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The Circular Economy Approach to Production Inefficiency: A Stochastic Frontier Analysis

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Abstract

The Circular Economy concept, which is based on the 3R principle, has led to the emergence of different ideas on waste management. On the one hand, waste management is expanded with the recommendations of the 5R and 10R hierarchies; on the other hand, it is defined to cover a significant part of the R stages of the recovery process. CE discussions are the efficiency analysis and use different indicators in performance measurements for which DEA is widely preferred. The stochastic frontier analysis (SFA) consists of assumptions about the functional relationship between inputs and outputs variables. Additionally, compared with non-parametric (SFA) considers the effects of random factors on outputs which strengthen the used estimation procedure. In this study, it is thought that one of the important variables of reducing inefficiency in the production function is the recovery in which the recycling of losses in the production process creates an important economic value while reducing the use of inputs or substituting them. Therefore, recovery is directly designed as an additional input using the Cobb-Douglas functional form. In the study, the 2000-2017 period data of OECD countries were used to analyze the effects of waste management, focusing on the recovery process, on economic growth. As a result, it was seen that the efficiency value calculated for OECD countries was 0,84 and the inefficiency in the production process decreased as the recovery rate increased. Even though the recovery process makes a positive contribution to local governments economically, the initial costs of carrying out this process may require significant expenditures. Therefore, policies should be developed by taking into account the capacities and scales of the municipalities for the financing of these expenditures.

Keywords: Circular Economy, Waste Management, Waste Hierarchy, Stochastic Frontier, Recovery, Recycling.

Üretim Etkinsizliğine Döngüsel Ekonomi Yaklaşımı: Stokastik Sınır Analizi

Öz

3R prensibine dayalı döngüsel ekonomi kavramı, atık yönetimi konusunda farklı fikirlerin ortaya çıkmasına neden olmuştur. Atık yönetimi bir yandan 5R ve 10R hiyerarşilerinin önerileriyle genişlerken, diğer yandan geri kazanım sürecinin R aşamalarının önemli bir bölümünü kapsayacak şekilde tanımlanmaktadır. Verimlilik analizi olan CE tartışmaları, VZA'nın yaygın olarak tercih edildiği performans ölçümlerinde farklı göstergeler kullanmaktadır. Stokastik sınır analizi (SFA) ise, girdi ve çıktı değişkenleri arasındaki işlevsel ilişki varsayımlarından oluşmaktadır. Parametrik olmayan yöntemlerle karşılaştırıldığında da (SFA), kullanılan tahmin prosedürünü güçlendiren çıktılar üzerindeki rassal faktörlerin etkilerini dikkate almaktadır. Bu çalışmada, üretim fonksiyonundaki verimsizliği azaltan önemli değişkenlerinden birinin, girdi azaltımı ya da ikamesi üzerinden üretim sürecindeki kayıpları geri dönüştürerek ekonomik değer yaratan, geri kazanım olduğu düşünülmektedir. Bu nedenle geri kazanım, Cobb-Douglas fonksiyonuna doğrudan ek bir girdi olarak eklenmiştir Çalışmada, geri kazanım sürecine odaklanan atık yönetiminin ekonomik büyüme üzerindeki etkilerini analiz etmek için OECD ülkelerinin 2000-2017 dönemi verileri kullanılmıştır. Sonuç olarak OECD ülkeleri için hesaplanan etkinlik değerinin 0,84 olduğu ve geri kazanım oranı arttıkça üretim sürecindeki verimsizliğin azaldığı görülmüştür. İyileşme süreci ekonomik olarak yerel yönetimlere olumlu katkı sağlamakla birlikte sürecin maliyetleri önemli harcamalar gerektirebilmektedir. Bu nedenle bu harcamaların finansmanı için yerel yönetimlerin kapasiteleri ve ölçekleri dikkate alınarak politikalar geliştirilmelidir.

Anahtar Kelimeler: Döngüsel Ekonomi, Atık Yönetimi, Atık Hiyerarşisi, Stokastik Sınır, Geri Kazanım, Geri Dönüşüm.

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Introduction

In recent years, the Circular Economy (CE) has been received increasing attention in the environmental research literature. Although the economic system is considered open-ended when evaluated from a linear perspective, it turns into a cyclical system when the relationship between resources and wastes is taken into account. In other words, some of the wastes can be turned into resources again and the economy can be made circular. Of course, not all waste can be recycled, partly because of some fundamental laws of physics (Andersen, 2007: 134). Waste management is built on this CE concept and defines the recycling process of wastes to sources.

