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The Repercussions of Economic Growth, Industrialization, Foreign Direct Investment, and Technology on Municipal Solid Waste: Evidence from OECD Economies

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Abstract: The paper's main objective is to evaluate the repercussions of economic growth, industrialization, and foreign direct investment (FDI) on OECD (Organization for Economic Cooperation and Development) municipal solid waste (MSW) from 2000–2020. Further study includes the role of technology in managing waste activities' repercussions. We also explore the mediation impact of technology and industrialization with economic growth on the waste of OECD economies. The empirical assessment is carried out in two ways. First, we use graphs to assess the evolution over the years and their association with the core factors. Second, we apply a proper econometrics series to examine the empirical nexuses between the relevant factors. The study finds that economic growth and industrialization evolve over time, increasing the waste of OECD economies. FDI inflow is unfavorable and increases waste production. However, the magnitude impact of FDI is lower than that of economic growth and industrialization. Technological advancement (research and development) is a significant factor in reducing waste generation. The later phase of economic growth is still not advantageous to reduce waste generation in the OECD. The OECD needs to manage industrialization and economic activities through a proper mechanism and tax on such activities that can increase unwanted waste. Further, through technology, the management of waste can be improved.

Keywords: municipal waste; growth; industrialization; technology; OECD; green economy

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1. Introduction

Economic growth and industrialization in the 20th and 21st centuries have increased pollution and have had diverse effects on human and animal health, contaminating underground reservoirs and destroying the natural ecological system. With the rising population, human and industrial waste has also accumulated significantly. The projected global generation of solid trash in 2020 was 2.24 billion tons or 0.79 kilos per person per day. The United Nations predicts that by 2050, annual garbage generation will have risen by 73% from 2020 to 3.88 billion tons, primarily due to the growing population and the increasing urbanization of those people [1,2].

Residential, commercial, institutional, and industrial activities are sources of solid waste. The specific forms of waste that constitute an immediate threat to exposed people or the environment are categorized as hazardous, and the treatment system is called hazardous-waste management. All nonhazardous solid waste from a community that must be collected, transported, and disposed of is considered municipal solid waste (MSW) [3]. It encompasses garbage and trash. Garbage consists primarily of decomposed food scraps; junk consists mainly of dry materials, such as glass, paper, cloth, and wood. Garbage is very putrefactive or biodegradable, whereas waste is not. Trash is rubbish that comprises large goods, such as old refrigerators, couches, or large tree stumps. Garbage demands particular collection and processing procedures [4].

In the developed world, MSW is properly decomposed with a systematic process to produce energy and reduce environmental impacts. However, in developing countries, traditional and less effective methods, which are harmful to the ecological system, are still being applied to treat urban MSW. For example, India's rising urban population has led to growing industrial output, which causes more urban waste production. Poor waste management can cause environmental damage, public health risks, and economic and social concerns. Further, MSW mismanagement threatens public health and introduces socioeconomic concerns [5]. MSW treatment can be dated to early civilizations as far back as 320 BCE, though having an official scavenger for such waste was not mandated in English cities until 1714. Cities, such as Boston, New York, and Philadelphia in the United States, started waste collection programs near the end of the 18th century. In the later part of the 19th century, scientists and engineers discovered methods to use technology to better manage MSW. More sophisticated and advanced technological improvements were then applied in the 20th century. In the current era, a more advanced technical approach is being used to produce energy from MSW [6]. Studies have proven that economic growth and financial development have diverse effects on ecological footprints [7,8]. Further economic growth is also essential to industrialization and technological development [9,10].

More advanced and efficient systems have been developed to treat MSW over time. MSW management is a systematical approach to treating MSW in a well-organized way that not only decomposes the waste but produces some economic output (energy) with less impact on the environment. Technological advancement is a source of producing more sophisticated treatment plants that could decompose MSW with less environmental impact [11]. Similarly, industrialization plays a significant role in technological advancement for economic growth. However, do advanced technological progress, economic development, foreign direct investment (FDI), urban population, and industrialization improve MSW management? This is a research question of great concern for environmental scientists, which still needs to be explored. To this end, our study contributes to the existing literature in several ways. First, we use a panel of OECD countries for a substantial period of 21 years (2000–2020) to evaluate the impact of economic growth and industrialization on MSW. Second, the study uses the squared GDP to measure the second development stage's impact on MSW. Third, we explore the impact of FDI and technological advancement on OECD solid waste. Fourth, we include the mediating impacts of economic growth and industrialization, increment in economic growth, and technology on MSW. In addition, we study the urban population's role in MSW. Finally, we use appropriate econometric series—including the cross-dependence test, Westerlund, and Driscoll and Kraay (DK)—for empirical analysis.

