b) assess the behavior of the expected values and coefficients of variation of the variables associated with grain production in Ceará in each of the climate definitions constructed in the research; c) estimate how grain farmers in the semi-arid region of Ceará make projections about the area harvested, land productivity, production value per hectare and average price received, from 1947 to 2020; d) estimate how rainfall affects forecasts of the area harvested, productivity, production value per hectare and grain prices in the period evaluated.

II. Methodology

The study uses rainfall information provided by the National Oceanic and Atmospheric Agency (NOAA, 2022) and Fundação Cearense de Meteorologia e Recursos Hídricos (FUNCEME, 2022), for the period 1901/2020. Information on the crops studied was collected from the Sidra database and the Statistical Yearbooks of the Brazilian Institute of Geography (IBGE). The period of data availability extends from 1947 to 2020. The grains that make up the series studied are: cotton, peanuts, rice, broad beans, beans, castor beans, corn, sunflower seeds and soybeans (IBGE, 1947-2021).

In this study, three types of variables are considered: endogenous, exogenous and constructed. Endogenous variables are those over which producers have some (but not all) autonomy in defining their magnitude and can make expectations about their future behavior. For the purposes of this study, these are: harvested areas (in hectares) and yields (in kilograms per hectare). Exogenous variables are those over which farmers have no decision-making power. In this group of variables there are those in which the farmer can build expectations by gathering information, such as prices. But there is also the exogenous variable, over which farmers not only have no influence, but also cannot build expectations because it is linked to natural phenomena. This is the case of annual rainfall. The third group of variables studied are those that are constructed from exogenous and/or endogenous variables. This group includes the quantity produced and the value of grain production per hectare. The average price and value of production per hectare, used in the research as a proxy for gross income, are updated to 2020 values, using the general price index of the Getúlio Vargas Foundation (IGP-DI) as an indexer. The 2020 values in reais were converted into US dollars, using the exchange rate of R$5.1558/US$. The methodological procedures adopted are presented below, followed by the research objectives.

a) Methodologies used to achieve objectives "a" and "b"

The first objective of the research is to create an outline of the distribution of rainfall in Ceará between 1901 and 2020 and try to capture within it descriptive statistics associated with the variables involved in grain production, and what was the behavior of rainfall in Ceará between the years 1947 and 2020.

To help interpret the rainfall observed in the semi-arid region of Ceará, a classification table was drawn up based on the data observed in the series from 1901 to 2020. To this end, the average and standard deviation of rainfall during this period were estimated and six (6) periods were outlined for the distribution of rainfall in Ceará. These periods are outlined in Table 1.

Table 1: Classification of rainfall in the semi-arid region of Ceará taking into account the mean and standard deviation (sd) of the rainfall distribution observed between 1901 and 2020

Períods	Range
Very rainy	Rainfall > (Average + 1 sd)
Rainy	(Average + 1 sd) > Rainfall > (Average +1/2 sd)
Normal-humid	(Average +1/2 sd) > Rainfall > Average <
Normal-dry	Average > Rainfall > (Average – 1/2 sd)
Drought	(Average – 1/2 sd)> Rainfall > (Average – 1sd)
Very drought	Rainfall < (Average – 1 sd)

Source: Values to be established based on NOAA data (2022).

To confirm the consistency of the classification outlined in the paper, a statistical test is carried out to assess whether the rainfall averages estimated for each of the periods are statistically different. If they are, it can be assumed that the classification adopted is of practical use. The test used was to estimate the following regression:

$$C_t = \beta_0 + \beta_1 D_1 + \beta_2 D_2 + \beta_3 D3 + \beta_4 D_4 + \beta_5 D_5 + \eta_t \quad (1)$$

In equation (1), C_t is the annual rainfall; D_1, D_2, D_3, D_4 and D_5 are binary variables, defined as follows: $D_1 = 1$ in the drought period; $D_1 = 0$ in other periods. $D_2 = 1$ in the normal-dry period; $D_2 = 0$ in the other periods. $D_3 = 1$ in the normal-humid period; $D_3 = 0$ in the other periods; $D_4 = 1$ in the rainy period; D4 = 0 in

the other periods. $D_5 = 1$ in the very rainy period; $D_5 = 0$ in the other periods. When $D_1 = D_2 = D_3 = D_4 = D_5 = 0$, the very drought period is defined. The linear coefficient β_0 being statistically different from zero will be the average rainfall for the years of the very drought period. Since the other β_r coefficients ($r = 1, 2, 3, 4, 5$) are statistically different from zero, this means that the rainfall associated with the period β_r in question is different from the other periods. The random term η_t, by hypothesis, meets the assumptions of the classic linear model and so the parameters of equation (1) can be estimated using the ordinary least squares (OLS) method (Wooldridge, 2019). The hypothesis of this stage is that rainfall in the semi-arid region can be ranked as follows:

Very rainy period > Rainy period > Normal-humid period > Normal-dry period > Drought period > Very drought period.

b) Measuring the instabilities/stabilities of the variables studied (objective "c")

In order to assess the instabilities or stabilities associated with rainfall, as well as the variables used to study grain production in Ceará, the coefficients of variation (CV) estimated for each variable were used. By definition, the CV measures the percentage relationship between the standard deviation and the arithmetic mean of a random variable. The CV is useful for measuring the heterogeneity or homogeneity observed in the distribution of the values of a random variable around its mean. CV can be used as a measure of inequality and/or to measure the accuracy of experimental results (Gomes, 1985; Garcia, 1989).

The advantage of using CV in this evaluation model over other measures of variability is that it is independent of the units in which the variables are measured. Thus, it allows the comparison of homogeneities/heterogeneities or stabilities/instabilities between variables measured in different units of measurement (Allison, 1978; Garcia, 1989; Lemos & Bezerra, 2019; Garcia, 1989; O'Reilly et al., 1989; Punt, 2003; Wiersema & Bantel, 1993).

The lower the CV, the more homogeneous the distribution of observations around the mean. In order to use CV as a measure of homogeneity/ heterogeneity or stability/instability in a distribution, it is necessary to define its critical values. Gomes (1985) established limits for classifying CVs in agricultural experimentation (Table 2).

Table 2: Classification of the coefficient of variation (CV) according to its amplitude

Classification of CV range	Range CV (%)
Low	$CV < 10$
Medium	$10 \leq CV < 20$
High	$20 \leq CV < 30$
Very high	$CV \geq 30$

Source: Gomes (1985).

c) Methodological strategies for achieving objectives "d" and "e"

To achieve the fourth specific objective, the research uses the definitions and procedures discussed below.

i. *Definition of the model used*

The study is based on the equation for defining the quantity of grain produced (Qt), which is the result of multiplying the harvested area (At) by the productivity of the land (Rt) defined by equation (2):

$$Q_t = A_t R_t \quad (2)$$

Taking the logarithm of equation (2), and calculating the derivative with respect to time (T), we obtain:

$$d[\ln(Q_t)]/dT = d[\ln(A_t)]/dT + d[\ln(R_t)]/dT \quad (3)$$

Assuming that the derivative of the logarithm of a variable in relation to time measures the growth rate of that variable over time, equation (3) shows that the growth rate of grain production will depend on the addition of the growth rates of harvested areas and yields.

The value of production per hectare of grain (Vt), which can be understood as a proxy for the gross income per hectare associated with grain production, is in turn defined as shown in equation (4):

$$V_t = Q_t.P_t/A_t \quad (4)$$

Substituting into equation (5) the value of Qt shown in equation (3), taking the natural logarithm, and making the total differential in relation to the time of the result, we obtain the result shown in equation (5).

$$d[\ln(V_t)]/dT = d[\ln(R_t)]/dT + d[\ln(P_t)]/dT \quad (5)$$

Equation (5) shows that the growth rate over time of the production value per hectare of grain is the sum of the growth rates of yields and grain prices.

ii. *Predicted value of a random variable*

Given a random variable (Y_t), its predicted value (Y_P) will differ from its observed value if there are information shocks caused by unforeseen situations at the time expectations were formed. This can be represented by the error term ξ_t shown in equation (6):

$$Y_t = E(Y_t) + \xi_t = Y_P + \xi_t \quad (6)$$

If the Y_t series, which in this study can take the values of harvested areas, yields, production values per hectare or average grain prices, is stationary, ξ_t is endogenously white noise, Although it is endogenously white noise, in this study we assume the hypothesis that ξ_t is affected by the exogenous variable, rainfall (X_t). This is because it is assumed that the unstable temporal distribution of rainfall could cause the residual (ξ_t), which makes the predicted value Y_P different from the observed value of Y_t, to be affected by this exogenous variable (X_t), which is unpredictable for grain production decision-makers. This can be seen in equation (7):

$$\xi_t = f(X_t) \tag{7}$$

Substituting equation (7) into equation (6) gives equation (8), defined as follows:

$$Y_t = Y_P + f(X_t) \tag{8}$$

In this research, the empirical framework designed to estimate each of the predicted values (Y_P) for harvested area, land productivity, production value per hectare and average grain prices is anchored in the ARIMAX methodology, which is an expansion of the Autoregressive Integrated Moving Average (ARIMA) models, with the insertion of exogenous variables (Box & Tiao, 1975; Camelo et al., 2018).

iii. *Box-Jenkins ARIMA models*

The formulations proposed by Box and Jenkins (1978), ARIMA (Auto Regressive Integrated Moving Average), are mathematical frameworks that aim to capture the behavior of a random variable that has values distributed in realizations in the form of time series. The time series Y_t can be represented as follows:

$$Y_t = \mu + \Sigma\psi_k u_{(t-k)} = \mu + \psi(B).u_t \tag{9}$$

Where ψ, defined as the linear filter, is represented by:

$$\psi(B) = \theta(B) / \phi(B) \tag{10}$$

The terms in equation (10) are defined by the following polynomials:

$$\theta(B) = 1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q \text{ ; e } \phi(B) = 1 - \phi_1 B - \phi_2 B_2 - \ldots - \phi_p B^p$$

Defining $\tilde{Y}_t = Y_t - \mu_t$, it will be possible to obtain the following transformation:

$$\phi(B)\, \tilde{Y}_t = \theta(B).u_t \tag{11}$$

In equation (11), u_t is a generally Gaussian "white noise". To do this, it must meet the following conditions: i) $E(u_t) = 0$; ii) $E(u_t^2) = \sigma_u^2 < \infty$; e iii) $E(u_t, u_{t+k}) = 0$, para $k = \pm 1, \pm 2, \ldots$. (Cochrane, 1997).

According to Box and Jenkins (1978) equation (12) is called ARMA(p,q) and can be rewritten as follows:

$$\tilde{Y}_t = \theta(B)\, \phi^{-1}.(B).u_t \tag{12}$$

Types of Box and Jenkins models when the series is stationary:

i) *Autoregressive (AR) models:* These are those in which $\theta(B) = 1$ and are said to be AR(p). These models are so called because Y_t, at time t, is a function of the values of this variable at times prior to t (t - 1, t - 2, ...);

ii) *Moving average (MA) models:* These are those in which $\phi(B) = 1$ and are said to be MA(q);

iii) Models which are both autoregressive and moving average (ARMA) are those which are made up of two parts: one part (AR) another part MA, and have the notation ARMA(p.q).

iv) If the series is not stationary, converting it to assume this condition will require differentiation (d) of the dependent variable (Y_t). In general, with up to three differentiations, a non-stationary series will become stationary. In this case, it is said to be an ARIMA (p.d.q) model, where "d" is the number of differences needed to make the original series stationary.

III. ARIMAX Model

The ARIMAX model is a generalization of the ARIMA method with the inclusion of exogenous variables. In this study, the exogenous variable used is the annual rainfall observed for the state of Ceará between 1947 and 2020.

The ARIMAX model is considered multi-variate because it adds a linear component to the observations of exogenous variables. The main difference between this model and ARIMA is that ARIMAX has, in addition to the autoregressive and moving average parameters, the input of exogenous and linear variables (Bennet, 2014; Box & Jenkins, 1978; Box et al., 2015; Camelo et al., 2018).

The ARIMAX model can be understood as a combination of the Auto-Regressive AR(p), Integrated (d), Moving Average MA(q) and Exogenous X(r) models, and can therefore be symbolized as ARIMAX(p.d.q.r). In this study, the exogenous variable to be inserted is the annual rainfall observed in the state of Ceará between 1947 and 2020, assuming the hypothesis that temporal instabilities in rainfall affect the forecasting capacity of the variables that define annual grain production in the state between 1947 and 2020. A simplified way of mathematically representing this model in a generalized way is described in equation (13), which is the application of equation (8) to this research.

$$Y_t = [\rho + \Sigma\beta_j Y_{(t-i)} + \Sigma\theta_j \epsilon_{(t-j)}] + [\Sigma\omega_j X_j + \varepsilon_t] \tag{13}$$

According to the model proposed in equation (8), the predicted value (Y_P) is defined in expression (13) as follows:

$$[\rho + \Sigma\beta_j Y_{(t-i)} + \Sigma\theta_j \epsilon_{(t-j)}] \tag{13a}$$

And the term $f(X_t)$ is represented by:

$$[\Sigma\omega_j X_j + \varepsilon_t] \quad (13b)$$

In this research, the variables Y_t to be predicted as Y_P are: harvested area; productivity; production value per hectare and average grain price in the semi-arid region of Ceará between the years 1947 and 2020. In this research, the exogenous variable (Xj) is annual rainfall.

a) Stationarity in the Box and Jenkins model

A stochastic process $Y_t = \psi(B)u_t$ is stationary if

$$\psi(B) = \Sigma_{k=0}^{\infty} \psi_k(B)^k \text{ converge to } |B| < 1$$

It is assumed that most statistical analysis procedures for time series are stationary. If they are not, it is necessary to transform the non-stationary ones into stationary ones. The autocorrelation function between the residuals is estimated. If the autocorrelation function stabilizes at the first lag, then the series can be assumed to be stationary. If this is not the case, the second, third or more lags are used to find stationarity. In general, series do not need more than three lags to become stationary (Makridakis et al., 1998; Morettin & Toloi, 2006).

b) Steps to follow to achieve the best fit in ARIMA models

In general, three (3) phases are followed to define the best fit for the Box-Jenkins model so that forecasts can be made. The first phase is model identification, which consists of two stages: data preparation and model selection. At this stage we check whether the series is stationary. Stationarity is verified using the ADF (Augmented Dickey-Fuller) unit root test. The autocorrelation function (FAC) and the partial autocorrelation function (FACP) of the series are then calculated, in addition to the graphical analysis which allowed the ARIMA model (p, d, q) to be selected.

After the identification stage, the model's parameters were estimated (second stage). The "d" parameter refers to the number of times the difference between the elements of the series was taken until it became stationary. In this study, only the first difference had to be taken to make the series stationary (d = 1). Calculating the autoregressive parameters p and the moving average q involves analyzing the FAC and FACP functions, respectively.

Still in phase 2 of estimation and testing, once the appropriate values have been defined, the analysis of the residuals (ξ) is carried out, which must be white noise. For this purpose, the Ljung-Box (LB) statistic is used, which must be non-significant at a significance level of at least 10%. Next, the mean absolute percentage error (MAPE) is analysed, which considers the relative error of each forecast, in order to compare the values predicted by the model with the observed values of the series, characterizing the forecasting capacity of the model adopted.

To assess the suitability of the adjusted model, in addition to the statistical significance of the parameters, it is considered that the model will fit better if the number of estimated parameters is as small as possible. This is the parsimony criterion associated with the number of regressors to be estimated. The following criteria are also used: the magnitude of the coefficient of determination (R^2), which assesses the percentage of variation in the variable analyzed that is explained by the structured model; Pearson's correlation coefficient, to assess the level of adherence of the values predicted by the adjusted model to the data observed in the series under analysis.

In the verification phase, the analysis of the model consists of checking for the lowest values for the AIC and BIC criteria (Akaike Information Criterion and Bayesian Information Criterion, respectively), since these criteria aim to indicate the most parsimonious model, i.e. with the fewest parameters, since they are built based on the estimated variance (σ) and sample size (n). The model with the lowest AIC and BIC values will be the one that best fits the data (Brockwell; Davis, 1991). Once the most suitable model has been fitted, the predictions obtained are assessed for their accuracy using the Mean Absolute Percentage Error (MAPE) value. The best model should have the MAPE value (Camelo et al., 2018; Box et al., 2015; Wooldridge, 2019).

IV. Results and Discussion

The results of the research are presented in the order in which the specific objectives are distributed in the initial section of the paper.

a) Results obtained for the first and second objectives

The results found for annual rainfall in the state of Ceará between 1901 and 2020 showed that the lowest rainfall was 250.90 mm in 1919. The highest was 1773.40 mm in 1985. These values gravitated around an average of 798.82 mm, with very high instability, according to the classification of (Gomes, 1985) measured by CV=33.56%). In the period from 1947 to 2020, the state's average rainfall was 768.76 mm, showing very high instability, as measured by CV= 33.64%. The highest and lowest rainfall occurred in 1985 (1773.40) and 1958 (286.90 mm), respectively.

Table 3: Years of occurrence, averages and coefficients of variation (CV) of rainfall classified into periods between the years 1901/2020 and the period 1947/2020 in Ceará.

	Period from 1901 to 2020				Period from 1947 to 2020			
	Years of occurrence		Average	CV	Years of occurrence		Average	CV
Periods	Totals	%	(mm)	(%)	Totals	%	(mm)	(%)
Very rainy	18	15.00	1250.03[A]	15.32	7	9.46	1302.83	18.21
Rainy	17	14.17	989.28[B]	3.73	12	16.22	988.47	3.29
Normal humid	20	16.67	860.86[C]	4,32	10	13.51	852.45	4.98
Normal dry	28	23.33	716.61[D]	6.26	18	24.32	726.39	6.51
Drought	23	19.17	589.37[E]	6.80	17	22.97	591.94	7.05
Very drought	14	11.67	407.37[F]	20.19	10	13.51	424.44	18.29
Ceará	120	100.00	798.82	33.56	74	100.00	768.76	33.64

Source: Estimated values based on NOAA data (2022). Observation: the indices superimposed on the rainfall averages observed in each period have the following meaning: A>B>C>D>E>F.