To express the concept of CE more clearly, CE aims to increase the efficiency of resource use to achieve a sustainable balance between the economy, environment, and society. CE is widely known as the 3R's principles: Reduction, Reuse, and Recycle (Ghisellini et al, 2016:11-15). Although CE terminology and 3R policies vary according to countries, when China, EU countries, and Japan are taken into consideration, it is seen that China's approach is partially derived from the policies and approaches adopted in other countries, especially Germany and other EU countries, as well as Japan (Preston, 2012:4). However, 3R and waste management policies may differ between countries due to the unique circumstances or political strategies of each country. While waste management in the EU is characterized by practical and effective 3R policies and policy makers' desire to simplify management systems, the policy ideal in China is the development of a circular economy aimed at reducing the amount of waste and its hazardousness (Sakai et al, 2011:87). In addition, incomplete or excessive regulations regarding waste management and careless use of waste can harm the environment (Gharfalkar et al, 2015:306).

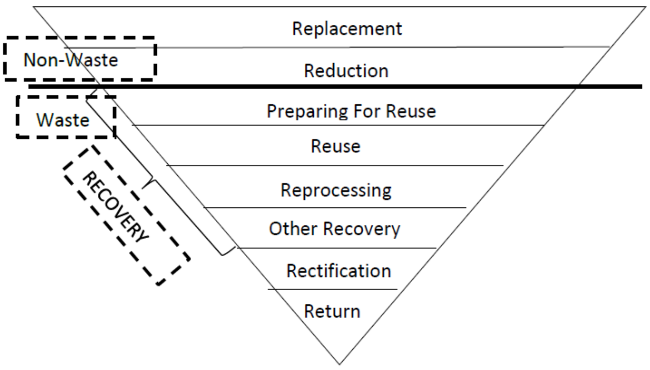
Reducing the use of resources means reaching the targets set for production and consumption by reducing pollution with the minimum use of raw materials and energy at the very beginning of the economic activity. In manufacturing, this principle means compacts and lightweight products, simplified packaging, and maximizing product function, all to reduce waste discharge. Reuse of a product in other facilities after it has been first made available, and means not allowing it to become toxic waste. Recycling means using a product many times in addition to its primary purpose (Feng and Yan, 2007:95-96). Recovery, on the other hand, is divided into two categories the recovery of materials and recovery of energy. Which of these two options is better for the environment and human health? Although preferred, recovery of materials has been often the most preferred option. Recovery of materials includes activities such as recycling and composting. It also requires a method of processing material or converting it into a new product (Hansen et al, 2002: 4). Energy recovery is preferred for materials that do not have a higher end-use than converting to energy. The choice of recovery options should consider not only the effects on waste but also the sustainability impacts of the technology used in recycling, such as greenhouse gas production, water consumption, social and economic impacts (Gertsakis and Lewis, 2003:11).

The Waste Hierarchy of Waste Framework Directive (WFD) 2008 is as follows; Prevention, Preparing for Re-use, Recycling, Recovery, and Disposal.

WFD2008 aims to promote technologies that focus on durable, reusable, and recyclable products within a product eco-design policy that addresses both the generation of waste and the presence of hazardous substances in waste under the heading of prevention. To facilitate or improve recovery, wastes will be collected separately if technically, environmentally, and economically feasible and will not be mixed with other wastes or other materials with different properties. The Member States shall determine in terms of recycling and reuse stages, in particular, the establishment and support of reuse and repair networks, the use of economic instruments, the purchase criteria. Finally, member states will ensure that, in cases where recycling is not performed, the waste goes through safe disposal processes, paying attention to the protection of human health and the environment (WFD 2008).

By identifying some areas of inequality in WFD2008, Gharfalkar et al, (2015) recommend the hierarchy that increases clarity and provides a basis for improvement in "waste" that can be turned into "resources".

Alternative Waste Hierarchy



Source: Gharfalkar et al, (2015:308)

Gharfalkar et al, (2015) expand the definition of Recovery and considers the sub-categories of Preparing for reuse, Reuse, Reprocessing, Other Recovery. It also offers 5Rs' of resource effectiveness. These are Replace, Reduce, Recover, Rectify and Return. Additionally, Potting et al, (2017) proposed 10R strategies as followed Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover. Although it is possible to increase the number of R strategies in question, it may not be possible to meet all objectives at the same time. It is also necessary to look at the trade-off, synergy, and complementarity relations among the strategies (Morselotto, 2020:10).

