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MODELLING OF THE HOUSEHOLD WASTE GENERATION IN JORDAN

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The main purpose of the article is to predict the household waste generation in Jordan in the short-run and explain factors highly likely impacting its generation. The results of analysis made by two methods – regression technique and time series modelling – are provided. It is concluded that time series modelling with the help of ARIMA(0,1,0) with drift is more reliable for the short-run forecasting of the waste generation in Jordan while the regression is more suitable for explaining the effect of input variables on an outcome.

Keywords: ARIMA models; consumption; cross-correlation; GDP; regression; population; waste.

МОДЕЛИРОВАНИЕ ОБРАЗОВАНИЯ БЫТОВЫХ ОТХОДОВ В ИОРДАНИИ

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Основная цель статьи - спрогнозировать образование бытовых отходов в Иордании в краткосрочной перспективе и объяснить факторы, с высокой вероятностью влияющие на их образование. Приводятся результаты анализа, проведенного с использованием двух методов: регрессионного метода и моделирования временных рядов. Вывод: моделирование временных рядов с помощью ARIMA(0,1,0) является более надежным для краткосрочного прогнозирования образования отходов в Иордании, в то время как регрессия больше подходит для объяснения влияния переменных на конечный результат.

Ключевые слова: ARIMA; потребление; ВВП; регрессия; население; отходы.

Million tons of the household waste are produced in Jordan every year. Along with other factors this situation has been dramatically worsened by the alerting refugee problem. The objective of the research is to predict the household waste generation in Jordan in the short-run and explain factors highly likely impacting its generation. It has been hypothesized that ‘gdp’, “consumption’ and ‘population’ are factors that impact the household waste generation.

Methodology

The comparative analysis made by two methods – log-linear regression technique and time series modelling (ARIMA). First, data is described in statistical terms providing numerical characteristics of variables as well as compute cross-correlation between series ‘waste-gdp’, ‘waste-population’, and ‘waste-consumption’. Data trends have been visualized and predictions of the dynamics of the waste generation have been made with the help of the regression technique. Second, a set of linear and non-linear models with different combinations of independent variables ‘population’, ‘consumption’ and ‘gdp’ have been analyzed. Then models with the highest R-squared-adjusted have been selected, and

models demonstrating high multi collinearity between variables have been excluded. By this models suitable for further econometric tests have been selected. Then alternative models based on values of the probability-value (p-value), R-squared-adjusted, information criteria Akaike (AIC) and Schwartz (BIC) have been analyzed. The following econometrics tests have been conducted: Ramsey test to check for omitted regressors, Goldfeld-Quandt test to check for the presence of heteroscedasticity, Durbin-Watson and Breusch-Godfrey tests to check for the autocorrelation. Based on econometric analysis the best fit model to explain the influencing factors on the waste generation in Jordan have been chosen. Third, time series modelling with the help of ARIMA models for the short-run forecasting of the waste generation have been conducted. Here the behavior of the Auto-correlation function (ACF) has been analyzed, and the distribution of residuals (to exclude autocorrelation) has been considered by performing the Leung-Box test. This allows to opt for the best fit model for forecasting.

The data set consists of annual time series for Jordan in the period 2000–2022. The following variables have been used: *waste* – total household waste generation, million tones; *population* – total population, million people; *gdp* – GDP at purchaser's prices, million, current US$; *consumption* – household final consumption expenditure (formerly private consumption in the World Bank definitions), million, current US$. The data for variables are in the tab. 1.

Table 1

Data set

Year	Population	Gdp	Consumption	Waste
2000	5.06	8460.79	6820.59	1.39
2001	5.16	8975.81	7274.36	2.21
2002	5.28	9582.51	7322.00	2.23
2003	5.4	10195.63	7844.29	2.27
2004	5.53	11411.71	9307.33	2.31
2005	5.68	12589.00	11055.43	2.36
2006	6.08	15056.98	12801.41	2.31
2007	6.47	17110.44	14826.94	2.21
2008	6.63	22658.73	16855.8	2.11
2009	6.78	24537.88	16818.31	1.92
2010	6.93	27133.80	17892.96	2.07
2011	7.11	29524.15	21784.51	2.02
2012	7.21	31634.56	24440.85	2.24
2013	7.69	34454.44	28939.44	2.57
2014	8.66	36847.64	30083.10	2.79
2015	9.49	38587.02	30719.72	3.37
2016	9.96	39892.55	31622.54	3.39
2017	10.22	41608.44	32867.61	3.41
2018	10.46	43370.86	33223.94	3.47
2019	10.7	44503.01	33240.85	3.44
2020	10.93	43579.92	NA	3.56
2021	11.15	45116.32	NA	NA
2022	11.29	47451.50	NA	NA

Author's development based on data for 'population', "gdp', and 'consumption' from [5], data for 'waste' from [4].

Additionally, the daily per capita waste generation, using data from the Table 1, has been computed. The average daily per capita waste generation in Jordan in 2000–2020 was 0.947 kg.

Research findings

Analysis of the cross-correlation function (CCF) for every pair of series shows that all variables demonstrate high correlation with 'waste'. There is no shift in time of one series relative to the other; series tend to move in one direction. The trend for the waste generation in Jordan is non-linear, more likely exhibiting the random work with drift. First, a log-linear regression to explain the average annual growth rate has been applied. The model estimation showed that every year the waste generation in Jordan increases on average by 3.3 %. Having analyzed linear and non-linear models with independent variables 'population', 'consumption' and 'gdp' in different combinations, two models with the highest R-squared-adjusted and lowest VIFs have been selected These models are supposed to explain the impact of different factors on the waste generation. Econometrics tests performed very similar results for both selected models. It is reasonable to opt for the model $waste = \log(gdp) + \log(population)$ as a better model since it has more significant beta-coefficients and a higher value of R-squared-adjusted.

The time series technique – ARIMA models – for the waste generation forecasting has been used. The analysis showed that the series took the compromised position between stationary and non-stationary processes. The auto simulation in R suggested ARIMA(0,1,0) with drift based on the minimum value of AIC criterion. The analysis of residuals of this model showed that they follow nearly normal distribution, so the point forecasts and forecasts for prediction intervals are rather accurate. To exclude autocorrelation of residuals the Leung-Box test has been performed. To sum up, the time series modelling with the help of ARIMA(0,1,0) with drift is more reliable for the short-run forecasting of the waste generation in Jordan while the regression is more suitable for explaining the effect of input variables on an outcome.

The comparison of computations made by two methods are represented in the Table 2.

Table 2

Waste generation forecast made by alternative methods, million tons

Year	Regression	Time series
2025	3.832	4.102
2030	4.258	4.645
2035	4.683	5.188

The research outcomes are useful for policy makers to realize the scale of the household waste problem and to optimize capital expenditures into the waste management system of Jordan. The research contributes to the solution of the waste management problem in terms of forecasting, necessary to put forward appropriate plans.

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