Applying the test to check whether the averages of the periods defined in Table 1 are statistically different or equal, the results shown in Table 4 were found.

Table 4: Tests to assess whether the rainfall periods defined in the research are statiscally different.

Varibles	Estimated Coefficients	Student statistics test (t)	Signifcance
(Constant)	407.372	17.661	0.000
D_1	181.994	6.221	0.000
D_2	309.233	10.946	0.000
D_3	453.485	15.079	0.000
D_4	581.903	18.682	0.000
D_5	842.662	27.400	0.000

Source: NOAA (2022). Obs: Adjusted R^2 = 0.896.

The results shown in Table 4 suggest that all 6 periods tested are statistically different, with practically zero probability of error. The adjusted coefficient of determination (R^2 = 0.896) corroborates the information that the adjustment achieved was robust from a statistical point of view. Based on these results, the hierarchy assumed in the research definition is confirmed: rainfall averages: Very rainy> Rany> Normal humid > Normal dry> Drought> Very drought.

From the evidence shown in Table 3, it can be seen that in the 74 years evaluated, 17 years (23%) were considered drought and 10 years (13.5%) were considered very dry. Thus, it can be concluded that in 36.5% of the years studied in grain production, rainfall fell into the drought and very drought periods. The average rainfall for these two periods was 529.90 mm.

The very high instability estimated for Ceará's rainfall between 1947 and 2020 influenced those associated with the variables used to study grain production, all of which were classified as having very high instability. In fact, the estimated coefficient of variation for harvested areas was 41.02%; the estimated CV for yields was 58.68%. The CV calculated for production values per hectare was 42.18% and that estimated for observed prices was 61.24%.

The averages, as well as the coefficients of variation (CV), estimated to gauge the levels of instability associated with the variables harvested areas, yields, production value per hectare and average grain prices are shown in Table 5. The results shown in this table suggest that the instability observed in rainfall in the state of Ceará between 1947 and 2020 is also evident in all the variables studied.

In fact, only the harvested areas showed instability classified as medium (CV = 19.33%) in the very rany period. The value of production per hectare showed high instability in the very rany period (CV = 27.73%). In all the other periods, the variables studied showed instabilities classified as very high according to Gomes (1985). This confirms the assumptions underlying this study that rainfall instability is transmitted to the variables studied for grain production in the semi-arid region of the state of Ceará (Table 5).

Table 5: Averages and coefficients of variation (CV) of the defining variables of grain production in the semi-arid region of Ceará according to the rainfall season, between 1947 and 2020.

	Variables							
	Area (1000 ha)		Yield (kg.ha^{-1})		Value (USD.ha^{-1})		Price (USD.kg^{-1})	
Períods	Average	CV	Average	CV	Average	CV	Average	CV
Very rany	1729.92	19.33	376.86	27.73	329.62	37.39	0.95	42.95
Rany	1587.82	33.14	619.05	53.78	298.40	32.29	0.60	58.98
Normal humid	1363.42	40.72	731.10	51.96	321.35	31.22	0.55	54.86
Normal dry	1239.26	45.66	588.43	53.33	368.40	39.21	0.81	61.78
Drought	1303.81	38.37	418.24	52.66	246.33	53.44	0.75	71.91
Very drought	884.95	47.47	308.85	53.15	270.86	47.43	0.90	54.24

Source: Estimated values based on original data from NOAA (2022) and IBGE (1947-2021).

b) Results achieved to meet the third and fourth objectives

Having presented the descriptive statistics of the decision variables in grain production in the semi-arid region of Ceará, we will now present and discuss the results of the adjustments to foster expectations associated with the study variables. The stationarity tests showed that the series of harvested areas, yields, production value per hectare and average grain prices were not stationary, but that it was possible to reverse this situation by making just one difference.

Table 3 summarizes these results. Generally speaking, it can be seen that the best adjustments were made using ARMAX (0.1.1.1) models for the variables harvested areas, yields and production values per hectare. For the stationary price series, the best fit was an ARIMAX (1.1.0.1).

Table 6 also shows that the Ljung-Box statistics, which test the hypothesis that the residuals are all not significantly different from zero, at least at the 35% probability level, suggest that the resulting residuals are white noise. The adjustments obtained showed coefficients of determination (R^2) ranging from 0.613 in the model estimated to forecast yields to 0.721 in the model estimated to forecast prices.

The MAPE ranged from 18.848 for predicting harvested areas to a maximum value of 31.396 in the model estimated for predicting yields. The BIC statistics ranged from 0.593 for the model created to estimate prices to 25.637 for the model created to estimate harvested areas. The estimated correlation coefficients between the observed values and the values estimated using the models ranged from 0.890 for the model created to forecast yields to 0.974 for the model created to forecast prices. In this way, all the results obtained for estimating the four variables can be considered parsimonious and robust from a statistical point of view.

The estimated coefficients associated with the regressions, including the exogenous variable (rainfall), were all statistically different from zero at least at an error level of less than 2%. These results consolidate the assumption that the exogenous variable used in the research does affect the projections of the variables used to forecast harvested areas, yields, production values per hectare and average grain prices in Ceará between 1947 and 2020.

Table 6: Adjustments obtained for the ARIMAX models for the forecasts of harvested areas (ha), yield per hectare (ton/ha), production value per hectare (US$/ha) and grain prices (US$/kg) in the semi-arid region of Ceará from 1914 to 2020.

Var.	Model	AR Lag 1	MA Lag 1	X Lag 1	MAPE	BIC	Ljung-Box Sign.	R^2	R Pearson
Area	ARIMAX (0.1.1.1)	0.000	0.510*	476.886*	18.848	25.267	0.275^{NS}	0.717	0.910
Yield	ARIMAX (0.1.1.1)	0.000	0.506*	0.342*	31.396	10.637	0,470^{NS}	0.621	0.890
Value/ha	ARIMAX (0.1.1.1)	0.000	0.723*	0.548*	21.817	11.998	0.679^{NS}	0.681	0.907
Price	ARIMAX (1.1.0.1)	0.290**	0.000	-0.001**	20.855	0.593	0.206^{NS}	0.721	0.974

*Sources: IBGE (1947-2021); NOAA (2022). Note: *significant to less than 1% error; **significant to less than 2% error; NS: not significant to at least 20.6% error.*

c) Results obtained to achieve objective "e"

The results shown in Table 7 suggest that the intensity and instability of rainfall interferes with the predictive capacity of the variables used to define grain production in semi-arid Ceará between 1947 and 2020. These results also show that, in general, the greatest

difficulties in predicting the variables used to define grain production in the semi-arid region of Ceará between 1947 and 2020 occurred mainly during the very drought periods, especially in the case of predicting productivity (CV=40.45%), harvested áreas (CV = 31.68%) and production values per hectare (31.38%).

Table 6: Estimated mean of absolute forecasted erros (%) for each of the rainfall periods defined in the survey.

	Períods (%)					
	Very rany	Rany	Normal humid	Normal dry	Drought	Very drought
Areas	11.59	13.54	14.52	11.17	12.99	31.68
Produtivity	26.24	17.31	8.72	17.35	33.50	40.45
Value	7.51	14.71	5.80	11.36	24.50	31.38
Price	17.20	16.25	11.46	7.66	9.87	10.50

Source: IBGE (1947-2021); NOAA (2022).

To estimated mean of absolute forecasted erros of prices was was higher during the very rany period (17.20%). The results also showed that in very rainy periods, such as those defined in this study, the produtivity predictions made by the estimated models had high average absolute errors in the drought period (33.50%) and in the very rany period (26.24%). This evidence shows that high rainfall intensities can also create problems for grain production in the semi-arid region, causing high instability in its produtivity.

V. Conclusions

The methodological procedures adopted in the research made it possible to answer two questions: 1 - does the rainfall observed in Ceará, one of the Brazilian states with the highest relative number of municipalities located in the semi-arid region, influence the forecasts of the variables that define grain production in the state? 2 - Do the forecast errors of the variables that define grain production differ between the periods in which the classification of rainfall in the state of Ceará is defined?

In fact, the results found in the research showed that between the years 1901 and 2020 the average rainfall in the state of Ceará was 798.82 mm, with CV= 33.64%, classified as very high.

The evidence found in the study also shows that the objective of segmenting the rainfall observed in the semi-arid region of Ceará between 1901 and 2020 into six periods was achieved: very rainy, rainy, normal humid, normal dry, drought and very drought. It was shown that rainfall instability in Ceará between 1947 and 2017 spilled over into the variables associated with grain production in the state's semi-arid region: harvested area, productivity, production value per hectare and prices. All of these variables show statistically different values within the rainfall ranges created in the research, which made it possible to rank these periods according to the magnitudes of the average rainfall, as follows: very rainy > rainy > greater than normal humid > normal dry > drought > very drought.

Average grain prices showed the greatest heterogeneity over the period studied. As expected, when rainfall was lowest (drought), the average price was highest. However, the average values of these prices were not statistically different in the three periods in which rainfall was characterized in this study.

The adjustments made to forecast the variables studied were all satisfactory from an econometric point of view and also from the point of view of the assumptions that guided the research. These results showed that all the variables associated with grain production in Ceará showed high instabilities induced by the different rainfall regimes that the research was able to map.

Thus, the general conclusion reached in the work is that the rainfall observed in the state of Ceará over a 120-year historical series (1901/2020) can be segmented into periods according to the intensity and instability in which they occurred, and that for this reason it also interferes in the forecasts of the variables that define grain production in different ways in terms of forecast errors.

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Informal Cross-Border Trade Along the Eritrean- Ethiopian Border: A Factor of Conflict or a Way of Building Peace?

By Biyan Ghebreyesus Okubaghergis

Abstract- This paper explores the role of informal cross-border trade (ICBT) along the Eritrean-Ethiopian borderlands amidst a situation of war and uncertainty. It seeks to understand whether ICBT has contributed to the socio-economic recovery of people living on either side of the border and to rebuilding peace. It draws on semi-structured interviews and focus group discussions conducted with local informants between May and November 2021, including smugglers, traders, local officials, border guards, and ordinary inhabitants of Serha and Senafe, as well as my previous fieldwork and personal experiences in Eritrea and Ethiopia. My findings reveal that despite some challenges, ICBT has the potential not only to mitigate socio-economic problems among war-torn borderland communities but also to enhance cross-border relations by breaking down the stereotypes of suspicion and mistrust concocted by the warring states.

Keywords: *eritrea, ethiopia, informal cross-border trade, peace-building, war.*

GJHSS-E Classification: *LCC Code: HC800-889*

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I. Introduction

Since 1998, the political and military tensions between Eritrea and Ethiopia across their shared border have inflicted immense suffering on the borderland communities of both states. The conflict has led to displacement, misery, and violence. It claimed the lives of between 70,000 and 120,000 innocent Eritrean and Ethiopian soldiers between 1998 and 2000, and resulted in the displacement of 600,000 borderland civilians from the Eritrean side alone (Mengisteab, 2011:17; Steves, 2004:119-33). It is also estimated to have cost Eritrea between $500 million and $1.5 billion, and Ethiopia over $2.5 billion.

The aftermath of the war heralded an even more dreadful situation known as the "no war, no peace" era. For almost 18 years between 2000 and 2018, the bilateral relationship between the two countries was marked by sustained propaganda campaigns, recurring cross-border skirmishes, and interference in each other's affairs (Kaleab, 2019), and resulted in loss of human life, displacement, family separations, and devastating losses of livelihood for the vast majority of the borderland populations (Okubaghergis, 2023).

On November 4, 2021, another ruinous war broke out between the multi-ethnic Federal Government of Ethiopia and Ethiopia's Tigray State, one of the country's ten constituent states, effectively sabotaging the 2018 peace deal in the region (Shaw 2021). The war quickly escalated into a regional crisis involving the Ethiopian National Defence Forces (ENDF), the Eritrean Defence Forces (EDF), and the Amhara Special Forces against the Tigrayan Defence Forces (TDF)[1], which resulted in the temporary loss of Mekelle, the TDF's power base. Although it is hard to gauge the full effects of this new cycle of humanitarian tragedy at the time of writing, the war has caused massive displacement and devastation, particularly among the borderland communities (Reuters, 2021).

Against this backdrop of tensions and conflict, engaging in informal cross-border trade (ICBT)[2] between Eritrea and Ethiopia would appear to be an exceedingly risky enterprise, and yet across the decades, borderland communities have been actively involved in ICBT along the entire length of the shared border and on the front lines during periods of intense military and political insecurity, including the civil war in Tigray. Surprisingly, the relaxation of border controls by Eritrea and Ethiopia indirectly facilitated ICBT, contradicting the narratives of warring parties in which borders typically function as physical barriers and symbols of division among borderland communities. This relaxation was a consequence of the alliance between the ENDF and the EDF and their penetration deep into Tigray to pursue the TDF, which accidentally gave borderland civilians a degree of freedom.

This article uses a qualitative approach to address the following research question: How has informal cross-border trade contributed to socio-economic development and rebuilding peace among the border communities amidst war and uncertainty in the Eritrean-Ethiopian border area? The period from November 2020 to June 2021, which was marked by the relaxation of border control systems due to the alliance between the Ethiopian and Eritrean forces, witnessed

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[1] To avoid confusion, the term Tigray Defence Force (TDP) is used in this paper to refer to the Tigraya rebel forces, which the Federal Government of Ethiopia has branded as 'terrorists'.

[2] In this paper the term "informal cross-border trade" refers to exports and imports of legal goods and services across internationally accepted borders that bypass the regulatory framework for taxation and other modalities set out by government.

ICBT activities across the common border, particularly in Senafe and Serha. The primary objective of this article is to contribute to the ongoing theoretical and policy debates on the interplay between trade and borders, and on the connection between trade and peace-building.

My findings demonstrate that the relaxation of controls at the border and its modified function as a consequence of the political and military alliances between the Federal Government of Ethiopia and the State of Eritrea have transformed the broader economic landscape of the border region. The borderland communities seized the new business opportunities that arose across the Serha-Zalambesa borderland, resulting in unauthorized flows of people and goods across the border. Despite a number of challenges, ICBT has become a significant livelihood for borderland communities who had lost their original sources of income because of the war. It has also played a role in de-escalating conflict and fostering peace among people living on both sides of the border, even though these encounters and interactions have been short-lived.

The article first provides notes on the methodology and contextual background and on the shifting conflict dynamics across the border region and the implications for the fate of its communities. It then situates the argument within the literature on the nexus between trade and peace-building, and goes on to focus on the war in Tigray and ICBT, what it means for socio-economic recovery, and the resulting challenges. The conclusion reflects on what ICBT might mean for the local people and offers academic reflections and policy implications.

II. Methodology

The empirical data for this article were collected through focus group discussions, semi-structured interviews, field notes, and personal observations during fieldwork conducted between June and November 2021. These data sets were supplemented by my previous four-year-long ethnographic fieldwork and personal experiences in relation to trade, war, and livelihoods in the Senafe and Serha areas in Eritrea, and in Zalambesa in Ethiopia.[3]

A total of 29 people (8 women and 21 men) were interviewed. To safeguard their privacy, the personal details in this paper have been substituted with the initials of their first names. The participants include smugglers, traders, local officials, border guards, and ordinary inhabitants from Serha and Senafe. All of them were selected based on their grasp of past and present cross-border life among borderland communities. This study will only serve as an initial exploration, however, and I hope its findings will encourage further detailed investigations encompassing the entire borderland region once the political and military tensions among the warring parties have subsided.

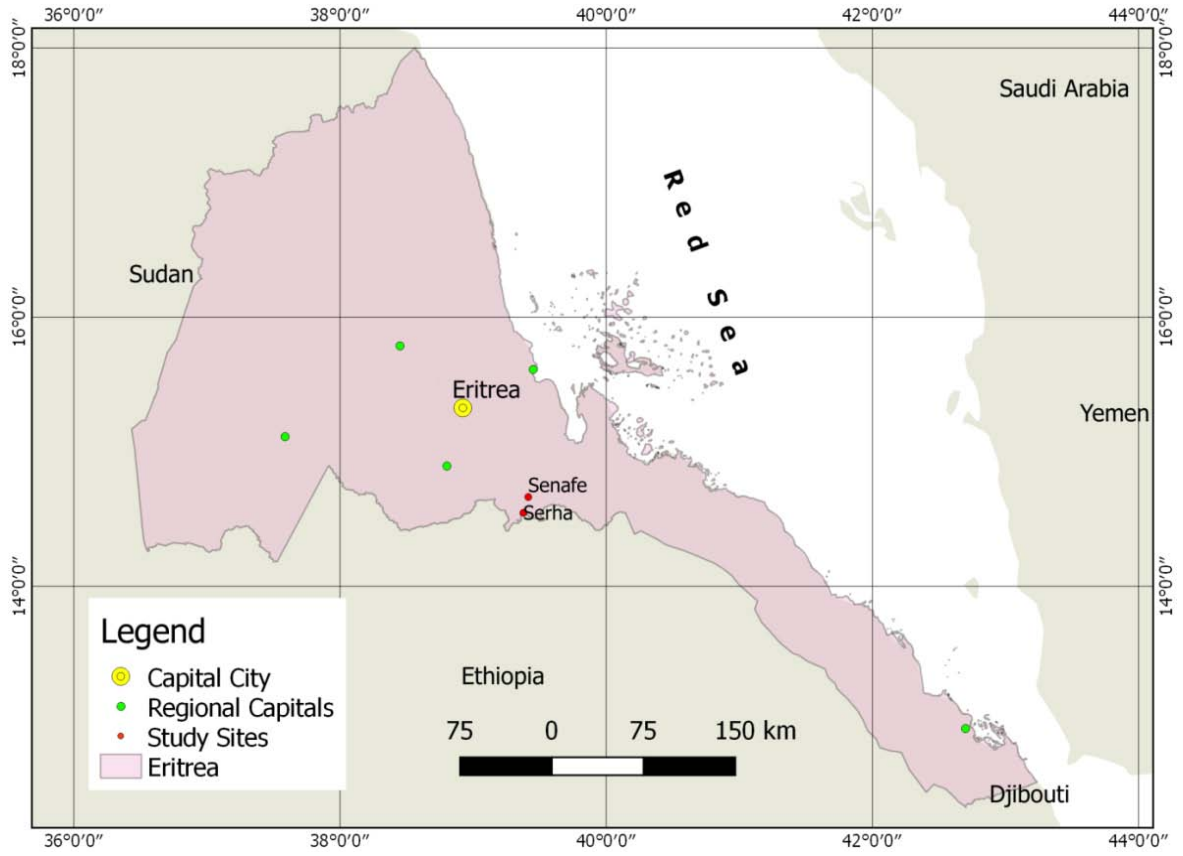
The sensitive and emotive nature of the topic under investigation gave rise to a number of ethical issues. During my research, I interacted with people from diverse socio-economic backgrounds. Securing informed consent posed challenges, as many of my interlocutors preferred anonymity and declined to be recorded. Many of these individuals only felt relaxed when my voice and video recorders were switched off, which made the process of building trust longer.