The rest of the paper is organized as follows: Section 2 presents the study's literature review. The empirical model, data, and methodology are described in Section 3. Section 4 describes the results and discussion, and Section 5 provides conclusions and policy outcomes.

2. Literature Review

The World Bank (What a Waste 2.0 report) predicts a 70% increase in waste production by 2050, while the population growth will be half that amount. More waste per person will be generated due to rapid urbanization and economic growth, which will exacerbate the urban waste problem. In low-income countries, 20% of municipal budgets go to waste management, but 93% of garbage is dumped or burned. What a Waste 2.0 predicts that garbage production in Sub-Saharan Africa and South Asia will double and triple, respectively, as urbanization and economic growth spread. Of the waste in these two regions, 69% and 75% is currently dumped or burned, respectively, worsening the situation [12]. The following review of the literature explains the relationship between different economic factors in MSW management.

2.1. Economic Growth and MSW Management

MSW is a significant environmental problem and a major source of environmental pollution, impacting human health and contributing to soil, water, and air contamination. The amount of solid waste has a positive and causal relationship with GDP as reported by the DG Environment News Alert Service in 2010. In the 15 member states of the European Union, for instance, municipal waste increased by 54% per person between 1980 and 2005, in line with GDP growth. Furthermore, municipal waste increased by 35% per person in OECD countries and 29% in North America [13]. Mazzanti [14] used the Environmental Kuznets Curve (EKC) hypothesis to assess Italy's regional revenue and municipal rubbish production and backed its efficacy. Everett [15] used the EKC to study the connection between environmental health and economic development. They found a tipping point at which declines followed GDP per capita growth in air pollution emissions. He [16] tested the EKC in emerging countries and found none endorsed it. Vassilis [17] studied decoupling by assessing the relationship between economic growth and environmental impacts. Decoupling was identified in all countries surveyed on average. Khajuria [18] used the EKC to find a delink between MSW generation and India's economic growth. Meanwhile, Yang and Yuan [19] discovered no statistically significant long-term linkage between Zhejiang's industrialization and environmental degradation.

2.2. Industrialization and MSW Management

The exponential increase in MSW creation is a global phenomenon attributable to rising populations, rapid urbanization, intensifying industrialization, and increasing economic prosperity. Various waste-to-energy conversion pathways indicate that MSW is a viable and attractive resource for producing green fuels [20]. Developing nations have instituted waste strategies to minimize the harmful effects of fast industrialization and urbanization. These methods have not yet resulted in procedures that suit societal needs, especially in MSW management, which requires a wide variety of actors and a complete plan. S-ISWM can assist developing-world communities to manage MSW. This research has substantial theoretical, practical, and political implications and can help create transdisciplinary public policies that benefit the environment, economy, and society while boosting efforts to accomplish SDGs 11 and 12 [21].

Urban waste management is evidently a major global environmental issue and growing research area. For example, research provides an overview of India's solid waste management to help relevant authorities and scholars [22]. Rising waste complexity and per capita rubbish creation hinder waste management in emerging countries. Waste management legislation and policies are therefore necessary. Modernization and industrialization create waste, which make these a problem in nations such as Malaysia, where The Solid Waste and Public Cleansing Management Bill, passed in August 2007 after a 10-year wait, might have far-reaching consequences on waste management [23].

2.3. Technology and MSW Management

Industrialization and population growth have risen recently making garbage management increasingly complex. Many developing countries struggle with municipal waste management. Untreated MSW is a significant source of environmental pollution [5]. Using it as a renewable energy source could help meet the growing need for electricity and eliminate this pollutant. Researchers are exploring MSW energy recovery and innovative waste monitoring technology. They are also assessing waste management technology's environmental and economic value, focusing on advancements made possible through synthesis [24]. Extensive research has gone into building a global MSW treatment system. One study analyzed MSW in eight Chinese coastal locations and found that MSW output is rising in Shandong, Guangdong, Zhejiang, and Fujian but dropping in other eastern coastal cities, provinces, and special zones. Of China's MSW, 3% is composted vs. 52% landfill and 44% incineration. As such, it is apparent that China needs a better waste system [25]. Additionally, food waste must be appropriately managed and recycled to reduce environmental and health problems. Notably, food waste has latent energy potential; however, food waste energy conversion is difficult for many reasons. Variable compositions, high moisture content, and low calorific value hinder the development of robust, large-scale industrial processes. Yet, there is MSW management technology to process food waste [26]. Focusing on critical locations, intensifying source separation, encouraging a green lifestyle, and implementing specific regulations and policies may help execute China's 13th Five and uncover knowledge gaps regarding MSW management [27–29].