All these technical differences related to waste management aside, the implementation of CE and related business models support achieving several of the Sustainable Development Goals (SDG) targets as well. For instance, CE practices directly contribute to SDG 8 (Decent Work and Economic Growth) (Schröder et al, 2018: 92). In a study in which the economic return is expressed in monetary values, it is claimed that the adoption of CE in the manufacturing sectors provides net material cost savings of 340-630 billion US dollars per year in the EU alone, while in the advanced scenario, this savings can reach 520-630 billion US dollars per year (Ellen Macarthur Foundation, 2013:66). EEA Report (2011) claimed that the recycling sector is currently dominated by seven core groups of materials (glass, paper, and cardboard, plastic, iron and steel, copper, aluminum and nickel, precious metals, other metals), and the turnover of recycling seven key recyclables relative to the total Gross Value Added of the manufacturing, electricity, and waste management industry in the EU increased from about 1.69 % to 2.7 % in the period 2004-2008. Despite these, the employment-related to materials recovery in Europe has increased from 422 inhabitants per million in 2000 to 611 in 2007.

As a result, although the recovery processes are classified in a narrow or broad sense, the economic contribution of the thought recovery process is widely accepted. This study investigates whether the recovery process contributes to reducing inefficiencies in the production function for OECD countries. In the first section of the study, the literature on efficiency analysis on waste management is examined, and in the second section, related literature on the stochastic frontier method is introduced. In the third and fourth sections, the results of the analysis of inefficiency effects in the production function and the results obtained are included, respectively.

1. Literature Background

In the literature, the circular economy is examined with eight different methods such as life cycle assessment, input-output analysis, material flow analysis, energy/exergy analysis, system dynamics, discrete event simulation, agent-based modeling, and operations research. Which method is suitable for analyzing CE? It seems quite difficult to answer this question. It can be said that they all have weaknesses that prevent them from addressing all of the components of CE (Walzberg et al, 2021:15).

In addition to the aforementioned methods, the method that is frequently applied in CE discussions is efficiency analysis. Efficiency can be defined as the ability of the amount of input to transform output depending on the production process (Çakmak vd., 2008:7). Efficiency analysis measurement although has an advance literatüre; Debreu (1951), Shepard (1953), Farrell (1957), Hoffman (1957), Boles (1966 and 1971), Aigner ve Chu (1968), Fare (1975), Charnes-Cooper and Rhodes (1978 and 1981), Banker-Charnes and Cooper (1984), Fare-Grosskopf and Lovell (1994), Batesse and Coelli (1988 and 1992), Batesse and Broca (1997) etc. are some example of important empirical studies.

In empirical studies, efficiency analysis is defined as input and output oriented. Depending on the progress of the literatüre, the analysis is differentiated as technical efficieny, allocation efficiency and scale efficiency. On the other hand; efficiency measurements can be done with parametric, semi-parametric and non-parametric approaches (Taşdoğan ve Taşdoğan, 2011:62-64).

Efficiency analyzes also use different indicators in performance measurements. Hu and Lee (2010) examine the effective use of three different industrial waste variables for thirty regions in China. The data envelopment analysis (DEA) with a single output (real GDP) and five inputs (labor, real capital stock, solid wastes, wastewater, and waste gas) is used to compute the target wastes of each region for each year. Zou et al (2007) propose non-radial DEA for environmental performance measurements and observe the change of environmental performance over time using the non-radial Malmquist index. Yeh et al., (2010) perform efficiency analysis by including SO and CO variables, which are defined as undesirable outputs. Wu et al (2014) use the further method of super-efficiency DEA window analysis to dynamically CE efficiency in China for a period of 2005-2010 in which it is examined the specific efficiency of three sub-systems, namely resource-saving and pollutant reducing sub-system, waste reusing and resource recycling sub-system and pollution controlling and waste disposing sub-system. Robaina et al, (2020) investigate labor, capital, and energy as inputs, and GDP, CO2 emissions, plastic waste, plastic recycling, and plastic recovery as outputs in the framework of multidirectional efficiency analysis.

While the DEA framework mainly focuses on economic cost minimization of waste, Sarra et al, (2017) used a modified DEA model for unsorted waste as an undesirable output to be minimized. The traditional DEA model has been accepted as a non-parametric technique that does not include statistical inference, that's why Simoes et al (2010) use the bootstrap methodology application which allows the statistical inference to the DEA estimators. Bosch et al, (2000) investigate the technical or productive efficiency of waste collection services in 75 municipalities in Spain then they have calculated a deterministic frontier, a stochastic frontier, and various non-parametric models.