In some instances, therefore, it took me much more time than I had expected to gain the participants' confidence in me. The restrictions and insecurity associated with conducting fieldwork were also additional barriers. I found it difficult, for instance, to access Zalambesa after the TPLF recaptured Mekelle on June 28, 2021 and the subsequent renewed closure of the border. This problem was overcome by relying on data from my previous fieldwork and the few residents of Zalambesa with whom I interacted in Serha. Fieldwork-related rules and restrictions were also barriers.

III. The Study Area: Senafe and Serha

My two case studies, Senafe and Serha, are located in the central section of the Eritrean-Ethiopian border (see map 1). These two sites were selected for three main reasons. Firstly, because they are located at a crossing point on the border between the two states, the borderland communities share long-standing bonds through friendship, intermarriage, and trade with their kin on the other side. Senafe is mostly populated by the Tigrinya- and Saho-speaking ethnic groups, while Serha is predominately inhabited by the Tigrinya-speaking ethnic group (Okubaghergis 2020: 65-89).

[3] Zalambesa is a small border town on the Ethiopian border. It is located in Gulomkada, the eastern zone of Tigrai state. It lies about 500 metres south of Serha, the Eritrean border town.



Source: GIS Lab, Department of Geography, College of Business and Social Sciences, Eritrea.

Secondly, over the last two decades, these towns have been the epicenter of deep-seated cross-border conflicts, proxy wars, and severe border enforcement practices between Eritrea and Ethiopia. Throughout the "no war, no peace" years, the Eritrean-Ethiopian border next to the border between the two Koreans was one of the world's "thick" borders, meaning a border that is exceptionally difficult to cross, both physically and mentally (Haselsberger, 2014). Consequently, traditional formal relations among families and friends across the border, particularly in Senafe and Serha, remained closed off for almost 20 years. The jubilation on both sides of the border when President Isaias Afowerki and Prime Minister Abiy Ahmed met at the Serha-Zalembesa crossing point on September 11, 2018 was a celebration marking the end of 20 years of deadlock (Eritrea Profile, 2018).

Thirdly, my previous ethnographic and personal observations reveal that the residents enjoyed particular benefits from the ICBT that began with the tightened border controls in April 2019 until the civil war in Ethiopia broke out in November 2020. It provided access to low-cost goods and services, and most importantly employment opportunities for Eritrean borderland communities, despite the rules and regulations imposed by Eritrea, Ethiopia, and the regional government of Tigray.

IV. A Review of the Informal Economy: Informal Cross-Border Trade

The past two decades have seen the emergence of a branch of literature on borders and borderland studies informed by a wide range of academic disciplines, including anthropology, sociology, history, international relations, and economics. These studies offer valuable insights into the political, social, and economic implications of cross-border trade on populations living close to borders (Titeca, 2012; Wafula, 2010). Numerous scholarly and policy works have examined the impacts of ICBT, and have resulted in the development of several perspectives, a discipline-related lexicon, and theoretical frameworks.

From one perspective, ICBT has been seen as socially and economically undesirable for reasons associated with its unintended consequences for established local industries, including distortions of producers' price incentives (Ama et al., 2016). It has been accused of having latent effects that disrupt the efficiency and advantages of intra-regional cross-border networks (Healy, 2011). It is also viewed as a source of foreign currency deficits.

From another standpoint, ICBT is seen as a potential way of alleviating poverty and deprivation by

providing economic benefits to marginalized borderland communities. As Minde (1998), Harper (1985), Echessah, and Ackello-Ogutu (1998) have demonstrated, households engaged in ICBT sustain themselves and their families through the income it generates for them. ICBT also serves as a source of employment for economically deprived segments of borderland communities where formal economic alternatives are unavailable (Titeca, 2012). However, it often goes unrecognized by governments as a legitimate part of a national or regional economy.

This latter view has found favor with many borderland scholars in Africa (Lesser & Moisé-Leeman 2009). For example, in an effort to understand and map the day-to-day opportunities and problems facing borderland communities in the Mano River region of West Africa, Albrecht and Drew explored how "ICBT of livestock, agricultural and manufactured goods, and handcrafts forms the backbone of many locals' livelihood and deepens cross-border connections" (2011: 67-74). In their view, this ICBT network is fueled partly by cross-border familial relationships and partly by transnational networks among traders, as is the case in many parts of the Horn of Africa, which is the focus of this article.

Similarly, Tekere et al. (2000), Muzvidziwa (1998), and Mijere (2006) argue that ICBT has contributed not only to the livelihoods of borderland communities but also directly or indirectly to the socio-economic rehabilitation of different socio-economic groups living across borders. In this sense, ICBT has become "a means of survival, a source of income and employment" for many underprivileged people living in border regions in Africa (Muzvidziwa, 1998). It also contributes towards rebuilding peace among borderland communities by offering them various opportunities, including employment (USAID, 2021).

In the same vein, a broad range of case studies has focused on border trade amidst conflicts in general and on ICBT and its implications for borderland communities in particular, especially in the Horn of Africa. For example, some scholars have observed the development and challenges of ICBT in the Ethiopian-Somalian, Ethiopian-Kenyan, Sudan-South Sudan, and Uganda-South Sudan borderlands (Little 2014; Rolandsen 2019; Carrington 2009; Little 2015). As Carrington boldly argues: "In places emerging from conflict, trade offers opportunities to revitalize a region, re-establish relationships and build new links between communities estranged by violence" (*Ibid*. 1). Similarly, ICBT can either help rebuild peace or become a conflict factor among individuals living on each side of a shared border (Rokhideh, 2021). However, I feel there is currently a gap in the research when it comes to understanding how ICBT makes a direct or indirect contribution to socio-economic recovery and rebuilding peace among people living in the Eritrean-Ethiopian border region.

This paper covers a particular aspect of these studies: ICBT from the theoretical perspectives of the borderland communities. It focuses on the role of ICBT for these communities as they seek means of survival amidst war and a state of uncertainty. When I use the term "informal cross-border trade", I am referring to the import and export of legal goods and services across internationally accepted borders that bypass the regulatory framework for taxation and other government-imposed systems (Lesser & Moisé-Leeman 2009). This trade takes place through unauthorized or unofficial channels, and is mostly carried out by small businesses across borders. The term "borderland", on the other hand, refers to the physical space along the border. A good starting point for this endeavor is the history of this particular borderland and its changing significance over time.

V. The Changing Significance of the Eritrean-Ethiopian Borderland

This section offers a historical overview of the ever-changing status of the border and its implications for the fate of borderland communities. Over decades of shifting political and military circumstances between Eritrea and Ethiopia, the borderland communities have been able to learn not only how to live with uncertainty, restrictions, and war but also how to capitalize on their special geopolitical position and cross-border socio-cultural and familial ties. In this context, borderland towns have assumed a central position in the relationships between the nationalities living on both sides of the border.

In 1991, the Ethiopian army crumbled in Eritrea and Ethiopia in the face of joint operations by the EPLF and the Ethiopian People's Revolutionary Democratic Front (EPRDF) (Welde Giorgis, 2014: 148-149). Eritrea gained its independence as a result, and the colonial border with Ethiopia was reinstated. These events changed the border's geopolitical function from an internal administrative border to an international border between two sovereign states. As the overwhelming majority of the interviewees from the Eritrean-Ethiopian border area confirmed, this transformation brought significant positive economic dividends to the border areas, including Serha, Senafe, and Zalambesa (Okubaghergis, 2018:8).

As the post-independence political economy of the case area shows, many borderland inhabitants seized the economic opportunities offered by the geopolitical reconfiguration and capitalized on a variety of border-related factors, including price differences and specialized products, to earn a livelihood and accumulate wealth. As one border-crossing resident put it, "The border turned out to be a new breadbasket for

most borderland inhabitants" (YAS, 2017). The ability to exploit the price differences on either side of the political border was viewed as a good tactic for amassing wealth through formal and informal trading in the borderlands. As I have written elsewhere:

> Senafe became a land port town, with booming centers of commerce and trade built from the wreckage of the war that had raged for thirty years, mainly with the support of local private investment, much of it from Senafe businessmen. This was further empowered by various social services that provided institutions built by the government of Eritrea. Many exported or imported goods destined for either Eritrea or Ethiopia were loaded, unloaded, and rerouted from here in different directions. The local people also derived a huge benefit from the network and other types of work (Okubaghergis, 2018:80).

It was a similar story in Serha, where formal and informal cross-border trade only continued for a short period until the outbreak of the border war in 1998. During an informal conversation at the Serha border crossing point after the peace deal between Eritrea and Ethiopia on November 27, 2018, an 89-year-old man told me:

> I was born and brought up in Serha and worked across the border throughout my life. I have witnessed several phases of this border transformation and its implications for the local communities and the economy in Serha and Zalambesa. The dissolution of the Eritrea-Ethiopian Federation, the period of armed struggle, and post-independence Eritrea are just a few of them. The largest amount of cross-border business took place from 1991 to 1998. Formal and informal cross-border trade activities were common, and Serha was a well-known hub for the whole network (GMS, 2018).

In other words, during much of the 1990s, this border region served as a hub for formal and informal trade, contributing to local development and employment. These activities in turn fostered broader socio-economic relations within ethnic groups and families, allowing local communities to forge an extensive intra-ethnic cross-border network, and acted as a vital source of security and trust-building. In the region, the two towns and their inhabitants generated income as a result of their geostrategic location, and this was boosted further by the treaty of friendship and cooperation signed between Eritrea and Ethiopia in Addis Ababa on July 13, 1993, which resulted in an unprecedented surge in investment and infrastructure expansion (Tesfai, 1998).

However, circumstances changed with the outbreak of the two-year border war (1998-2000) and the subsequent "no war, no peace" situation, which lasted from 2000 to 2018 (Bereketeab 2013). The militarization and heightened security of the entire border area in response to an increase in the constant national security threats from one side or the other left the entire border region in a state of uncertainty. The borderland communities, which share the same culture and the same language, found themselves cut off from one another. In the words of an elderly woman whose daughter is married to a man from Zalambesa:

> It has been exactly 20 years since my daughter and I saw each other. I have only received information about her whereabouts, health, and family situation from family members in the UK and Israel or through the Red Cross. I know that she already has a large family. But it is not possible for us to meet or speak to each other as there is no line of communication. The closure of the border has separated us from one another. Recently, I heard that her elder son has married, but nobody has crossed the border. She did it without our being there, which is not only hard to believe but difficult to even imagine (SSU, 2017).

After two decades of limited cross-border exchanges, the Eritrean-Ethiopian rapprochement of 2018 transformed the border region once again, drastically relaxing the strict border control mechanisms (*Addis Standard*, 2018). On September 11, 2018, the Eritrean-Ethiopian border reopened at Serha-Zalambesa, Bure-Debai-Sima, and Rama-Kisad-Iqa (*Eritrea Profile*, 2018). No barrier now existed to stop the mobility of people, goods, and services from one political jurisdiction to the other as regards reuniting families, engaging in trade, or establishing businesses. Economically, Senafe and Serha flourished once again as centers of informal and formal cross-border trade, and the residents resumed their main activities. According to one of my informants, more than 2,000 vehicles of different types and functions crossed the international border at the official Zalembesa-Serha (Senafe) crossing point every day (AGD, 2018).

The socio-economic uplift was short-lived. A mere eight months after it reopened, the border was formally closed once again on April 19, 2019 for unknown reasons (*Africanews*, 2019). The decision prompted shortages of foodstuffs, fuel, and medicines in the border area, particularly on the Eritrean side. Life along the shared border was also impacted by the presence of the army. Cross-border social visits, shopping, and trade were all affected. As a result, as many interviewees put it, the failure of both governments to address local people's concerns drove them to become involved in informal cross-border trade practices throughout the border region. For example:

> For us, the borderland community, the border closure impacted every aspect of everyday life. The whole region was reduced to a pre-2018 situation. We are already cut off from our natural market and best livelihood alternative by the decision of the authorities from the two sides of border just for their respective competing agendas. It has caused a significant disruption of supply and demand chains, and so we are compelled to engage in this business, ICBT (MJM, 2019).

Local Ethiopian smugglers brought cheap goods to the Eritrean-Ethiopian border and sold them at reasonable prices to Eritrean traders there. The main imports from Ethiopia to Eritrea were foodstuffs,

manufactured goods, and other materials that were expensive in Eritrea (Okubaghergis 2020: 188).

Worse still, the outbreak of war in Tigray in early November 2020 brought a costly cycle of perpetual crises to the region. Numerous reports have noted that the relationship between Eritrean President Isaias Afowerki and Ethiopian Prime Minister Abiy Ahmad, together with the intransigent and inflexible position of the TPLF were the causes of the war (Shaw 2021, 60-73; *Africa Institute* 2021). Whatever the reasons might have been, the war in Tigray triggered major military and political upheavals throughout the Eritrean-Ethiopian border areas. However, as the next part of this article will show, despite – and partly because of – war and conflict, ICBT offered the borderland communities new opportunities.

VI. War in Tigray and ICBT in the Border Area

This section of the article goes into detail on the impact of ICBT on the borderland communities' socio-economic recovery and its indirect involvement in building peace, drawing from accounts offered by smugglers, traders, local officials, border guards, and ordinary inhabitants from Serha and Senafe. The overwhelming majority of them highlighted the fact that ICBT has played a positive role in reducing the socio-economic gaps created by war and uncertainty and in moderating tensions between the Eritrean and Ethiopian borderland communities. I will now take the discussion further by comparing the extent of this impact on the two towns, while also shedding light on the remaining impediments to the smooth operation of ICBT.

Within two weeks of the outbreak of war between the Federal Government of Ethiopia and the country's Tigray State in November 2020, the borderland communities found themselves caught in the middle of a military confrontation. As the Ethiopian Federal and Eritrean armies gathered for a ground invasion aimed at unseating the TPLF-led regional government in Tigray, the TDF shelled Senafe and Serha from Irob and Adigirat respectively. The ENDF and EDF then launched a powerful counter-offensive at Zalambesa and cleared the TDF from the border areas near Adigirat (BMS, 2021), all just one week after the beginning of the all-out war.

The war in the borderlands remained at a relatively low level of intensity, but as the Eritrean army deployed along the border on high alert, tensions remained high and there was a pervasive climate of suspicion from November 2020 through June 2021 (field notes, June 20, 2021). There were sporadic clashes between the ENDF and the TDF. A 34-year-old Eritrean field commander described the situation on the ground in blunt terms:

Weyani stooges, including militias and former members of the TDF, are very much alive on the Ethiopian side of the border, although they are unable to cause significant disruptions on the Eritrean side. EDF members are present carrying out sensitization work. They prevent subversive activities... The people act as the eyes and ears of the government and automatically report back to the relevant parties when they see or suspect anyone. Nonetheless, these are episodic clashes between the ENDF and the TDF in certain isolated areas (MSO, 2021).

The conflagration in Tigray spiraled out of control, resulting in all-out war in all parts of the region. The war underscored the complexity of ethnic and political tensions in Ethiopia, and the conflict was fueled by historical grievances. The international community, including the UNO, the United States, and the European Union attempted to end the war, but in vain (Tronvoll, 2022). All the warring parties met, but with little success. The ENDF, the EDF and the local regional militias made initial gains on the battlefield, including capturing Mekelle. After seven months of fighting, the TDF managed to take Mekelle back by force and with the support of the Tigrayan people on June 21, 2021.

Amidst these confrontations, ICBT emerged as a new livelihood among borderland communities because of price differentials and an imbalance of demand and supply on the Eritrean side of the border. The border area rapidly turned into a site of socio-economic exchanges as a result of the easing of checkpoint restrictions. As a 39-year-old Irob man told me:

> Since the onset of the civil war in Ethiopia, we have been accorded special economic opportunities against our expectations. As you see, we have been trading across the border. Both men and women participate in small-scale trading of all types of goods, and all the border crossing points across Schimezana plain are increasingly busy. [...] We have gained significant benefits from this business, and have been making a living (GKM, 2021).

The Eritrean border towns of Serha and Senafe served as the central hubs, while Zalambesa, an Ethiopian border town, functioned as the primary operational area. All three places became focal points for local borderland communities from Eritrea and Ethiopia engaged in trade, including the exchange of various smuggled goods. The products imported from Ethiopia largely included foodstuffs, construction and agricultural materials, and electronic and household goods (see Table 1).