2.4. FDI and MSW Management

FDI opposes the improvement of urban green total factor productivity, which leads to better MSW management due to its negative effect on the green technical advancement index. Regional differences exist in terms of FDI's impact on urban green TFP. FDI hurts resource-based and non-coastal cities more than coastal, non-opening, and China–Europe railroad cities [30]. Other studies investigated the impact of FDI on environmental quality in different regions and countries. Hoang et al. [31] performed research to explore fears that FDI would lead to ecological degradation and to verify the reliability of the classic Environmental Kuznets Curve (EKC) in the context of developing economies in Asia. Results from this investigation support the generalizability of the polluted heaven hypothesis and the EKC curve in this area. FDI also has significant ecological effects. Wartini [32] suggests that FDI can have both sound and adverse outcomes in developing countries such as Indonesia. According to his findings, the host state must prioritize environmental preservation and attract high-quality FDI. Similarly, many other studies investigated the impact of FDI on the environment [32–37]. However, the effect of FDI on MSW management is unknown and needs to be explored.

3. Model Specification and Econometric Methodology

Waste generation is a significant problem, polluting the environment and adversely affecting people's health. In addition to acting as a breeding ground for disease-carrying organisms and generating methane, poorly managed garbage can also encourage urban violence. Therefore, this paper's main objective is to evaluate the repercussions of economic growth, industrialization, and FDI on OECD (shown in Appendix A, See Table A1) municipal waste generation. Further, it investigates the role of technology in managing waste activities' repercussions. The study's models are as follows:

$$\mathrm{WM_{it}} = \alpha_0 + \alpha_1\mathrm{GDP_{it}} + \alpha_2\mathrm{IND_{it}} + \alpha_3\mathrm{UPOP_{it}} + \alpha_4\mathrm{FDI_{it}} + \alpha_5\mathrm{Tech_{it}} + \mu_{1,it} \quad (1)$$

$$\mathrm{WM_{it}} = \alpha_0 + \alpha_1\mathrm{GDP_{it}} + \alpha_2\mathrm{GDP^2}_{\mathrm{it}} + \alpha_3\mathrm{IND_{it}} + \alpha_4\mathrm{UPOP_{it}} + \alpha_5\mathrm{FDI_{it}} + \alpha_6\mathrm{Tech_{it}} + \mu_{2,it} \quad (2)$$

The dependent variable is municipal waste (WM). Economic activities (economic growth) are measured by GDP per capita. In Equation (2), we added the squared term of GDP per capita to measure the second development stage's impact on OECD countries' waste generation. According to Dinda, Yasmeen et al. [38,39], people and states are more conscious about health and environmental consequences at the later development phase. Additionally, technological advancement encourages countries to manage their environmental issues with sustainable growth. IND is industrialization measured by the value added by an industry (as a percentage of GDP). UPOP is urban population. FDI is foreign direct investment. Tech is technology measured by research and development expenditure (% of GDP).

The last regressions (Equations (3) and (4)) include the mediating impact of economic growth, industrialization augmentation, and economic growth and technology. The mediation effect model is as follows:

$$\mathrm{WM_{it}} = \alpha_0 + \alpha_1\mathrm{GDP_{it}} + \alpha_2\mathrm{IND_{it}} + \alpha_3\mathrm{UPOP_{it}} + \alpha_4\mathrm{FDI_{it}} + \alpha_5\mathrm{Tech_{it}} + \alpha_6\mathrm{GDP_{it}}{*}\mathrm{IND_{it}} + \mu_{3,it} \quad (3)$$

$$\mathrm{WM_{it}} = \alpha_0 + \alpha_1\mathrm{GDP_{it}} + \alpha_2\mathrm{IND_{it}} + \alpha_3\mathrm{UPOP_{it}} + \alpha_4\mathrm{FDI_{it}} + \alpha_5\mathrm{Tech_{it}} + \alpha_6\mathrm{GDP_{it}}{*}\mathrm{Tech_{it}} + \mu_{4,it} \quad (4)$$

All variables are the same; however, GDP (economic growth) × IND and GDP (economic growth) * Tech are interaction terms. All data are extracted from the world development indicators and OECD Statistics.

3.1. Econometric Methodology

To evaluate the nexuses between the variables, the study uses a step-by-step econometric analysis to uncover comprehensive empirical findings. As this study is an OECD panel, the analysis begins from cross-sectional dependency (CD). Subsequently, the study follows the panel stationarity and co-integration tests before long-run empirical estimation. Finally, DK is applied for long-run effects.

3.1.1. Cross-Sectional Dependence and Stationarity Assessments

A panel study often involves cross-sectional dependence among the countries due to growth and the inflow of FDI, which affects the world economies [40,41]. Direct estimation would not be a sensible strategy to generate accurate and effective long-run parameters in this situation. The cross-sectional dependence test suggested by Pesaran [42] is used for identification.