Table 1: Price differences in consumer and construction materials across the entire Eritrean side of the border before (Summer 2020) and after (post-November 2020) the outbreak of war in Tigray and the subsequent relaxation of border controls (field notes, 2021).

S. No.	Description	Unit	Price in Nakfa	
			Summer 2020	Winter and Spring 2021
1.	Sorghum	quintal	1,500.00	700.00-800.00
2.	Wheat	''	2,000.00	700.00-800.00
3.	Rice	''	4,500.00	1,500.00
4.	Wheat flour	''	1,800.00	900.00
5.	*Teff* -white	''	4,00-5,000.00	2,300.00
6.	*Teff* -reddish	''	5,000- 6,000.00	2,500.00
7.	Red Paper	kg	130.00-200.00	60.00-70.00
8.	Pure water	litre	25.00-30.00	10.00-15.00
9.	Coffee	kg	160.00-260.00	50.00-60.00
10.	Sugar	kg	30.00-50.00	20.00-25.00
	Fuel			
1.	Benzene	litre	22.00-30.00	15.00-17.00
2.	Petrol	litre	26.00-30.00	12.00
	Building materials			
1.	Cement	quintal	2,500.00-2,800.00	300.00-400.00
2.	Joists	piece	350.00-400.00	100.00
3.	Galvanized steel sheets	piece	700.00-600.00	150.00-180.00

From the Eritrean side, traders traveled to the markets in Senafe and Serha from Zoba Debub (Southern zone), Zoba Meakel, and Semenawi Keih Bahr (Northern Red Sea zone). Most were small retail traders and business owners who arrived daily on donkeys, camels and bicycles, and even in small trucks. The largest volume of merchandise came via Adigrat and from as far away as Mekelle. The borderland smugglers, particularly those from Senafe, Serha, and Zalembesa, occupied a strategic position in this new contraband network on both sides of the border: the traders could not achieve their goals without the complicity of the smugglers.

Senafe also received goods from three other routes, however: Sebiya, Drim Ruma, and Mekheta. Residents and businessmen from Senafe brought supplies along four trading routes the most important source being the Zalembesa-Serha-Senafe route. Most of the smugglers who traveled along this route were between eighteen and fifty-five years old, and came mainly from the Irob ethnic tribes.[4] As most of the interviewees underlined, and as my personal observations confirmed, the majority were men. They used this particular trade route for three reasons: the absence of critical security threats from the remnants of the TDF forces because the territory was controlled by the EDF, the relatively shorter distance compared to the Serha-Zalembesa route, and fewer checkpoints.

One smuggler explained this to me in greater detail:

> Most of us smugglers use the Sebiya, Drim Ruma, and Mekheta trade route primarily because of the smaller numbers of checkpoints and local militia. There are also numerous hiding places and ways to escape unchecked. On the Serha-Zalembesa route, however, we face many challenges. There is also more anxiety at each checkpoint because of supervision, controls, and checks. Passing through each of the checkpoints without any hurdles or payments is very difficult (MZS, 2021).

The Eritrean smugglers usually leave from Zalembesa and other Tigrayan cities and towns and travel to Serha and Senafe during the night to hide from the Eritrean checkpoint guards, local militias, and other agencies. According to the interviewees, most of these were less vigilant between 1:00 a.m. and 5:00 a.m. after an exhausting day of work. Others, mainly smugglers who originally come from the border areas, leveraged their local knowledge of the land and people to easily slip out unnoticed at any time. Some used public buses or private cars and made payment or deals with checkpoint guards so they could pass through without any problem.

The Eritrean smugglers frequently made considerable profits by selling their imported Ethiopian items at higher prices than they would have been able to in their home country. They bought cheap goods in

[4] The Irob are a sub-group of the Saho ethnic group. They speak Saho and mostly live in the central area of the Eritrean-Ethiopian border region. They are partly Orthodox and partly Catholic, and predominantly farmers and pastoralists.

Ethiopia, which they sold at a great profit on their return to Eritrea, albeit at lower than during pre-war prices (see Table 1). Eritrean smugglers wielded considerable financial power in the transaction process, driving the market and dictating the Nakfa-Birr exchange rates, which was received in Tigray with unqualified satisfaction.

The flourishing ICBT gave rise to a new service economy. Residents of Senafe and Serha offered hospitality services, setting up tearooms, small eateries, bars, stores, and hotels. A 47- year-old woman who owned a small fast-food and tearoom in Serha explained this development and its positive implications:

> Immediately after the military build-up in this area, many Eritrean-Ethiopian soldiers gathered around this town and I started this business. The situation turned out to be a blessing in disguise for me and other residents. The fallout from the ongoing crisis is ICBT between the two borderland communities, which has resulted in increased cross-border economic activities and interactions. The town became a booming center of trade and commercial activities, attracting people from different directions. This in turn enabled us to make a living (LGA, 2021).

A similar version of this story was told to me by a 43-year old man who owned a small hotel with full facilities, including tea rooms and eateries:

> Following the softening of the border controls, most of us (residents) reinvested our money intensely in the service sectors, as the town turned to being a hub for a growing network of cross-border mobility of goods and people from Ethiopia to different parts of Eritrea (ABQ, 2021).

The cross-border contraband also created employment opportunities for many unskilled and unemployed young people. It allowed them to make more money and had a significant impact on the daily lives of people who were affected by the conflict. Many young people were able to do various wage-paying jobs, including construction, loading and unloading, and service centers in Serha and Senafe, something that had previously been restricted by the strict border regulations. Tigrayan smugglers supplied cheap construction materials and the necessary consumables to regular markets, and sometimes to workplaces, particularly in Serha. A 23-year-old interviewee from Serha told me:

> ICBT in this section of the border is not just a livelihood for people living on both sides of the border; it is also a source of stability and new fortunes, and has contributed to a surge in employment that has allowed many people to take different menial jobs. It is a key source of income for many borderland people, both Eritreans and Ethiopians (YGS, 2021).

In line with Tekere et al. (2000), Muzvidziwa (1998), and Mijere (2006), all these stories demonstrate how ICBT has contributed not only to the livelihoods of borderland communities, but also directly or indirectly to the socio-economic rehabilitation of various war-torn socio-economic groups living along the border, including farmers, smugglers, traders, intermediaries, women, and many young people who have been devastated by war. They also reveal how ICBT has helped to soften the hard border along the frontier between Eritrea and Ethiopia and re-establish ties between war-torn family members on both sides of the border while the two warring parties engaged in a terrible war (Tronvoll, 2022).

In this sense, the trade indirectly contributed to reconciling families. The towns, particularly Serha and Zalambessa, were meeting places for families who had been separated by war. People flocked to the market centers not only for the ICBT, but also to update one another about family members and other social issues. In particular, Eritrean families from mixed backgrounds crossed the border to find out about the fate and whereabouts of family members they had lost touch with because of the war in Tigray (field notes, 2021). During my fieldwork in Senafe, for example, I observed numerous clandestine funeral ceremonies in Senafe to honor family members who had been killed in the war.

ICBT therefore opened up opportunities for regular meetings and exchanges in market places, and these kinds of interaction and connection provided a platform for ethnic Tigrayan and Saho communities to reconnect and reintegrate family members who had been separated by war. As one local interviewee noted, this in turn allowed the borderland communities to gain a better understanding of how people can make the best of being trapped by the dynamics of conflict involving all the warring actors in the war in Tigrai (TAS, 2019).

VII. The Challenges for ICBT

However, the socio-economic opportunities connected with ICBT were not always without their challenges. Many participants faced significant issues when it came to accessing local markets, especially on the Tigrayan side. As one interviewee put it: “Some pro-TPLF militia groups and scattered former TPLF members attack or attempt to confiscate the possessions of Eritrean smugglers in order to sever the existing cross-border trade network between the two peoples” (MKS, 2021).

Many Tigrayans, particularly Irob smugglers, faced intimidation from the TDF. Others were compelled to stop doing business and asked to join the struggle against the Federal Government and its regional allies in whatever capacity or ways they could. An Irob interviewee of mixed Eritrean-Ethiopian parentage revealed that in most isolated Tigrayan border areas, members of the TDF sometimes issued stern warnings or threats against ICBT activities during night-time (THS, 2021).

Smugglers, intermediaries, and local borderland residents on the Eritrean side also mentioned various other hurdles involved in carrying out ICBT. These challenges varied depending on the trade route because of the differing sets of rules and restrictions relating to the mobility of people, goods, and services, particularly those imposed by Eritrea for security reasons. Many participants encountered restrictions from local militia, members of the EDF, and local municipal workers after crossing the border into Eritrea, and expressed dissatisfaction with these limitations.

During my fieldwork in Senafe, one of the members of my focus group told me about his personal experiences:

> From Zalambesa to Senafe or from Sebai to Senafe there are at least three checkpoints on average, though they are not as hard as during the "no war, no peace" decades. At each checkpoint, we have to take an informal route. Checkpoint guards, local militia, members of the EDF, and other local government authorities are everywhere. You have to hide from everybody, from staging places on the Ethiopian side to this town. This is why we resort to conducting our business under the cover of night (MIS, 2021).

The border restrictions on the Eritrean side were even stricter, however, and sometimes led to goods being confiscated. It might be argued that the aim of these security efforts was to contain threats from Tigrayans because of the war in Tigray. Many members of the Tigrayan political elites, scholars, and artists made hateful and derogatory speeches against Eritrea, even before the outbreak of the war in 2020. As one official from Serha said of the restrictions: "It also meant to contain trafficking of illegal and harmful goods such as drugs and weapons, which are categorically banned in Eritrea" (KMS, 2021).

There was a significant disparity in the level of border controls between the two case study towns, however: the Eritrean state deployed substantial forces in Serha and its surrounding villages because of its proximity to the international border and the fragile peace. By contrast, being a few kilometers away from the common border, Senafe and its people enjoyed a relatively safer position, leading Eritrea not to install as many checkpoints and patrol forces as in the Serha area.

Apart from the state-level restrictions, there were also other challenges from members of the local communities, some of whom bore grievances against the Eritreans because the war had damaged the exiting cross-border community relations. According to one interviewee from Serha:

> The present situation on the ground is quite delicate. The humiliating defeat of the TPLF in November 2020 is widely perceived not just as a defeat but also as a humiliation for the people of Tigray, breeding a sense of betrayal and outrage among TPLF supporters against Eritreans, and resulting in a new uneasiness among the border area people. In fact, some of them bluntly tell us that the day will come to claim their return (YWS, 2021).

The Nakfa-Birr exchange rate and the dominance of Eritrean smugglers were another challenge, particularly for Tigrayans. As a Tigrayan interviewee in Zalembesa told me:

> Eritrean smugglers control the market because they have a financial advantage. It is very difficult for us to compete with them. We need some regulatory mechanisms (AGZ, 2021).

This had been an area of concern for many Tigrayans even before the outbreak of the war in Tigray. During my fieldwork in Zalembesa in 2018, a 28-year-old businessman shared a similar story:

> Eritreans are benefiting more than us. They take advantage of the exchange rate difference between the Nakfa and the Birr on the black market. With 100 nakfa, they can buy so many things from Ethiopian side of the border, but we cannot do the same on theirs. It would therefore be beneficial to have regularity in our cross-border exchanges (BSZ, 2021).

In short, this points out how in some cases the positive relationship shown by the Eritrean borderland communities was not reciprocated because the war in Tigray brought immense suffering to the people of Tigray. The smugglers faced challenges, particularly from the remnants of the Tigrayan militia, the Tigray Regional Special Forces, and TPLF party members, who lost ground following the fall of the regional dstate of Tigray to the ENDF and the EDF. This reveals that there were obstacles that hindered genuine people-to-people cross-border encounters and interactions, thereby obstructing the construction of a trajectory toward peace.

On June 21, 2021, the situation changed abruptly. Under massive pressure from the United States and the international community, the ENDF and the EDF withdrew all their forces from the interior of Tigray (Ghebreab, 2021). This move initially triggered a reorganization of supply circuits from the Ethiopian side to Eritrea. For the first time, Eritrean smugglers illegally sold goods brought from Eritrean markets including yeast, salt, edible oil, sugar, and wheat flour to Tigrayan traders. A few months later, however, Eritrea banned cross-border economic activities, and as a consequence Zalambesa, which was an epicenter of cross-border trade, became a frontier town. Most of its residents fled for their lives to the immediate neighboring villages, towns, and cities, and former ICBT hotspots and routes fell under the control of EDF or TDF forces.

VIII. Conclusion

In this paper, I have sought to understand how ICBT offered economic opportunities during the war in Tigray and created a setting for encounters and

interactions among the borderland communities inspired by Eritrea's softening of controls along the border with Ethiopia as a result of the countries' joint military enterprise in the war in Tigray. The objective of this article has therefore been to contribute to the ongoing theoretical and practical policy discourse on the nexus between trade and borders on the one hand, and trade and peace-building on the other.

My article is situated in broader contemporary borderland studies and draws on detailed fieldwork research carried out mainly on the Eritrean side of the borderlands. I argue that soft borders are helpful for border communities even where a war is under way. Through ICBT, which was historically the people's natural response to Ethiopia's deficit economy and later on to Eritrea's post-independence transition, the two communities were able to make a living, and as a result the borderlands rapidly became a center for socioeconomic exchanges.

As Rokhideh (2021) has noted, ICBT helped the border people make a socio-economic recovery amidst war and a state of uncertainty. In a technical sense, to use the words of Nugent and Asiwaju (1996), the common border served the border communities as "conduits and opportunities" in this context. Despite the complex and obscure military situation, many Eritreans crossed the border to shop in the markets of Zalembesa and Adigrat, where prices were much lower than they were in Eritrea. In turn, these constant encounters and interactions slowly provided them with a setting for rebuilding a feeling of trust toward each other.

Another important feature in this microcosm of war and trade is the primacy of intra-ethnic relations. It presents the complex dynamics of these family relations in the conflict in the region. Notwithstanding the effects of the state of war and the State narratives of exclusion and practices, the communities on both sides of the border, who are related by culture, history, and language, as well as by economic and other cross-cutting interests, maintained their ties and shaped their own world. This article therefore argues that ICBT not only has the potential to mitigate conflict amongst borderland communities, but also enhances cross-border relations by breaking down stereotypes of suspicion and mistrust concocted by States.

However, the socio-economic opportunities associated with ICBT were not without their problems. Many of those involved in the business faced significant challenges, including border controls, border regimes, limited access, and confiscations by various border authorities including border patrols, militias, local municipality officials, and members of the armed forces. For Tigrayans in particular, the Nakfa-Birr exchange rate and the dominance of the Eritrean smugglers were further challenges in the markets, which were controlled by Eritrean smugglers because of the financial advantage they held over Tigrayans, which was a source of dissatisfaction.

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What is a House? Exploring the Relationship between Housing and Economic Development

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Abstract- The debate on the hypothesis that massive housing construction is the starting point of economic development has been ongoing since the end of World War II. Proponents of this hypothesis believe that housing serves as an impetus for economic development, and there is practical evidence to support this view. Opponents, however, state that housing is not a cause but a consequence of development. This latter group, in line with mainstream economic models, considers housing as a private consumer good, such as automobile, clothing, food and furniture. While the supply of housing entails enormous economies of scale, the consumption gives rise to interdependence costs. To internalize these costs, economic goods associated with interdependence costs require group or political consideration. Thus, it becomes inappropriate to model a house as a consumer good. The purpose of this article is to show that physical structure alone does not constitute a house. Private and public goods, complementary to housing, which lead to scale economies and elimination of interdependence costs excluded from relevant housing models, produce inadequate definition of a house.

Keywords: public services; publicly provided private goods; housing demand; economic development.

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What is a House? Exploring the Relationship between Housing and Economic Development

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Abstract- The debate on the hypothesis that massive housing construction is the starting point of economic development has been ongoing since the end of World War II. Proponents of this hypothesis believe that housing serves as an impetus for economic development, and there is practical evidence to support this view. Opponents, however, state that housing is not a cause but a consequence of development. This latter group, in line with mainstream economic models, considers housing as a private consumer good, such as automobile, clothing, food and furniture. While the supply of housing entails enormous economies of scale, the consumption gives rise to interdependence costs. To internalize these costs, economic goods associated with interdependence costs require group or political consideration. Thus, it becomes inappropriate to model a house as a consumer good. The purpose of this article is to show that physical structure alone does not constitute a house. Private and public goods, complementary to housing, which lead to scale economies and elimination of interdependence costs excluded from relevant housing models, produce inadequate definition of a house. If these public goods complementary to housing are the stimuli needed for sustainable economic development and growth, then the debate should be about the definition of a house-is a house an economic consumer product or a political good?

Keywords: public services; publicly provided private goods; housing demand; economic development.

I. Introduction

The view that massive housing construction is the starting point of economic growth and development has been in the literature since the end of WW II, when nations were faced with the challenge of providing accommodations for returning veterans. The period also witnessed many nations preparing for independence from their colonial masters. Development models were needed for the new nations. The debate has continued well over seven and a half decades. Some nations that gained independence developed and others remain underdeveloped, yet there is no consensus among social researchers and economists about the significance of land use and housing in the process of development.

Arku (2006) partitions the discussion into a historical perspective and categorizes the debate into opponents, moderates, and proponent. The opponents argue that the concept of housing being considered a source of development was entirely in contrast to the fundamental economic theory. Development in the eyes of earlier twentieth-century economists arises from industrialization through capital accumulations (Harrod, 1939; Domar, 1947; Solow, 1956), and any use of capital for consumer item such as housing would tie up capital meant for economic growth. To these economists, housing is a "non-productive capital durable" and a "social expenditure" that usurps capital available for industrialization.