We apply a panel unit root test in the second step to accommodate the cross-sectional dependency. In the case of cross-dependency, the traditional first-generation unit root tests (such as Phillip Perron, Levin, Lin, and Chu) are unreliable identification methods [43]. Regarding this, we follow the "second-generation unit root tests" CIPS and CADF presented by Pesaran [44] to categorize the variables' orders of integration. When CD is present, the CIPS and CADF methods have a higher chance of producing reliable results. If the null hypothesis is rejected, this implies that stationary variables exist.

3.1.2. Co-Integration Assessments

When stationarity has been established, the next stage in establishing the model's scope is to test for co-integration between the variables. We follow the Westerlund, J panel co-integration test for long-run determination as data is spatially dependent [45].

3.1.3. Driscoll and Kraay for Long Effects

The preceding steps encourage the use of the standard error approach for long-run coefficient analysis proposed by Driscoll and Kraay (DK) [46]. Since it produces a robust estimate using the average values in the hetro-autocorrelation, it is a more suitable method in the case of cross-sectional dependency [47]. The DK method also has several other benefits. For instance, it is equally beneficial for balanced and unbalanced data. For example, it is helpful consistently for both flat and imbalanced data. It addresses the issues with CD, auto-correlation, and heteroscedasticity to give accurate findings [48].

4. Results and Discussion

Table 1 gives the summary statistics of each variable of the panel. The results show that the average value of waste is 492.7307 per capita with a standard deviation of 142.5481. The average weight of OECD economic growth is 34,227.65 per capita, and maximum and minimum values are 112,417.9 and 4099.306, respectively. However, technological advancement reveals fewer variations with an average value of 1.783702. Foreign investment maximum (139.4199) and minimum (−57.53231) show higher variations. At the same time, the average values of industrialization and urban population are 24.90457 and 76.27445, respectively.

Table 1. Descriptive statistics.

	Mean	Std. dev.	Min	Max
WM	492.7307	142.5481	127.5	860.3
GDP	34,227.65	22,210.93	4099.306	112,417.9
IND	24.90457	5.431949	10.42672	40.29481
UPOP	76.27445	11.23144	50.754	98.079
FDI	5.29706	12.66458	−57.53231	139.4199
Tech	1.783702	1.034355	0.16427	5.43562

Table 2 displays the correlation between the variables. The table demonstrates that economic growth, industry, urban population, and FDI increase waste generation in OECD economies. However, technological advancement shows a negative correlation. Further, the magnitude impacts of economic growth, technology, and industry are higher, respectively, on OECD waste. The cross-dependency findings are given in Table 3. The results suggest that all variables are cross-sectional dependent. This means that OECD countries should be cautious about policy-making, as it can affect other countries.

Table 2. Correlation analysis.

	Wm	gdp	Inds	UPOP	FDI	RDI
WM	1.0000					
GDP	0.5417	1.0000				
IND	0.3281	0.3128	1.0000			
UPOP	−0.1262	−0.3991	−0.3139	1.0000		
FDI	0.0825	0.1340	−0.0729	0.0327	1.0000	
Tech	−0.4023	0.4882	−0.1137	0.4206	−0.0827	1.0000

Table 3. Dependency testing.

Variables	CD-Test	*p*-Value	Average Joint T	Mean ρ	Mean abs (ρ)
WM	6.026	0.000	21.00	0.05	0.39
GDP	90.151	0.000	21.00	0.74	0.82
IND	51.143	0.000	21.00	0.42	0.56
UPOP	67.494	0.000	21.00	0.56	0.83
FDI	16.094	0.000	21.00	0.13	0.25
Tech	39.826	0.000	21.00	0.33	0.62

Table 4 presents the stationarity test findings of each variable. The outcomes of the CIPS and CADF statistics indicate that all variables are co-integrated after taking the first difference. However, these results are inadequate to identify the long-run relationship. Therefore, the study applied Westerlund (shown in Table 5) and found that some panels and all the study panels are co-integrated. Consequently, e conclude that co-integration exists among the model indicators.

Table 4. Unit root analysis.

	CIPS		CADF		Decision
	Level	First dif	Level	First dif	
WM	−1.404	−3.775	−1.155	−2.486	I (1)
GDP	−1.510	−4.681	−1.485	−2.937	I (1)
IND	−2.086	−4.041	−1.833	−2.780	I (1)
UPOP	−2.222	−3.856	−0.861	−2.062	I (1)
FDI	−3.501	−5.423	−1.813	−2.422	I (1)
Tech	−1.664	−3.569	−1.836	−2.499	I (1)

Note: significance at 5% and 10%.

Table 5. Co-integration analysis.

Westerlund Test for Cointegration (2005)		Statistic	*p*-Value
Regression			
Some panels are cointegrated	Variance ratio	−1.5858	0.0564
All panels are cointegrated	Variance ratio	−1.8764	0.0303
Mediation effect Regression (1)	Variance ratio	−1.6337	0.0512
Mediation effect Regression (2)	Variance ratio	−2.0260	0.0214

4.1. Assessment of Waste, Industrialization, and Economic Growth of OECD

Most of the OECD countries are highly advanced countries with a high level of industrialization and economic growth relative to other nations. Therefore, the repercussions of rapid economic growth and industrialization significantly impact waste. Figure 1 shows that economic growth has increased over time (2000–2018). This means that OECD economic activities are expanding over time through industrial expansion, trade, etc. Cross-wise, Figure 2 reveals that the industrial sector is also expanding with economic growth in OECD economies.

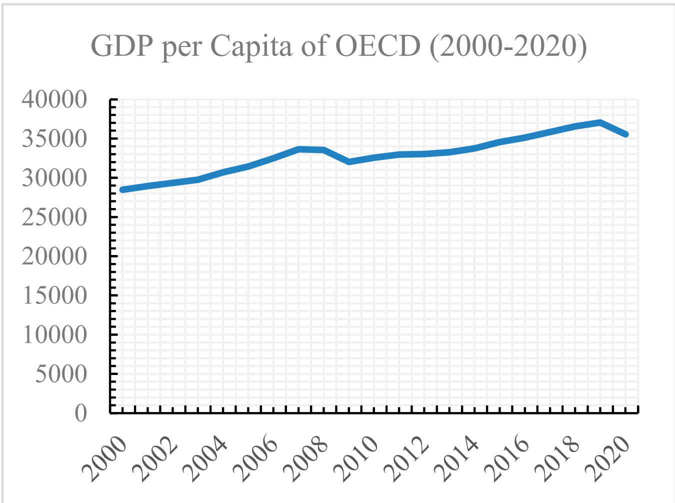

Figure 1. Per capita GDP growth of OECD.

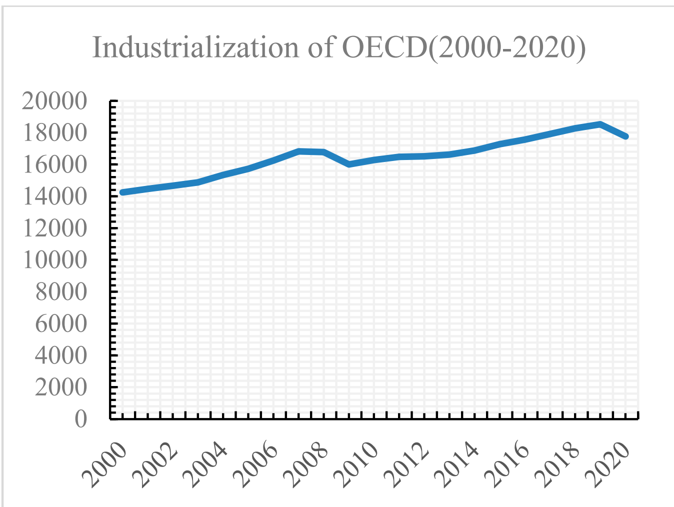

Figure 2. Industrialization evolution of OECD.

According to a World Bank report (2022) [1], rapid population growth and urbanization will raise annual waste production by 73% from 2020 to 3.88 billion tons in 2050. As shown in Figure 3, it is evident that municipal waste increased in OECD countries from 2000–2018. However, it decreased from 2019 to 2020, resulting in less growth and industrial production. The COVID-19 pandemic may be a possible reason for less economic expansion and waste material.