The proponents are of the view that instead of housing being regarded as a mere "biproduct" or a consequence of economic growth, it should be viewed as a precursor or prerequisite for development and growth (De Soto, 2000; Cohen, 2001). Furthermore, housing investment has a far-reaching impact on economic development as it creates employment, income, saving, stable settlement, and lessens absenteeism (Howenstine, 1957; Strassman, 1985). Thus, housing improvement must not wait until economies attain higher income as opponents of housing investment imply (Bauer, 1955).

The economic significance of housing construction is evident in Southeast Asia countries (Singapore, Hong Kong, South Korea, and Taiwan) who recognized the relevance of residential housing for the masses all through the last six decades and these countries are currently among high-income nations (Phang, 2001). Chen, Guo, and Zhou (2011) carried out empirical studies, using panel data, and found a stable long-run relationship between housing investment and GDP growth in China. Anna Tibaijuka (2013), in her "*Building Prosperity: Housing and Economic Development,*" pursues the debate a little further by noting that housing is almost a public good and regards housing construction to be a spark for national economic development.

a) The Nature of the Good

Researchers who disagree that land use and housing construction stimulate economic development do so under the premise of the neoclassical economic theory. Under this conceptualization, housing is modeled as a single private consumer product such as clothing, food, furniture, and automobile. It is a private good because it is thought to possess the economic attributes of a private good. These are rivalry and excludability characteristics. The private good rivalry characteristic lies in the fact that once purchased, the quantity of housing available for sale is reduced. While the excludability attribute of housing means that houses

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provide shelter only to the owner or renter and no one else outside the home simultaneously enjoys the accommodation provided by the house. Under this theoretical framework, housing is a private good, and ownership depends on income and price.

The question now is based on the nature of the good, does housing as a consumer good emit social cost (spillover or negative externalities) on others in the same vicinity, and does it promote social well-being to individuals in the same neighborhood (positive externality)? To answer these questions, we must consider not only the physical structure of the house as a shelter, but we must also give factual details of the architectural design of modern houses. It is also imperative to consider the scale economies in the provision of shared complementary private and public goods. A home in the form of a single-family, multiple-family, or apartment has public good attributes compared to clothes, food, automobile, and furniture devoid of collective characteristics. Therefore, if many quasi-public goods are parts of housing, it becomes a theoretical inadequacy to model a house akin to private consumer goods.

Whether or not general housing construction is the starting point of economic development depends on the definition of a house. While opponents of the debate believe housing is a consumer good based on mainstream economic modeling, nonetheless, supporters of the hypothesis that general housing construction is the foundation of industrialization and development have not provided sufficient arguments within economic theories to support their claims. The purpose of this paper is to bridge the gap between opponents and proponents of the debate using the relevant resource reallocation theory. The goal is to improve the indispensability of land use and housing in the process of economic development. Thus, a broadly defined housing scheme should be accepted as the heartbeat of resource reallocations and an engine of economic growth.

II. The Housing Models

Algebraically, individuals maximize their utility (pleasure or wellbeing) in the consumption of housing *(H)* and composite goods denoted by *(C)*. For individuals *a* and *b* whose houses are standing on adjacent land in the same community, their consumption bundle could be expressed in two different models. The first is where housing and all its amenities are perceived as a private consumer good, a physical structure, which makes households *a* and *b* independent of one another. The second model identifies interdependency between neighbors a and b due to the presence of quasi-public goods and externalities.

a) Housing as Independent Private Consumer Goods

Both households *a* and *b* maximize the objective functions

$$U^a = U^a(H^a, C^a) \quad and \quad U^b = U^b(H^b, C^b) \tag{1}$$

Subject to the constraint

$$I^a = p_h H^a + p_c C^a \text{ and } I^b = p_h H^b + p_c C^b \tag{2}$$

The Langrage function becomes:

$$\int_s = U^a(H^a, C^a) + \lambda(U^b - U^b(H^b, C^b) + \Pi[I^a + I^b - p_h(H^a + H^b) - p_c(C^a + C^b)] \tag{3}$$

where p_h and p_c are prices of *housing (H)* and *composite* goods *(C)*, respectively. I^a and I^b are incomes for households *a* and *b* and in stratified income communities, they are in the same income group. The first order condition and subsequent algebraic manipulations, efficiency requires that,

$$[\delta U^a/\delta H^a]/\ \delta U^a/\delta C^a = [\delta U^b/\delta H^b]/\ [\delta U^b/\delta C^b] = p_h/p_c \tag{4}$$

which could also be expressed as $(MU_H{}^a)/(MU_C{}^a) = (MU_H{}^b)/(MU_C{}^b) = p_h/p_c$. These expressions are positive. In other words, trade efficiency requires that the marginal rate of substitution (MRS) between *housing (H)* and *composite* goods (*C*) are equal for both consumers. In this case, for consumers *a* and *b*,

$$MRS^a{}_{HC} = MRS^b{}_{HC} = p_h/p_c \tag{4a}$$

For the entire community, given production efficiency, social efficiency dictates that,

$$MRS_{HC} = MRT_{HC} \tag{5}$$

where the term MRT_{HC} represents the marginal rate of transformation between *housing (H)* and *composite goods (C).* That is, the tradeoff between society's choice to construct housing or produce composite goods. In economics, it is the simple opportunity costs of *housing* expressed in terms of *composite* goods or vice versa.

b) Housing as Interdependent Political Goods

In Equations (1) through (5) there is a price mechanism that allocates housing and the composite goods, making housing an ordinary consumer item. We could have another model for households *a* and *b.*

$$U^a = U^a(H^a, C^a) \quad and \quad U^b = U^b(H^b, H^a\ C^b) \tag{6}$$

Equations (1) and (6) are similar but different in that U^b, the well-being of the second household is affected by the housing choice of the first household H^a. Thus, there is a third item (H^a) in the utility function of consumer *b*, U^b. This is the externality item or a spillover effect oozing from the housing choice of household *a*.

The constraint function Equation (2) remains the same and the Langrage becomes:

$$\int_s = U^a(H^a, C^a) + \lambda(U^b - U^b(H^b, C^b, H^a) + \Pi[I^a + I^b - p_h(H^a + H^b) - p_c(C^a\ C^b)] \tag{7}$$

The first order condition and exchange result from (7) becomes,

$$[\delta U^a/\delta H^a]/\ \delta U^a/\delta C^a\ +\ [\delta U^b/\delta H^a]/[\delta U^b/\delta C^b] = p_h/p_c \qquad (8)$$

As compared to Equation (4), $[\delta U^a/\delta H^a]/\ \delta U^a/\delta C^a] > 0;\ [\delta U^b/\delta H^a]/\ [\delta U^b/\delta C^b] < or > 0$ depending if household *a's* housing behavior $(\delta U^b/\delta H^a)$ are harmful $[(\delta U^b/\delta H^a)$ is negative] to *b* or beneficial $[(\delta U^b/\delta H^a)$ is positive] to household *b*. Let the second term of (8), $[\delta U^b/\delta H^a]/[\delta U^b/\delta C^b] = \Omega$. The exchange result between household *a* and *b* becomes:

$$MRS^a{}_{HC}\ +\ \Omega\ \neq\ MRS^b{}_{HC} \qquad (8a)$$

Equation (4a) is no longer true as indicated in Equation (8a); the marginal rate of substitution between the households and the top-level outcome, the society's marginal rate of transformation is no longer equal as indicated in Equation (9) below.

$$MRS_{HC} + \Omega \neq\ MRT^b{}_{HC} \qquad (9)$$

The symbol **Ω** in Equation (9) mostly appears in environments as a spillover. Economists refer to it as externalities. Coarse (1960) identifies it as a social cost; and Buchanan and Tullock (1962) calls it interdependence costs. These externalities cumulate to blights. Investors would not move capital to areas that are saturated with blights (Wassmer, 2008). It affects every economic agent, including individuals and firms. Externalities result from improper land use and poorly defined housing. Massive housing construction provides public goods in the community that eliminates the externalities.

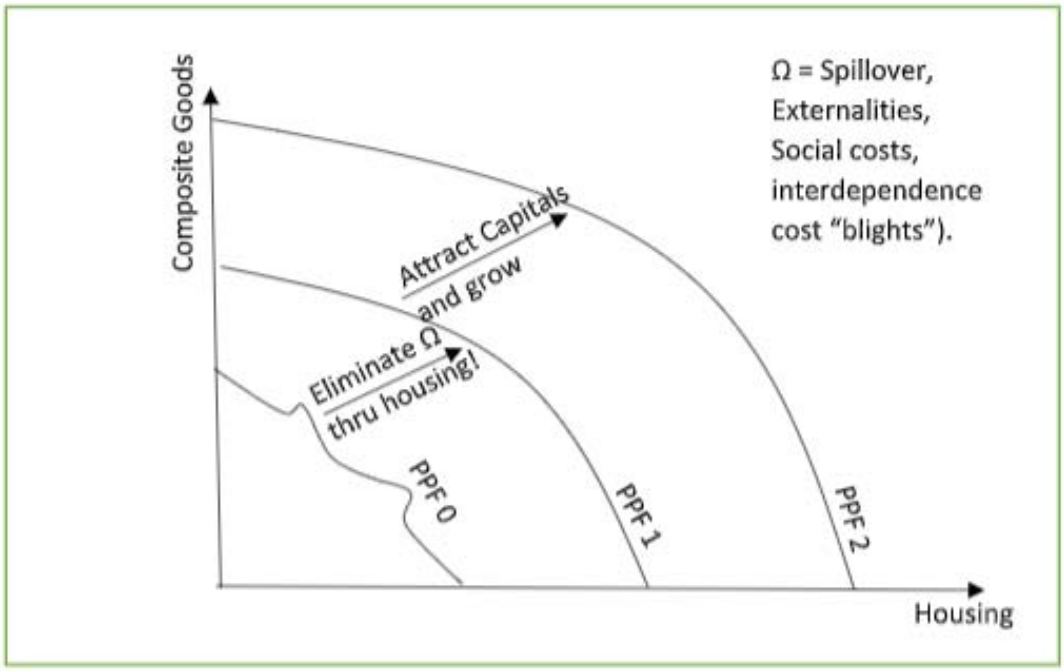

Figure 1: Externalities and Production Possibility Frontiers.

The market cannot allocate externality because it has no price. The government, as representative of the public, eliminates externalities through proper public policy on the use of land. Why land? Because land is a significant economic resource, and externalities occur owing to the sharing of land. The second model is the scenario proponents of debate have in mind. However, housing, externalities and quasi-public goods are separately analyzed in the literature because houses or homes are modeled as economic consumer goods.

As seen in figure 1, many nations of the world are underdeveloped because they are stuck on PPF0. They cannot move to their initial production frontier (PPF1) due to the presence of externalities—inefficient resource allocations. Reallocation of resources requires inclusive housing programs along with essential complementary quasi-public goods, as described in the next section. This would move these societies to efficient PPF1 and attract capital for growth and development (PPF2). PPF0 has an unusual shape because it does not comply with the concept of opportunity cost.

The practice in underdeveloped countries suggests that land use and housing construction are entirely within the choice of the individual; people build as they deem fit with complete disregard to the interdependence costs associated with the use of land and housing. This practice corresponds to the view that housing is a consumer good similar to other private goods.

However, in developed countries, whether in rural areas or big cities, developers authorized by the government in the form of permits construct rows and miles of housing in different sizes and shapes for people to buy according to their income. The land is zoned

into industrial, commercial, residential, public parks, schools, etcetera. Residential properties are broken into single and multiple family units as well as apartments. These forms of land use—collectively provided housing scheme—comply with Buchanan and Tolluck's (1962) analysis that some human activities fall within the realm of political rules and other by private economic decision. Therefore, the view that land use and housing development creates the momentum for economic development is equivalent to the conclusion by Enajero (2018) that many, if not all, human activities are both political and economic (public choice).

In other words, a free market based on individual choice is the first best economic resource allocative mechanism. However, on several human activities such as land use and housing, the market mechanism fails in the efficient allocation of resources. When this occurs, the government, an agent of public choice, implements the reallocation of resources—the second-best solution.

III. Housing Complementary Goods

To determine whether housing constitutes the starting point of economic development, we would have to answer the question, what is a house? There are private and public goods, integral to housing, that yield economies of scale. These quasi-public goods include internal plumbing for drinking water and sewage, electricity, and gas supply. These are known as utilities. Public or collectively consumed goods complementary to housing include walkways, streets, safety (fire and police protection), garbage collection, sanitation, streetlights, parks, library, and K-12 education. These are public goods that cannot be separated from the home. In fact, in choosing a community, potential homebuyers lay more emphasis on the quality of the complementary goods than the physical housing structure.

The efficient use of land by zoning requires residential housing standing in rows or circles, on streets connecting roads and avenues leading to the highways. Revenues generated from taxes imposed on housing are used to finance public goods. Investments in these private and public goods complementary to housing exploit scale economies and would not occur without a well-coordinated neighborhood and regional planning; thus, recognizing community interdependence. While the provision of these housing amenities attracts tourism and capital, the absence creates blights, (Ω) (Wassmer 2008) that repel the capital needed for industrialization and development. Perhaps, these complementary private and public goods to housing are the social capital lacking in underdeveloped countries discussed extensively in the economic literature (Hanka and Engbers, 2017; Jordan 2020; Khadjavi, et. al 2021; Gao et. al. 2024). If these social capitals complementary to housing, albeit modeled separately in the housing market, are necessary to attract financial and physical capitals, then massive housing construction is inevitably a prerequisite for rapid economic development.

To internalize externalities (spillover effect) as indicated by omega sign Ω in Equation (9), and provide complementary public goods, public choice prevails over individual choice in housing construction. Collectively provided housing is development of its own in the locality. It is a "catalyst" for faster national economic development because such public choice practice creates a conducive environment and provides the infrastructure for capital productivity and profitability.

a) Housing and Human Attributes

Besides, the architectural design of the modern ideal home portrays human dignity. At the entrance is a place for visitors to hang a jacket, a hallway leading to the family or living room (parlor), a space for the lady of the house, kitchen, dining room, nursing room, bathroom, and toilets. Others may have a home office, and balcony (Clark, 1986). All members of the household have separate rooms for privacy, and all gather in the dining room and parlor for meals and family meetings, respectively. Thus, the "idealized" and standardized family home portrays economic, aesthetic, sanitary, material, spiritual, and teaches morality and patterned behavior. Attributes that display human virtues are necessary social assets (Wright, 1981).

The human aspects brought about by homeownership are numerous. Housing encourages the household to accumulate savings as the value appreciates over time. These savings are carried forward from generation to generation. The households indirectly learn low time preferences, the human attributes to postpone or spread consumption to the future. The opportunity cost of wealth creation is recognized. It empowers the households to be part of a society, and the tendencies to engage in civil strife and rebellious destruction of properties are reduced (Yew, 2000). Massive housing construction narrows the inequality gap between the wealthy and the poor in any society (Imbroscio, 2023).

b) Macroeconomic Ties

The view that housing is the building block of economic development also has some macroeconomic implications. Housing supply and demand are accompanied by macroeconomic consequences via the financial sectors. In many economic systems, the proportion of consumer spending carries about 70% of the gross domestic product (GDP). Most of the spendings could be linked to housing and housing-related expenditures. The mortgage markets serve as solid supports to the entire financial markets. In today's economies centered on money and banking, the role of

mortgages in the financial system cannot be over-emphasized.

Above all, housing and the complementary amenities that completely define a home require low-skilled labor, domestic materials, and low technology that are in abundance in underdeveloped countries. Housing and affiliated goods do not require heavy machinery and high technology. (Spence and Cook, 1973). Thus, a general housing scheme could be a sound macroeconomic policy aimed at providing shelter and reducing high unemployment in developing countries (Graham 1994).

IV. Conclusion

For the past 75 years, there have been debates concerning the impact of massive housing construction on economic development. Supporters think housing should be viewed as a precursor or prerequisite to economic development and growth. Opponents believe housing is a "non-productive capital durable" and a "social expenditure" that usurps capital available for industrialization. This latter group views and models housing equivalent to automobiles, clothes, foods, furniture, and other private goods.

This paper broadly defines a "modern house" to include complementary quasi-public goods. The absence of these private and public goods that are integral to housing results in externalities. The market fails in the allocation of externalities, and the reallocation function of a government necessitates the elimination of externalities by proper land use and housing construction. Therefore, the provisions of these quasi-public goods along with housing eliminate externalities and prepare a nation for capital inflow, industrialization, and development.

It is also shown that housing is much more than the physical structure that provides shelter. It reshapes the household to be an economic agent. Housing encourages the household to accumulate savings as the value appreciates over time. These savings are carried forward from generation to generation. The households indirectly learn low time preferences, the human attribute to postpone or spread consumption to the future. Moreover, since the residents of collectively provided housing enjoy similar public goods and services, social inequality between the rich and the poor is narrowed.

Therefore, the housing complementary private and public goods, albeit, separately discussed extensively from housing in the economic literature, could be considered the social capital lacking in underdeveloped countries. If these social capitals complementary to housing are necessary to attract financial and physical capitals, then, massive housing construction becomes a mandatory prerequisite for rapid economic development.

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Mapping Waste Generation and Economic Growth: Insights from Input-output Analysis in Malta

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Abstract- The search for an economy that is not riddled with externalities is an ongoing one. However, to reach this objective, policy making must shift its focus from the end of pipe solutions and obtain a deeper understanding of the connection that economic development and growth holds with environmental degradation. This study focuses on the connection that the economy holds with waste generation and via the application of the Waste Input Output model, it puts forward estimatesillustrating how a €1-million injection in final demand impacts total waste generation, considering, both direct and indirect production and waste generation effects. The research is based on the Maltese Islands and uses 2015 as a base year. This is in view that the most recent input-output tables published by the national statistics office are built on this year. Results note that the waste generated by the construction industry remains by far the largest with 1,535.07 tonnes generated for every €1 million. Other concerning figures arise from the health and social work and agricultural sectors which result in 523.33 and 135.57 tonnes of waste respectively when there is an injection of 1 million euros.