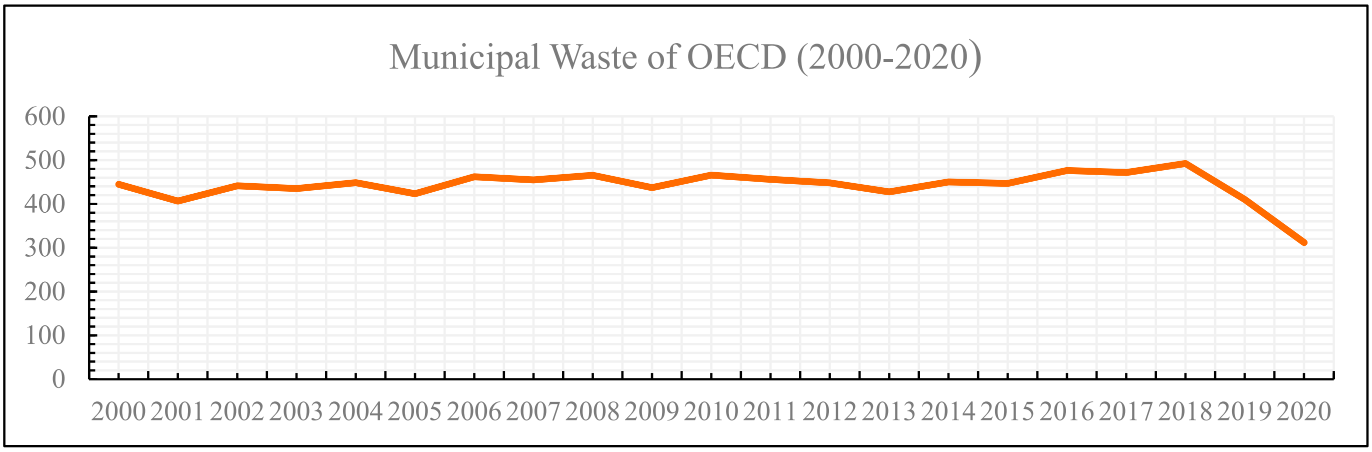

Figure 3. Municipal waste trend in OECD (2000–2020).

Figure 4 shows that waste generation and economic growth have a positive relation, endorsing that economic growth can increase the waste footprint. The World Bank (2022) estimates that waste generation rates are rising, amounting to an impression of 0.79 kg per person per day. Figure 5 indicates that industrialization is causing an increase in waste production and degradation of the environment.

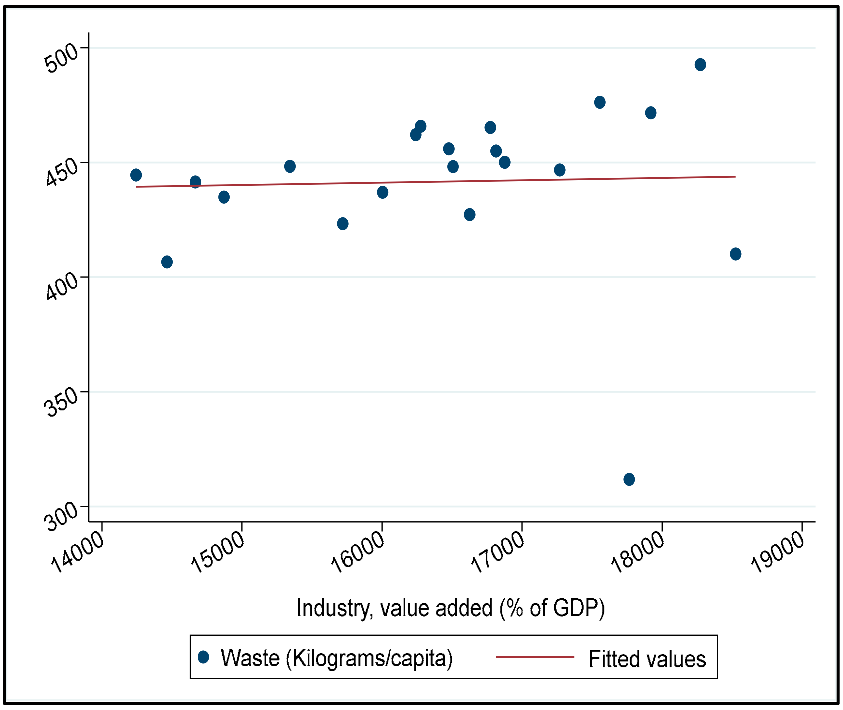

Figure 4. Growth and waste relationship.

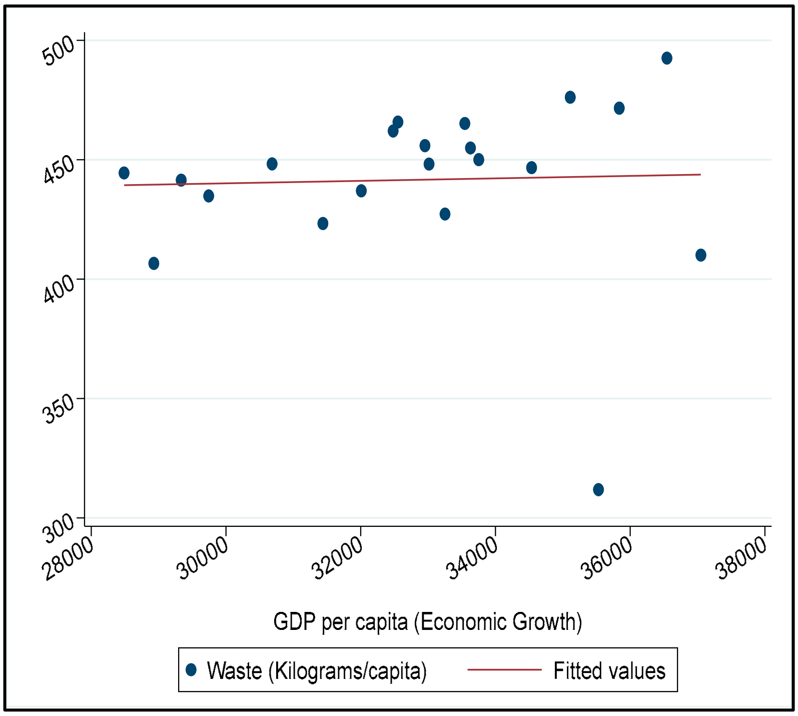

Figure 5. Industrialization and waste relationship.

4.2. Long-Run Effects by DK

A graphical assessment is not enough for a broad conclusion. Therefore, the study applies DK for thorough analysis. The results of economic growth and waste are given in Table 6. The study includes the GDP per capita (growth) impact on OECD waste generation. The findings reveal that economic expansion (growth) positively increases the waste of OECD economies. As economic activities increase, they can pollute the environment by increasing waste. A 1% augmentation in economic activities will cause a rise in the level of waste by 0.522%. The results can be validated by Chen et al. [49] and Alajmi [50], who estimated that economic growth increases waste production.

Table 6. Economic growth and waste generation.

Variable(s)	WM	WM	WM	WM
GDP	0.522 ***	0.478 ***	0.281 ***	0.00143 *
	(0.0587)	(0.0613)	(0.0647)	(0.000721)
GDP^2				4.151 ***
				(1.077)
IND		0.406 *	0.947 ***	0.935 ***
		(0.231)	(0.305)	(0.298)
UPOP			−2.426 ***	−2.345 ***
			(0.490)	(0.469)
FDI			0.00904 ***	0.00935 **
			(0.00311)	(0.00330)
Tech			−0.358 ***	−0.334 ***
			(0.0339)	(0.0390)
Constant	0.344	2.091 *	15.65 ***	4.716
	(0.593)	(1.085)	(2.345)	(12.70)
Observations	798	798	798	798
R-squared	0.050	0.052	0.102	0.103
Number of groups	38	38	38	38

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

However, this regression study did not control for the other critical economic factors. As such, in the second regression, we included the industrialization impact on waste generation. The results in column (2) show that industrialization activity is unfavorable and increases waste production. A 1% increase in industrialization will increase OECD's waste by 0.406%. This means that industrial activities are the main reason for the rise in trash and pollution. The results are consistent with Bai and Sutanto [51], who found that industrialization and economic growth lead to more solid waste generation. These two regressions were run without controlling for other essential factors.

We included the other important factors in the third regression for more robustness. The results in column three reveal that FDI inflow in OECD countries can be the reason for increasing waste generation. A 1% increase in the inflow of FDI will significantly increase the waste of the OECD by 0.00904% to 0.00935%. However, the magnitude impact of FDI is lower than economic growth and industrialization. The results align with Caiyi et al. [52], who found that FDI inflow is harmful and increases solid-waste emissions. On the other hand, the impact of the urban population is favorable, as a 1% increase in the urban population will decrease waste by −2.426% to −2.345% in OECD economies. A possible reason could be that the urban population is more advanced and is aware of how to handle waste and its consequences for the environment. Technological advancement (research and development) significantly reduces waste generation by −0.358% in the OECD. Technology can detect waste and the processes that generate larger waste quantities, thereby managing it more effectively. Technology helps make the entire waste management process cost-effective, efficient, and environmentally friendly [53].

The second phase of economic growth can differ in controlling and managing waste generation. Therefore, the following regression included the squared GDP per capita to assess the second development phase. The regression outcomes show that economic growth is still not advantageous to reduce waste generation in the OECD. It is possible that if the economy lacks management and a proper policy implementation mechanism, then production waste will not be controlled even with development. Economic growth means the expansion of economic activities, including production, business, and industrial sector expansion that eventually will produce waste and harm the environment. However, waste management would be more effective and efficient through technological development (research and development).