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Mapping Waste Generation and Economic Growth: Insights from Input-output Analysis in Malta

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Introduction

Over the past few years, the search for an economic growth model that is not riddled with externalities has become an integral part of the agenda of many decision makers. While economic expansion has, for a long time, been given precedence, the repercussions are now evident. More economies are seeking to sustain growth while consuming less resources and avoid environmental degradation – a goal that for a long time has eluded many.

Waste generation represents one such side effect - which was secondary to the immaterial economies of finance, knowledge, and hi-tech. However, the consistent escalation in generation figures shifted waste's marginality to a more central role necessitating heightening attention towards the requirements of collection, disposal and treatment (Massarutto, 2007). In the case of islands, the impacts felt by escalation in waste generation figures are amplified. The limited land availability together with the challenges posed by insularity and high population density remove any possibility of making waste management straightforward. Furthermore, islands often have limited treatment facilities which in turn requires transportation of waste fractions over long distances while areas that are of special interest including protected and sociocultural heritage make the siting of waste facilities more difficult (Santamarta et al., 2023).

The rising waste generation figures caused supranational administrations like the European Union (EU) and the United Nations (UN), have introduced measures like the Circular Economy Action Plan and Sustainable Development Goals (SDGs) respectively (Alcay & Montañés, 2021). While the Circular Economy Action Plan, aims to "scale up the circular economy from front-runners to the mainstream economic players" (European Commission, 2020), SDG 12.5 seeks to substantially reduce waste generation through prevention, reduction, recycling, and reuse and ultimately decouple waste from economic growth. However, to achieve this goal, a deep understanding of economic correlations is required.

This paper aims to highlight the relationship between waste generation and economic growth using waste input-output analysis (WIOA). This model extends the standard Leontief demand-driven model which views the economy as an interconnected system where industries affect one another directly and indirectly (Miller & Blair, 2009). Here, the Leontief model is expanded to include the "dynamics of waste treatment" to measure the waste footprint of the different industries within that economy. A distinctive aspect of the input-output model is its ability to determine both direct and indirect waste generation, whereby direct waste generation refers to waste generated directly from the industries being examined while indirect waste generation refers to all materials required along the production chain to manufacture a final product (Salemdeeb et al., 2016).

In view of the publication 'Supply, Use and Input Output tables: 2015" by the National Statistics Office, Malta (NSO, 2021), the research is based on 2015 and focuses on the Maltese Islands. This research builds on a previous (unpublished) study by the same authors which was centred on 2010 data whereby the clear connected between waste and the economic sectors stressed the necessity for a policy effort that does not burden societies with externalities The study also points

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out that the out-of-mind, out-of-sight measures are no longer viable particularly in the case of islands (Camilleri-Fenech, M., Cassar, I.P., Gabarrell., X., Oliver-Sola, J. Farreny, 2018).

Malta presents an ideal scenario since the island measures 316 km^2 and hosts a population of 542,051[1] people. Therefore, the quantities and type of waste generated is of great concern not only aesthetically but also from a space and management perspective. Additionally, prior to the negative impact of the Covid-19 pandemic, Malta underwent extensive economic expansion. In fact, between 2012 and 2019, the Maltese economy experienced an average growth in its GDP of 6.4% per annum (National Statistics Office, 2020). However, this positive development was not without any negative repercussions. The State of the Environment Report, 2018 notes that "waste generation per capita (in Malta) remains high when compared to EU countries". It further adds that "resource productivity, as compared to previous years, has dropped, indicating that we have become more 'wasteful' of resources" (ERA, 2018).

This study utilizes the Leontief Input-Output Analysis (IOA). The analysis undertaken will employ the latest available Symmetric Input-Output Table (SIOT) for the Maltese Economy, that of 2015, obtained from the National Statistics Office of Malta (NSO). The WIOA will seek to demonstrate the in-depth relationship that waste generation has with economic intensification while comparing results obtained utilizing an SIOT for 2010[2] in order to identify any potential important shifts in sectoral behaviour between the two periods. IOA has long been extended to account for environmental pollution generation and abatement which are associated with industrial activities - examples include, Moll & Acosta, 2006 and Kjaer et al., 2015, while more focused studies on waste generation include Tsukui et al., 2015 and Dimitrios Hristu-Varsakelis, Karagianni et al., 2012.

I. Literature Review

Input-output analysis was extended to environmental pollution generation and the abatement measures required with industry activity in the late 1960s (Miller & Blair, 2009 p. 446). Miller & Blair, 2009 point to three categories of models, namely, (1) generalized input-output models – which are formed by augmenting the technical coefficient matrix with additional rows and/or columns to reflect pollution generation and abatement activities; (2) economic-ecological models – which extends the interindustry framework to include additional "ecosystem" sectors where flows are recorded between the economic and ecosystem sectors and (3) commodity-by industry models which express environmental factors as commodities in a commodity-by-industry input-output table (Miller & Blair, 2009 p.446). The model utilized in this study will take the form of a generalized input-output framework whereby a technical coefficient matrix with additional rows and/or columns will reflect pollution, that in this study is represented in the form of commercial and industrial waste. This approach will assist in the identification of both impacts and future planning applications (Miller & Blair, 2009). Ultimately, this study aims to provide a physical dimension of the economy and assist in identifying which industries are causing the highest waste impact as a result of their production activities. Additionally, the results generated will identify the type of waste originating from the different industries and will therefore potentially be of assistance for policy makers in the planning of treatment facilities.

IOA has been used extensively for the measurement of sustainability impacts across the supply chain. The possibility to couple monetary with physical data on various environmental indicators allows for a transformation of monetary transactions to reveal environmental impacts which in this case consist of solid waste generation (Malik et al., 2021).

While. (Liao et al., 2015) have the possibility of utilising a high-resolution waste generation WIO model that consists of more sophisticated waste types and treatments, in this case a low-resolution table was utilised. However, both studies employ two components of the WIO model, which evaluate the amount of upstream waste production embodied in the downstream supply chain thus allowing for a more holistic perspective of waste generation, while making it possible to move away from end-of-pipe strategies (Liao et al., 2015).

Salemdeeb et al., 2016, utilize waste input-output analysis to understand the link between economic activity and waste generation with the aim of quantifying the waste that arises in the supply chain. Using the original extended model to define the matrix of environmental outputs, which in this case refer to waste generation, results point to the construction sector, followed by the mining and quarrying industry as the two top waste producers in the UK. Tsukui et al., 2015, on the other hand, utilize interregional waste input-output (IRWIO) analysis to examine how consumption by metropolitan residents in Tokyo releases repercussions on landfill sites in other regions. The use of IRWIO allowed the authors to investigate the direct and indirect effects of consumption by Tokyo residents on other regions in Japan. Consumption is often the go-to solution to stimulate economic activity however it also increases industrial waste produced by these regions. Since post-consumer waste is exported to regions

[1] Figure as per News Release NR119/2023 published on July 10, 2023.

[2] The 2010 study was carried out as part of the doctoral research Camilleri Fenech, M. (2020). Understanding Waste Flows. An industrial ecology approach to the generation of waste, its flows and the connection it has with economic shifts. A case study of the Maltese Islands.

outside Tokyo it also impacts waste treatment and landfill sites within an interregional context. The research concludes that although consumption in Tokyo promoted production activities in outside regions, the value of induced production in industrial sectors was only half as much as that of the Japanese capital city, while value added was only about third that of Tokyo. Furthermore, although Tokyo residents stimulated recycling of municipal solid waste thus reducing waste quantities that needed to be treated outside the city, the total amount of induced landfill volume was 1.7 million cubic meters, which is 2.4 times greater than that of Tokyo. Additionally, the environmental burden in terms of carbon emissions was the same in Tokyo as in other regions (Tsukui et al., 2015). Varsakelis et al., 2012, utilize input-output analysis to allocate the production of Greenhouse Gases (GHG) and waste to the various sectors of the economy. The authors emphasize the interdependence of sectors with respect to changes in the final demand and correlate pollution and energy usage to economic production on a sectoral basis. The research, together with quantifying the macroeconomic effects arising from optimizing production to meet environmental goals, serves to translate pollution targets to sectoral production targets. Additionally, it determines whether a reduction in one pollutant automatically creates savings into another.

II. Materials and Method

a) Data

This study shall employ the an SIOT for the reference year of 2015 published in 2021 as it is at present the most recent SIOT published by the National Statistics Office (NSO) of Malta .Waste generation data, including the treatment figures were supplied by the NSO and the Waste Management Unit within the Environmental Resource Authority (ERA). Minor clarifications, mainly focused on waste originating from hotels, was requested to WasteServ Malta Ltd. Figures in the sectoral waste generation table were compiled by the authors to adapt them to the European Statistical Classification of Economic Activities (NACE) Rev 2. In view that the Maltese economy is an open one, as evidenced by the relatively high trade to GDP ratio of 283.5%[3], the SIOT for domestic production and the respective imports table were aggregated into a single 17 by 17 industry by industry SIOT representing now total input requirements and total supply of output. The imports and SIOT of domestic production table were summated (see Annex A) since the items listed in the imports table refer to materials imported by economic sectors to supplement production and therefore contribute to process waste. This allows for a lifecycle approach whereby process waste includes both the indirect waste generated from imports and the direct waste during processing until they reach final treatment including when this requires exportation.

Table 1: Sectoral waste generation in 2015[4]

	A: Agriculture [1-3]	C to E: Production [5-36]	B&F: Quarry & construction [41-43]	G: Distribution [45-47]	I: Hotels & restaurants [55-56]	Q: Health & Social Work [86-88]	S: Other services [94-96]	Total	% of total
Landfill	1,736	766	589	0	5,532	0	340	84,053.0	5.5
Incineration	5,166	564	0	0	0	424	7	6167.32	0.4
Recovered	20	4,678	890,853	0	0	0	8	900,756.6	59
Recycled	4	3,907	320,829	10,908	0	0	27,839	414,485.5	27.2
Physico-chemical treatment	16	0	0	0	0	0	0	40.73	0
Mineral waste dumped at sea	0	0	111,560	0	0	0	0	111,560	7.3
Other	0	8,704	0	0	0	0	0	8,704	0.6
Total	6,942	18,620	1,323,831	10,908	5,532	424	28,194	1,526,147	100

Source: NSO, ERA & WasteServ Malta Ltd

[3] The trade-to-GDP ratio is an indicator of the relative importance of international trade in the economy of a country. It is calculated by dividing the aggregate value of imports and exports over a period by the gross domestic product for the same period. The EU average trade to GDP ratio, for 2021, amounted to 93%, with Malta recording the second highest ratio in 2021 (World Bank, 2022).

[4] Only sectors for which waste generation data is currently available are shown.

The figures presented in Table 1 refer to commercial and industrial waste and construction and demolition waste. Municipal Solid Waste (MSW) is excluded in view that it refers to waste that is "mixed or separately collected *from households*" and which "does not include waste from production, agriculture… or construction and demolition waste" (European Parliament and Council, 2018). Input-output methodology on the other hand, emphasizes the economy's production side, accounts for the interdependence between industries and focuses on upstream environmental impacts (Kitzes, 1987). It should also be noted that Sectors E37-39, which refer to water supply and waste collection treatment and disposal activities are also excluded as this avoids issues of double counting since the output of these sectors refers to remediation facilities for waste originating from the other economic sectors.

The research is therefore focused on commercial and industrial waste together with construction and demolition waste. The Long-Term Waste Management Plan 2021-2030 for Malta refers to industrial waste as the by-product of industrial processes such as manufacturing of goods and the extraction and treatment of minerals. Commercial waste, on the other hand, arises from the tertiary or service sector e.g., retailers, catering establishments etc., The plan also notes that commercial waste is frequently discarded with the MSW collection thus creating a data gap which is not possible to identify with the provided information (Ministry for the Environment, 2020).

As can be noted in Table 1, the major waste flow originates from the construction industry reaching 1,323,831 million tonnes. In the same Waste Management Plan, although the majority of waste stream is inert, the sheer volume poses significant challenges in terms of void space necessary to continue the practice of landfilling. Although, dumping at sea is an internationally approved option, studies on the topic are limited with the most recent one dating 2005[5]. Impacts of this practice are largely undocumented, and the spoil ground is largely considered an underwater quarry. Additionally, spillage from the barges transporting construction debris to the spoil ground is a regular occurrence with rubble being detected 4 km to the north-west of the designated zone (Deidun, 2020).

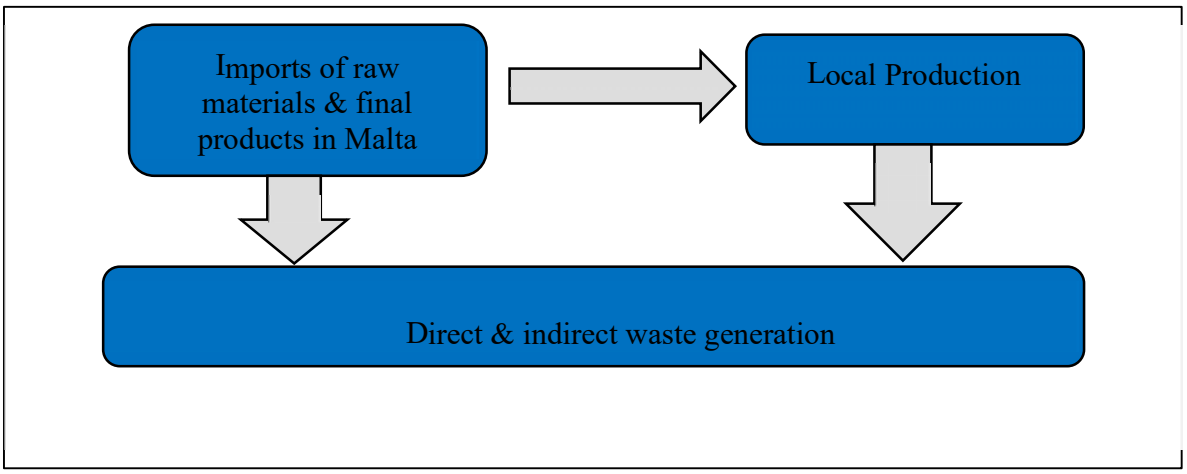
Table 1 shows only those sectors for which waste generation data is available. This is a limitation of this study as some sectors are not included. While the quality of the raw data of waste figures for 2015 improved as compared to 2010[6], the collated table still cannot be considered as a high resolution. This imposes limitations in that the more sophisticated waste types and treatments cannot be accounted for and therefore it is not possible to trace the trajectories of the more detailed waste flows into their corresponding treatments and identify the wastes that are embodied in those streams that are driven by each category's final demand (Liao et al., 2015).

b) Method

This research does not seek to contribute to the Leontief Input Output analysis (IOA) but utilizes the methodology to determine the waste footprint of the industrial sector in Malta. IOA has been utilised extensively to determine the environmental and, more specifically the waste impact (amongst others, see Reynolds et al., 2014, Saito, 2013, Salemdeep et al., 2016, Meng-i Liao et al., 2015). The input output framework evaluates backward linkages which represent the demand side and forward linkages, which represent the supply side. This allows for the identification of the most important sectors in the economy (Bartokova, 2018) and in the case of waste IOA, for the exposure of the industry responsible for the highest waste impact within that economy. Nakamura & Kondo, 2009, (p.220) define waste footprints as "the amount of waste that was generated directly and indirectly to deliver a unit of its product to the final demand". The method applied in this research follows the approach utilised in Butnar & Llop, 2007 but focus is shifted from greenhouse gas emissions to waste. An advantage of this methodology is its ability to estimate both *direct* and *indirect* waste arising from changes to the final demand of each specific sector. However, while several research papers mention the terms 'direct and indirect' waste arisings, few define them. In this paper, the definition utilized in this study is that adopted by Reynolds et al., 2014, which describe *direct* waste generation as the "waste generated by an industry's own on-site production processes". *Indirect* waste generation, on the other hand, is defined as the "volume of waste generated throughout the supply chain as a result of the production processes of all industries in that supply chain underpinning the production of the final product by each sector."

[5] Axiak, V., (2005). *An overview of marine dumping activities in Malta including legal, institutional, and technical aspects.* https://era.org.mt/en/Documents/OverviewDumpingActivities.pdf

[6] The waste statistics for 2010 were used for a similar unpublished study carried out by the same authors.



Source: Authors' Own

Figure 1: Direct & Indirect waste generation

Together with quantifying the waste footprints of industries operating in Malta, the research will determine how a hypothetical increase of €1 million injection in final demand[7] will impact upon waste generation. The calculation method utilised is explained in the methodology below.

Equation 1: Leontief Inverse

$$L = (I - A)^{-1}$$

Where L = Leontief Inverse Matrix
I = Identity matrix
A= matrix of technical coefficient of imports + domestic consumption

Matrix A is obtained by adding the imports and domestic production and then calculating the resulting matrix of technical coefficients. This allows for the examination of the underlying system of interactions and interdependencies (Bartokova, 2018) and is essential since the imports table refers to the materials brought in the country to supply the different production sectors and therefore contribute to process waste. Additionally, it corresponds to a life-cycle methodology whereby waste generated is accounted for from its inception until its final treatment including export. Matrix A measures the fixed relationship between outputs and inputs of a sector and thus calculates the proportions that in the Leontief model are assumed to be constant. Every column in the A Matrix represents the partial cost of the input (excluding costs of primary inputs) which are sustained when a euro's worth of commodity is produced for each sector.(Chiang & Wainwright, 2005).