Therefore, in the next step, we included the mediation factors of growth, industrialization, and technology in reducing the waste of OECD countries. The results in Table 7 indicate that technology mediation impact with change is significant in controlling the destruction of the OECD. A 1% increase in technological advancement with economic growth would reduce the waste of the OECD by −0.980%. This means that technological development is essential and contributes positively to controlling waste. However, the impact of economic growth with industrialization on waste is significant and positive to increase the waste of OECD generation. A 1% increment in economic development with industrialization will raise the waste by 5.094%. The critical point is that the magnitude impact of growth and industrialization is stronger than the technological mediation influence. It implies that technological advancements alone are not enough to reduce waste, as industrialization is increasing beyond the limit. As such, there is a dire need to manage waste with proper policy implementation.

The impact of FDI is again negative in improving waste generation. Further, the magnitude impact of FDI (0.00736% to 0.00883%) is still lower than economic growth and industrialization. The effects of industrialization and economic growth are unfavorable; a 1% increase in economic development and industrialization would increase the waste by 0.478, 5.302%, 1.008% to 0.406%, 0.175%, and 0.872%, respectively. The technological impact favors controlling waste; however, the significance level is lower. The urban population again seems to be positive in their behavior and contributes positively to reducing the waste of OECD countries.

Table 7. Mediating the impact of growth, industrialization, and technology.

Variable(s)	WM	WM	WM
GDP	0.478 ***	5.302 ***	1.008 **
	(0.0613)	(1.608)	(0.369)
UPOP		−2.551 ***	−1.834 ***
		(0.457)	(0.354)
FDI		0.00736 **	0.00883 ***
		(0.00272)	(0.00277)
Tech		−0.416 ***	−0.178
		(0.0518)	(0.163)
IND	0.406 *	0.175 **	0.872 ***
	(0.231)	(0.0775)	(0.274)
GDP*IND		5.094 ***	
		(1.649)	
Tech × GDP			−0.980 ***
			(0.317)
Constant	2.091 *	25.73 ***	16.60 ***
	(1.085)	(3.878)	(2.348)
Observations	798	798	798
R-squared	0.052	0.110	0.116
Number of groups	38	38	38

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5. Conclusions and Policy Implications

Solid waste generation is a serious problem that has significant consequences for both the environment and human health. Uncontrolled waste can breed disease-carrying organisms and produce methane. Therefore, this paper's main objective was to evaluate the repercussions of economic growth, industrialization, and FDI on OECD municipal waste generation. Further study included the role of technology in managing waste activities' repercussions. We also referred to the mediation impact of technology and industrialization with economic growth on the waste of OECD economies. The empirical assessment was carried out in two ways. First, we used graphs to assess the evolution over the years and their association with the core factors. Second, we applied an appropriate econometrics series to examine the empirical nexuses between the concerned elements.

However, a slight decrease was found in 2019–2020. The study found that economic growth and industrialization evolve. However, a slight decline was noticed in 2019–2020. The pandemic may have affected the economic growth and industrial activities of OECD economies due to lockdowns. In the cross-examination, the study discovered that the municipal waste of the OECD increased from 2000–2018. However, it decreased in 2019–2020. This means that contraction in industrial and economic growth activities is the main reason for waste generation declining. Waste generation, industrialization, and economic growth have positive relations, endorsing the notion that economic growth can increase the waste footprint. The study applied DK for empirical analysis and revealed that economic expansion (growth) improves the waste of OECD economies. Industrialization and FDI inflow are unfavorable and increase waste production. However, the magnitude impact of FDI is lower than economic growth and industrialization. Technological advancement (research and development) is a significant factor in reducing waste generation. The second phase of economic growth can differ in controlling and managing waste generation. Therefore, the subsequent regression included the squared GDP per capita to assess the second development phase.

The regression outcomes showed that economic growth is still not advantageous to reduce waste generation in OECD countries. Technology mediation's impact on change is significant to control the waste of the OECD. However, the effect of economic growth with industrialization's impact on waste is substantial and positive in increasing OECD waste generation. The urban population again seems to be positive in their behavior and contributing positively to reducing the waste of OECD countries. As such, based on the study findings, some policy recommendations can emerge. Paramount is the fact that the OECD needs to manage industrialization and economic activities.

Further, a proper mechanism should be developed, including a tax on such activities that can increase the unwanted waste. Additionally, through technology, the management of waste can be improved. For example, some subsidies can be offered to increase the efficiency and management of waste generation. Notably, awareness is another factor that can contribute positively.

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Appendix A

Table A1. OECD economies.

Australia	Finland	Korea	Slovak Republic
Austria	France	Latvia	Slovenia
Belgium	Germany	Lithuania	Spain
Canada	Greece	Luxembourg	Sweden
Chile	Hungary	Mexico	Switzerland
Colombia	Iceland	Netherlands	Turkey
Costa Rica	Ireland	New Zealand	United Kingdom
Czech Republic	Israel	Norway	United States
Denmark	Italy	Poland	
Estonia	Japan	Portugal	

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