Equation 2: Linking sectoral waste generation with final demand

$$F = G(I - A)^{-1}Y$$

Where,

F = a column vector of aggregated waste generation by type of treatment
G = matrix of sectoral waste output per unit of production
Y = a column vector of sectoral final demand

Column Vector F represents the aggregated waste generation by type of treatment for each sector under consideration whilst. Matrix G[8], represents the matrix of sectorial waste output per unit of production, whereby every element represents the quantity of waste generated by sector (in tonnes) per monetary unit of final production in activity of each respective sector. The elements in column vector Y put forward the level of final demand for each sector. From this input-output model it may be inferred that when final demand increases the sectoral volume of waste generation will also increase. This increase in waste generation will also capture the resulting waste generation as a result of the direct and indirect production effects generated as a result of the initial increase in final demand. In applying this methodology, it is possible to quantify how a shift in the demand of activities, for example, a change in consumption, will impact waste generation both *directly* and *indirectly* and across all the sectors to satisfy a unit of final demand for the sector. This analysis is therefore of value to understand avenues through which environmental, and specifically waste, burdens are spread across the economy and makes the development of a waste policy that is integrated with economic policy.

[7] Final demand refers to household final consumption together with expenditure of non-profit institution serving household (npish) and government final consumption expenditure , gross capital formation and exports of goods and services (NSO, 2016).

[8] The resulting G matrix based on the 2015 SIOT and data is presented in Table 2.

Equation 3: Quantity of sectoral waste generated due to an exogenous shift in demand.

$$\delta F = G(I - A)^{-1}\delta Y$$

Equation 3 measures the changes in the quantity of sectoral waste generated (ðF) which results from an exogenous shift in final demand (ðY) (Nakamura, 1999). It notes an entire sequence which commences with an exogenous shock in sectoral demand causing impacts on the total amount of waste generated (Butnar & Llop, 2007 p.390).

The research put forward in this study may be considered of policy relevance because it highlights how shifts in economic activity extend to treatment facilities particularly for islands like Malta where space is of essence and expansion of treatment facilities is subject to extensive nimbyism. The results are of value not only to identify and quantify the connection between economic sectors and waste generation but also to highlight the impact this will have on treatment facilities.

III. Results

One of strengths of IO methodology lies in its ability to capture both direct and indirect waste arisings across the supply chain. Both direct and indirect waste generation arisings can be found in Figure 2 as simple waste multipliers which demonstrate the quantities of waste generated by different economic sectors when final demand increases by 1 million euro. These figures quantify the impacts resulting from economic decisions including the repercussion certain decisions will have to the waste treatment facilities. Consequently, WIOA can also serve as a form of environmental accounting on a macroeconomic level. To this end, environmentally extended input-output analysis (EEIOA) has the ability to map impacts resulting from the purchase of goods and services and has been proposed as a tool to measure sustainability related issues across supply chains (Malik et al., 2021).

As indicated in Section 2.1, the workings commenced with the addition of the imports and domestic production table which is referred to as the intermediate demand table (Annex A). This step was followed by the removal of the E37-39 sector (see Annex A). This sector is subsequently removed in view that waste originating from the industry which is subsequently treated in the waste facilities is not double counted. Therefore, the waste generated from the various industrial sectors is accounted for only within the sectors from where it originates. If the E37-39 sector is retained, this same waste would be accounted for also at the treatment stage leading to the double counting of waste.

The calculation and summation of the column vectors of the results of the first equation $L = (I\text{-}A)^{-1}$ determines the sector output multiplier (SOMs).

SOMs measure the effects of one monetary unit change in the final demand for each sector on the total output production of all sectors, considering direct and indirect effects. The SOMs demonstrate which industrial sector would generate most waste when 1million euros are injected into the economy. The magnitude of a SOM is driven by the level of intermediary inputs that a sector generates as a ratio of total inputs compared to its primary inputs. These exert a direct influence on the size of the multiplier, therefore the higher this ratio, the higher stronger the multiplier effect. Furthermore, the higher the backward inter-industry linkages the larger the magnitude of the SOMs (Cassar, 2013).

In this case, since the imports have been included in the initial summation of the A-matrix, it is possible to examine the impact that increases in production will have on the demand for imports. In the WIOA presented in this research, these linkages are crucial to examine the impact that a €1 million injection in the economy will have on waste generation and on the treatment facilities available.

Table 2: Matrix G – Waste input-output multipliers for 2015

tonnes	A	C to E [36]	B & F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T, U
Landfill	7.51	0.90	1.05	0.21	0.38	5.64	0.21	0.15	0.18	0.21	0.44	0.18	0.10	0.23	0.18	2.38	0.00
Composting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Incineration	21.88	1.47	0.68	0.35	0.56	1.78	0.37	0.96	0.33	0.32	0.51	1.63	0.78	468.07	0.38	0.48	0.00
Recovered	69.12	70.82	1029.66	39.98	77.03	60.06	26.63	15.10	94.51	31.45	35.09	40.67	33.07	35.74	22.54	51.23	0.00
Recycled	26.84	28.50	372.89	22.46	29.47	25.30	10.74	6.40	34.66	12.22	13.58	15.26	12.28	14.01	9.04	191.71	0.00
Pysico-chemical	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stored	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mineral waste dumped at sea	8.54	8.50	128.81	4.97	9.58	7.41	3.30	1.87	11.80	3.91	4.37	5.07	4.12	4.42	2.79	6.32	0.00
Other	1.61	5.54	1.99	0.58	0.92	1.69	0.54	0.27	0.51	0.48	0.40	0.37	0.26	0.86	0.41	1.28	0
TOTAL SECTORAL WASTE MULTIPLIER	**135.57**	**115.72**	**1535.07**	**68.55**	**117.94**	**101.88**	**41.78**	**24.77**	**142.00**	**48.58**	**54.38**	**63.17**	**50.61**	**523.33**	**35.35**	**253.41**	**0.00**

Source: Authors

Table 2 provides the results of the WIO 2015 applied in this study. As can be noted, the construction industry generates, by far, the largest quantity of waste (1,1535.7 tons) when there is a €1 million injection in final demand. This is not unique to Malta. In fact, the construction sector produces the highest amount of waste when compared to other sectors on a worldwide basis (Osmani & Villoria-Saez, P., 2019) and also within the EU (Wahlström et al., 2020). The sector is typified by high recovery rates, which suggests an elevated circularity, however, in many cases the recovery rates are largely met because of backfilling which is considered as a low grade recovery application and therefore not an optimal solution (EEA, 2020). Backfilling characterizes the CDW treatment practices of many EU member states including Malta but, despite contributing to the recovery rates, it reduces the potential to shift towards a circular waste management that is steadfast and consistent (EEA, 2021).

The shift to backfilling results in a reduction in landfilling. However, it must be pointed out that prior to 2010, CDW placed in quarries was registered as landfilled. In fact, in 2015, the amount of CDW landfilled is negligible and used for landfill capping. The shift towards recovery was induced by the Waste Framework Directive 2008/98/EC which in Article 11 required that by 2020 Member States (MS) recover 70% by weight of this waste (European Parliament and Council, 2008).

Recycling gained ground in various industrial sectors including construction. Although difficulties still exist since the materials generated from work related to demolition and renovation are often not suitable for reuse and closed-loop recycling (EEA, 2021), it is positive to note that recycling within the construction industry registered a significant increase. Generally this take the form of aggregates for concrete and roadworks, crushed and other material used for renovation works and the recovery of metals (ERA & Ministry for the Environment, 2021). In a recently published standard (SM510:2022), the Malta Competition and Consumer Affairs Authority (MCCAA), examines the current practices within the construction industry with regards to the C&D waste that results from the demolition, excavation, and construction activities. The standard provides guidance for good practice, particularly building owners, developers, architects, and contractors and includes (1) the need to minimise the generation of waste and (2) the reduced dependency and consumption of natural raw materials, while underlining the importance of reusing and recycling the material generated during demolition, excavation and construction activities. Furthermore, the standard provides guidelines that facilitates the process during the planning stage to facilitate practices towards recycling-orientated deconstruction and controlled excavation methodologies that minimise or eliminate waste disposal. The standard aims to reduce dependency on backfilling (Malta Competition and Consumer Affairs Authority, 2022).

However, barriers to achieve high circularity remain. These include (a) the price competition with virgin material, (b) confidence in quality & structural properties, (c) the content of hazardous substances, (d) lack of sufficient and reliable data and (e) the time delay between implementing a circular action and its benefits (EEA, 2020). The Construction and Demolition Waste Strategy for Malta 2021 - 2030, nonetheless points out that more effort needs to be placed to move towards increased recycling and reuse within this industry (ERA & Ministry for the Environment, 2021).

Recycling has in fact, garnered interest throughout all sectors. This treatment method, together with it contributing to resource efficiency thus reducing environmental impact, also boasts of financial benefits. Technological improvements have facilitated the process and reduced costs. All NACE sectors register a steady multiplier including agriculture (26.84), transport (29.47), information and communication (25.30) and other services (129.09).

Recovery has also accumulated additional interest from all industrial sectors. Although, as discussed in the previous paragraph, the benefits of this activity in the case of CDW are questionable, interest in this treatment sector is increasing. Additional interest in recycling and recovery, particularly within industrial areas, can be generated with the introduction of industrial symbiosis. The potential for industrial symbiosis within the Hal Far cluster in Malta was recently studied by Vella (2022). The study noted that the potential for symbiosis exists for cardboard, chemicals and solvents, metals, polymer and wood. It also highlights that presently there are already 4,319 kg/week of by-products that are re-circulated within the economy, additional possibilities of re-circulation exist for 362 kg/week. In addition to this the potential for energy recovery from 11,429 kg of waste materials can be tapped into (Vella, 2022).

Changes are also noted in treatments like composting which, while they feature in 2010 with 302.72 tonnes, in 2015 composting is absent. Despite Malta's highly calcareous soils (ERA, 2018), composting continues to be unpopular, to the extent that it no longer features amongst the treatment options. One should keep in mind that farmers are likely to be doing this practice on their own initiative and therefore the figures are not registered in the national statistics. Furthermore, animal dung is widely available with an average of 26,000 kgs of manure (including chicken and cow manure) produced. However, the continuous and over usage of manure and slurry can be of concern since its nutrient content needs to carefully managed as it can result in significant enrichment of surface and

groundwaters (Green, 2019). For this reason, the usage of such materials is controlled under what was previously known as the Nitrate Directive (now forms part of the Water Framework Directive) (Green, 2019). In the Malta Rural Development Programme (National), specifically under the Agri-Environment Climate Measures (AECM) 5, composting was one of the activities promoted (European Agricultural Fund for Rural Development 2014-2022, 2014), however the impact of the initiative was limited. The same document states that 30% of manure produced is applied in fields (p.57) with manure management contributing to one-third of the greenhouse gas (GHG) emissions generated by agriculture (European Agricultural Fund for Rural Development 2014-2022, 2014). Storage is another 'treatment' option that is missing. This is generally used when waste owners retain items under a better market price is found.

IV. Discussion

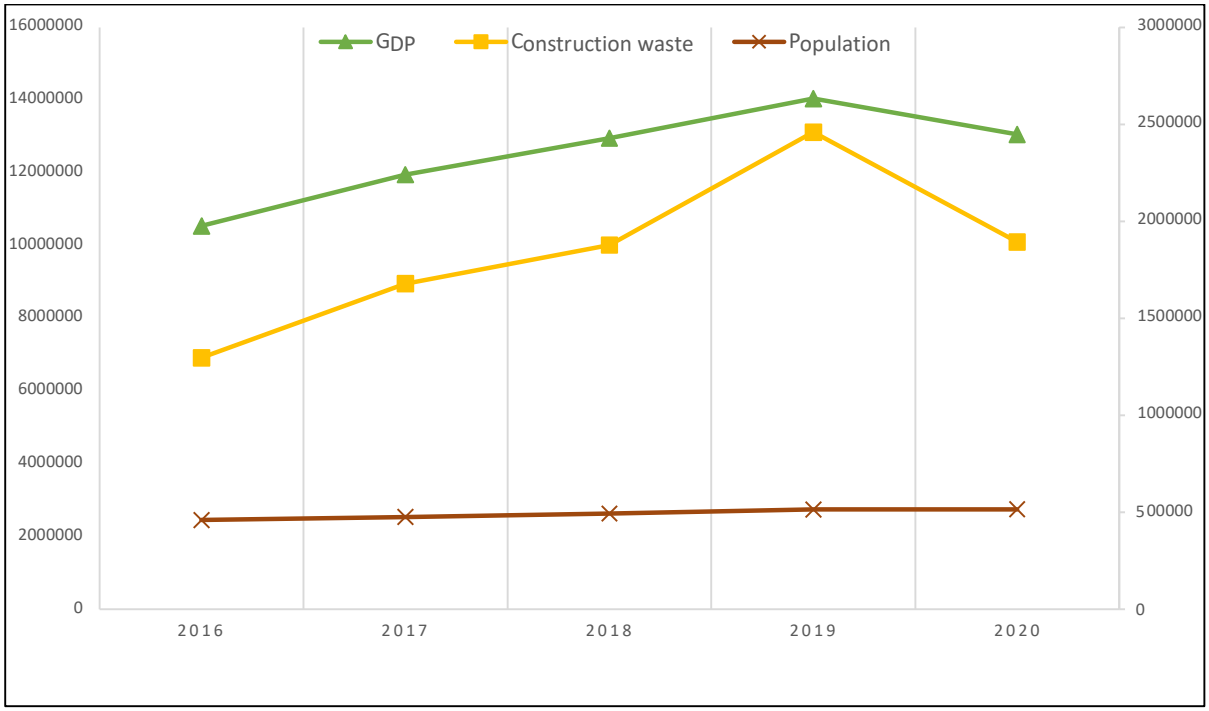
This section provides an overview of the shifts registered in waste generation and treatment between on the basis of the SIOT for 2010 and the SIOT for 2015 to gain an insight into the impacts resulting from recovery and recycling measures together with the policies abounding from the EU.

Notable shifts were mainly recorded in the recycling and recovered categories. Recycling figures increased from 161,732 tonnes to 414,485 tonnes amounting to 61% increase. The main changes were registered in the C&D waste category and in the Sector S: Other services. In the case of the former, recycling consists of metal mainly originating from demolition activities and the recycling of excavated material. These shifts are mainly motivated by financial gain since the legislation promised in the Waste Management Plan for Maltese Islands 2014-2020 (Pg. 133) (MSDEC, 2014) was published recently as Subsidiary Legislation 549.161 Construction and Demolition Waste Framework Regulations.

Recycling figures also increased for Sector S. In this case these figures consist mainly of paper, cardboard plastic packaging but also of other forms of paper and cardboard waste metallic and glass waste, rubber waste and finally wood and textile waste. While Malta registered various difficulties with the recycling targets (MSDEC, 2014) [Pg.135], the initiatives were starting to register some changes.

While total industrial waste generation increased from 1,224,516.29 tonnes in 2010 (See Annex B) to 1,526,146.9 tonnes in 2015, shifts in the treatment methods employed changed considerably. In fact, while in 2010, a total of 707,022.61 tonnes of waste were landfilled, in 2015 this went down to 84,053 tonnes. On the other hand, recovery increased substantially (from 68,793.66 to 900,756.6 tonnes in 2015) with changes registered mainly in Sector: 41-43 Quarrying and Construction. In fact, prior to 2012, C&D waste disposed of in quarries was registered as landfilled. However, after this year this type of disposal is registered as recovery. In fact, the recovery figure increased from 15,809 tonnes to 900,756 tonnes. This shift also assisted Malta to achieve the targets set by Article 11 of the Waste Framework Directive which required Member States that "by 2020, the preparing for reuse, recycling and other material recovery of non-hazardous construction and demolition waste ….. shall be increased by a minimum of 70% be weight". This legislative requirement also resulted in a decrease in the quantity of mineral waste disposed at sea which fell from 290,120 tonnes in 2010 to 111,560 tonnes in 2015.

On a national basis, the generation of construction waste depends on the GDP, population and CDW related regulatory measures (Osmani & Villoria-Saez, P., 2019). In Malta, between 2010 and 2020, the building permits issued for residential properties increased continuously particularly between 2015 and 2019, when permits rose from 3,950 to 12,490 respectively. The figure fell to 7,840 in 2020 (Statista, 2022) mainly due to the Covid-19 slow down. Figures for construction waste follow the observed trends in GDP as can be noted in Figure 1.



Source: National Statistics Office

Figure 1: GDP, construction waste and population in Malta between 2016 and 2020

The Construction and Demolition Waste Strategy for Malta 2021-2030 states that waste generation depends on (1) the present level and magnitude of development, (2) excavated material and (3) waste generated from demolishing activities. Furthermore, the strategy seeks to improve on the waste classification and source separation, explore ways of applying the polluter-pays-principle and promote markets for secondary raw materials (ERA & Ministry for the Environment, 2021).

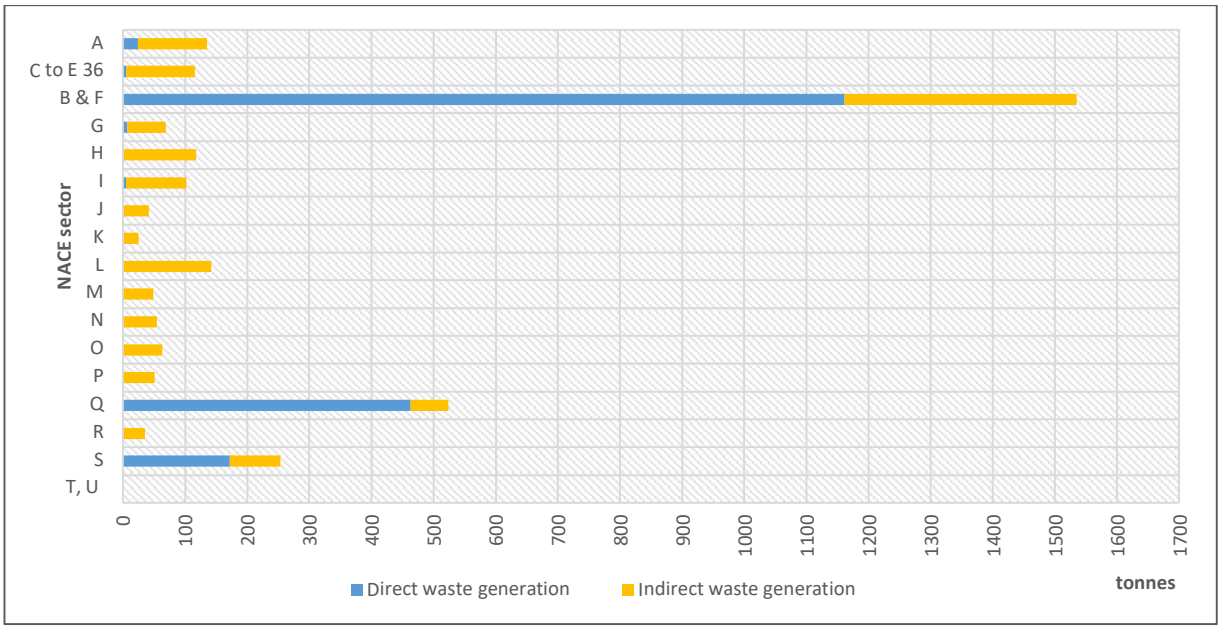
a) *Waste intensity indicators and direct and indirect waste generation*

Waste intensity indicators are driving force indicators that demonstrate the response to improved eco-efficiency measures. Since, this research is focused on the production side, the quantity of waste generated is divided by the Gross Value Added (GVA). GVA captures the value, which is added by economic sectors, that is, the cost between the total output of the sector and the cost of intermediate inputs, according to institutional sector (Wieland & Kavonius, 2016) and in view of this, provides a superior measurement of a specific sectoral economic contribution compared to total output (Miller & Blair, 2009).

The notion of multipliers rests upon the difference between—the initial effect caused by an exogenous change in final demand and the total effects of that change. The total effects accounts for both the direct and indirect effects or what is termed as simple multipliers (Miller & Blair, 2009 p.244). The examination of waste multipliers allows for the examination of trends as to which economic sectors have the highest waste multiplier when they experience a 1-million-euro injection and how this injection will impact treatment facilities when the waste generated is reassigned amongst the different treatments available. The direct and indirect waste multipliers are shown in Figure 2 below. The figure shows that direct waste generation is caused mainly by the construction, health care and social work and the other services sectors. Reasons for CDW generation vary, among others, from lack of on-site waste management plans, time pressure, and ordering errors (Osmani & Villoria-Saez, P., 2019). Health care waste, on the other hand, tends to be heavily regulated in view of the that it can be a source of infection, injury, or health related impact. The need for education is particularly felt in this area since there are a lot of misconceptions about what constitutes hazardous waste and what does not. This would be very beneficial in proper infection control and waste reduction (Woolridge & Hoboy, 2019). This is also applicable to Malta where there is a clear need for clarity among healthcare institutions and professionals. Waste management practices need to be established in the daily routine and prioritized through training and education with all staff (Attard Bason, 2015).

All other sectors, while having a negligible contribution to direct waste generation, make an indirect contribution. This means that certain economic sectors like transport, information and communication, financial and insurance real estate, professional, administration,

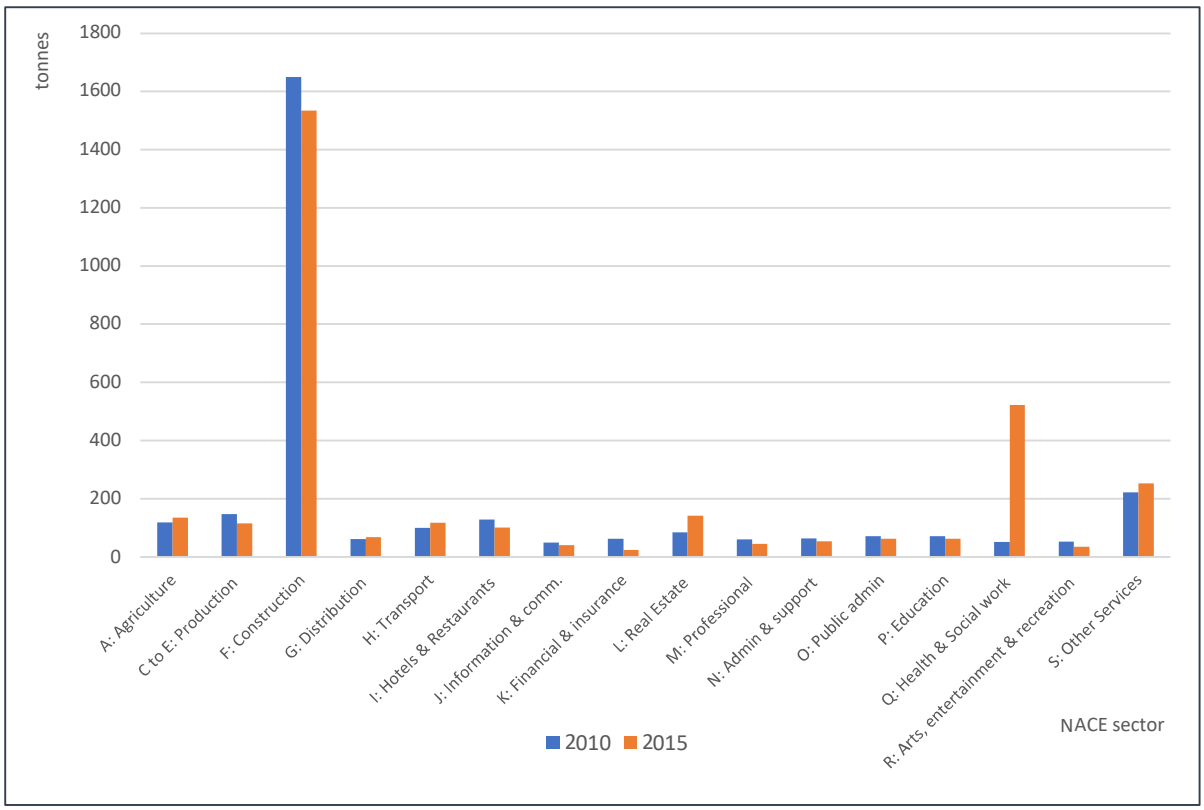
public administration and education do not generate waste directly but induce indirect waste generation by requesting services from the other sectors of production.



Source: Authors' calculations

Figure 2: Direct and indirect waste generation based on the SIOT for 2015

The results of the waste input-output multipliers are consistent with those of 2010. Shifts are registered both in an upwards and downwards direction, however it should be noted that the relative ranking of the waste input-output multipliers amongst the various sectors does not vary.



Source: Author's calculations

Figure 3: A comparison of waste input-output multipliers on the basis of the SIOTs for 2010 and 2015

The WIO multipliers display both upward and downward shifts between 2010 and 2015. In some cases, this could signify an improvement in efficiency of industries however it could also show a downward trend in that economic sector or improvements in data collection.

A strong difference can be noted in the Sector Q: Health and Social Work, whereby in 2010 the WIO reached 52.21while in 2015, the figure amounted to 523.33. While absolute waste generation figures originating from the sector increases to 424 tonnes changes can also be noted in the industry-by-industry input-output table whereby final consumption increased to €769.4 million. In 2015 intermediate demand from other sectors amounted to 15.2 while in 2010 it amounted to 8.9.

The consistently high waste multiplier for the construction sector suggests that not enough effort has been undertaken to reduce the waste generated despite the shift towards recovery and recycling discussed earlier which should be taking place.

V. Conclusion

The research presented here quantifies the waste impact when the economy is injected with €1 million thus providing a more complete picture of economic growth that includes the induced waste repercussions. Direct and indirect quantification of waste generation is one of the strengths of the methodology utilised in this research. This means that while certain industrial sectors might be lauded for low direct waste generation, the impacts of their supply chains cannot be dismissed. A total of eight NACE sectors do not impact waste generation directly but cause considerable impact on indirect waste generation. Therefore, while in national statistics their waste impact is negligible, the WIOA developed in this research study assists in quantifying the real growth registered. The research study therefore makes the case for more widespread economic accounting that accounts for both direct and indirect impact since the cost to treat waste externalities must be deducted from the economic multipliers. This means that the additional growth registered by, for example, the manufacturing industry needs to account for the treatment of 115.72 tonnes of waste. The results and discussion presented should therefore aid policy makers in gaining a deeper understanding of the underlying linkages between sectoral specific production and waste generation and in doing so will hopefully allow for the formulation of more effective industrial policy aimed at mitigating the generation of such externalities.

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Annex A: 2015 (domestic production plus import table) at current prices in Euro millions

2015 total (dom+imp) Input-output table (current prices), Euro millions		Industries																
		Intermediate Demand																
Industries	A	C to E 36	E 37-39	B & F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T, U
A: Agriculture [1-3]	46.6	62.2	-	0.7	0.1	3.2	61.7	0.1	0.1	0.1	0.1	7.1	0.1	0.0	0.0	0.2	0.0	-
C to E: Production [5-36]	59.0	1,631.3	11.0	299.2	102.1	126.4	287.7	64.9	24.3	37.3	53.3	20.6	26.2	15.9	104.9	34.0	33.2	-
E37-39: Waste treatment	0.6	7.2	26.9	1.2	1.1	0.9	1.6	1.0	0.5	0.4	2.2	2.7	16.0	0.3	5.1	0.5	0.7	-
F:Construction [41-43]	8.7	81.1	4.2	245.8	31.2	60.3	29.7	9.1	4.5	65.4	16.9	14.9	22.6	15.7	15.9	7.8	4.7	-
G:Distribution [45-47]	23.7	186.7	2.9	64.3	28.0	34.4	94.7	9.8	4.2	7.4	7.4	8.7	5.4	2.2	17.9	13.2	7.2	-
H:Transport [49-53]	21.5	89.0	2.5	17.9	143.9	377.6	13.8	18.2	26.9	3.4	22.5	29.3	11.1	4.7	6.0	13.5	1.7	-
I:Hotels & restaurants [55-56]	0.6	6.4	0.3	3.6	13.6	20.7	15.2	6.3	11.1	2.0	13.0	32.7	6.8	2.1	6.5	13.4	0.5	-
J:Information & communication [58-63]	1.8	31.9	1.6	10.3	29.7	22.3	10.0	415.4	47.7	12.0	28.3	8.1	40.9	7.9	11.3	1,707.4	1.3	-
K:Financial &insurance [64-66]	8.3	117.0	1.9	32.0	68.9	50.5	33.6	40.4	5,102.4	103.4	76.4	20.3	10.3	7.6	13.5	97.3	4.7	-
L:Real estate [68]	0.4	27.4	0.3	4.9	44.2	9.5	38.8	8.1	5.9	11.7	10.2	3.9	5.4	3.6	3.1	12.0	1.5	-
M:Professional [69-75]	6.3	74.4	4.8	57.6	60.5	56.5	58.0	141.4	71.6	21.3	401.0	20.5	41.6	11.9	7.5	644.2	4.3	-
N:Administration & support [77-82]	6.5	57.1	10.0	10.6	31.8	78.4	15.5	119.0	46.4	6.7	46.8	178.5	55.8	10.5	23.3	76.3	6.5	-
O:Public administration [84]	7.4	48.8	2.6	19.8	19.7	70.9	8.7	10.6	5.4	4.2	8.3	7.0	2.8	1.9	6.6	5.0	1.1	-
P:Education [85]	0.5	5.6	0.7	0.8	1.6	1.8	1.0	3.8	2.5	0.1	4.3	3.3	3.8	6.1	2.9	6.6	0.8	-
Q:Health & social work [86-88]	-	0.2	0.2	0.0	0.2	0.1	0.2	0.1	1.8	0.1	0.1	0.1	2.4	0.8	8.2	0.7	-	-
R: Arts, entertainment & recreation [90-93]	2.0	4.0	1.2	3.0	5.3	28.4	1.8	82.6	5.9	0.3	9.9	32.1	1.8	4.1	2.2	638.9	0.1	-
S:Other services [94-96]	0.1	3.0	0.1	1.5	3.4	4.4	12.6	3.0	3.6	0.2	1.9	1.3	0.6	0.3	1.7	2.6	2.2	-
T,U: Households as employers [97-98]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-	-
Total Inputs / Ouput	**289.3**	**3,314.1**	**112.8**	**1,139.9**	**1,565.1**	**1,473.7**	**1,146.4**	**1,494.4**	**6,138.5**	**790.7**	**1,333.8**	**879.5**	**788.6**	**594.0**	**785.1**	**4,384.9**	**164.0**	**9.3**
Final Demand	**307.1**	**4,125.7**	**57.3**	**893.5**	**1,066.3**	**1,044.9**	**1,029.6**	**622.7**	**5,483.1**	**600.2**	**820.5**	**539.1**	**966.6**	**572.0**	**770.4**	**4,293.3**	**124.3**	**9.2**
Primary Inputs (net of imports)	**95.3**	**880.8**	**41.9**	**366.6**	**979.9**	**527.7**	**462.0**	**560.6**	**773.8**	**514.9**	**631.4**	**488.5**	**534.8**	**498.3**	**548.4**	**1,111.1**	**93.5**	**9.3**

Annex B: Waste input-output multipliers based on the SIOTs for 2010 and 2015

Waste input output multipliers	2010	2015
A: Agriculture [1-3]	118.54	135.57
C to E: Production [36] *	147.9	115.72
F: Construction [41-43]	1650.34	1535.07
G: Distribution [45-47]	61.89	68.55
H: Transport [49-53]	100.31	117.94
I: Hotels & Restaurants [55-56]	128.92	101.88
J: Information & communication [58-63]	49.63	41.78
K: Financial & insurance [64-66]	62.88	24.77
L: Real Estate [68]	85.66	142
M: Professional [69-75]	60.57	45.58
N: Administration & Support [77-82]	63.56	54.38
O: Public administration [84]	71.05	63.17
P: Education [85]	71.05	63.17
Q: Health & Social work [86-88]	52.21	523.33
R: Arts, entertainment & recreation [90-93]	52.9	35.35
S: Other Services [94-96]	222	253.41

Annex C: Direct and indirect waste generation on the basis of the SIOT 2015

	Total Sectoral Waste Multiplier	Direct waste generation	Indirect waste generation
A	135.57	24.00	111.57
C to E 36	115.72	5.62	110.10
B & F	1535.07	1161.35	373.72
G	68.55	6.97	61.58
H	117.94	0.00	117.94
I	101.88	4.83	97.05
J	41.78	0.00	41.78
K	24.77	0.00	24.77
L	142.00	0.00	142.00
M	48.58	0.00	48.58
N	54.38	0.00	54.38
O	63.17	0.00	63.17
P	50.61	0.00	50.61
Q	523.33	462.88	60.44
R	35.35	0.00	35.35
S	253.41	171.95	81.46

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ASSOCIATE OF SOCIAL SCIENCE RESEARCH COUNCIL is the membership of Global Journals awarded to individuals that the Open Association of Research Society judges to have made a 'substantial contribution to the improvement of computer science, technology, and electronics engineering.

The primary objective is to recognize the leaders in research and scientific fields of the current era with a global perspective and to create a channel between them and other researchers for better exposure and knowledge sharing. Members are most eminent scientists, engineers, and technologists from all across the world. Associate membership can later be promoted to Fellow Membership. Associates are elected for life through a peer review process on the basis of excellence in the respective domain. There is no limit on the number of new nominations made in any year. Each year, the Open Association of Research Society elect up to 12 new Associate Members.

Benefit

To the institution

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Global Journals sends a letter of appreciation of author to the Dean or CEO of the University or Company of which author is a part, signed by editor in chief or chief author.

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Career | Financial

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Preferred Author Guidelines

We accept the manuscript submissions in any standard (generic) format.

We typeset manuscripts using advanced typesetting tools like Adobe In Design, CorelDraw, TeXnicCenter, and TeXStudio. We usually recommend authors submit their research using any standard format they are comfortable with, and let Global Journals do the rest.

Alternatively, you can download our basic template from https://globaljournals.org/Template.zip

Authors should submit their complete paper/article, including text illustrations, graphics, conclusions, artwork, and tables. Authors who are not able to submit manuscript using the form above can email the manuscript department at submit@globaljournals.org or get in touch with chiefeditor@globaljournals.org if they wish to send the abstract before submission.

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Authors must ensure the information provided during the submission of a paper is authentic. Please go through the following checklist before submitting:

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2. Authors must accept the privacy policy, terms, and conditions of Global Journals.
3. Ensure corresponding author's email address and postal address are accurate and reachable.
4. Manuscript to be submitted must include keywords, an abstract, a paper title, co-author(s') names and details (email address, name, phone number, and institution), figures and illustrations in vector format including appropriate captions, tables, including titles and footnotes, a conclusion, results, acknowledgments and references.
5. Authors should submit paper in a ZIP archive if any supplementary files are required along with the paper.
6. Proper permissions must be acquired for the use of any copyrighted material.
7. Manuscript submitted *must not have been submitted or published elsewhere* and all authors must be aware of the submission.

Declaration of Conflicts of Interest

It is required for authors to declare all financial, institutional, and personal relationships with other individuals and organizations that could influence (bias) their research.

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Plagiarism is not acceptable in Global Journals submissions at all.

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- Writings
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- Illustrations
- Lectures

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- Graphic representations
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2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

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Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

Declaration of funding sources

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Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for writing a good quality Social Science Research Paper

Techniques for writing a good quality homan social science research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of homan social science then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.
Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

19. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

20. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

21. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

22. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

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Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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