When the case includes multiple-input and single-output production functions, the stochastic frontier consists of assumptions about the functional relationship between inputs and outputs variables. Additionally, compared with non-parametric the stochastic frontier analysis (SFA) considers the effects of random factors on outputs which strengthen the used estimation procedure.

Another advantage of SFA is the measurement of productivity and efficiency it is crucial what factors determine the measured values. While the DEA model uses a two-stage procedure, the efficiency values and the regression parameters are estimated unbiased in one step with SFA. In addition, in the SFA approach, it is possible to test which data is most suitable for the functional form. Finally, more complex models can be estimated with SFA than with DEA (Mutz et al, 2017: 614-615). Therefore, DEA is a deterministic method without considering noise. By contrast, the SFA method differs between inefficiency and noise with a functional form for the underlying technology (Molinos-Senante and Maziotis, 2021:2)

Vishwakarma et al, (2012) performed SFA for a total of 22 cities of India to evaluate Municipality Solid Waste Management. The estimation model includes various combinations of input-output variables in the different functional forms to choose an appropriate SFA production function model, hence Cobb-Douglas half normal production function was the best alternative to represent the efficiencies of Municipality Solid Waste Management. Finally, the results indicated that there existed significant inefficiencies among the 22 municipalities and larger municipalities have shown better efficiencies and better management.

Giovanis (2012) examines the relationship between the recycling rate of solid waste and air pollution using data obtained from a waste municipality survey in the state of Massachusetts for the period 2009-2012. Two different econometric methods are used in the study. The first approach is the fixed effects model, the second is the Stochastic Frontier Analysis (SFA) with the fixed-effects model. The SFA model is applied to predict the technical efficiency of each municipality and its ranking accordingly. The SFA results provide insights for municipalities to perform better on air quality, with municipalities offering both drop-off and curbside services for garbage, food, and garden waste and the pay-as-you-throw (PAYT) program.

Agovino et al, (2020) investigated the relationship between firm competitiveness and recycling rate by using the Cobb-Douglas production function in SFA, the function consists of firm competitiveness as output and the inputs are recycling rates of packaging waste, e-waste, and bio-waste. The results of the study show that the recycling rates of packaging e-waste and bio-waste affect firm competitiveness in Europe.

Fan et al, (2020) used SFA to evaluate the efficiency of municipality solid waste collection services in 30 provinces of China for the period 2008 to 2017. The results implied that It has been determined that the proportion of the population aged 15-64, GDP per capita, the added value of the tertiary industry, and the level of education have the most important effects on efficiency. This study preferred the volume of municipality collection as an output variable in form of the Cobb-Douglas production function because the main purpose is to increase the amount of solid waste collected for preventing harmless treatment.

Although SFA models are superior to DEA models, SFA applications seem to be quite limited in the literature. In existing limited studies, although the Cobb-Douglas production function is applied, recycling is not modeled as an input variable. In this study, it is thought that one of the important variables of reducing inefficiency in the production function is the recovery in which the recycling of losses in the production process creates an important economic value while reducing the use of inputs or substituting them. Therefore, recovery is directly designed as an additional input using the Cobb-Douglas functional form.

2. Methodology

Since the panel data set uses more observation values compared to the cross-section data in the estimation of stochastic production functions, it allows better results in determining the effects of unknown variables on technical efficiency values. In addition, by separating the inefficiency effects from the error term, it can loosen the rigid assumptions of the variables in the analysis, increase the degree of freedom, increase the consistency of technical efficiency estimates, and detect the efficiency changes that occur in production technology in a certain period (Coelli et al, 2005: 275).

Stochastic production function estimates are based on the assumption that decision-making units encounter technical inefficiency while producing a certain level of output. In estimated models, firms are assumed to be constrained by the parametric function of known inputs, unknown parameters, random error term, and other factors associated with the error term when using a data combination of inputs. Therefore, the growth of the effects of these variables causes to increase in the technical inefficiency of the stochastic production function. Most of the theoretical studies on the stochastic limit of the production function cannot describe the effects of technical inefficiency with appropriate explanatory variables (Taşdoğan, 2013:10-11). When empirical studies are evaluated, technical inefficiency effects have come to the fore with the studies of Kalirajan (1981) and Pitt and Lee (1981). These papers use a two-stage approach to technical inefficiency effects. In the first step, the limit of the stochastic production function is determined and the inefficiency effects are estimated under the assumption that the inefficiency effects are uniformly distributed. In the second stage, technical inefficiency effects are estimated with a regression equation (Battese and Coelli, 1995: 325-326). Kalirajan (1981) uses the assumption that the error term is normally distributed in estimating the second stage of inefficiency effects. Pitt and Lee (1981), on the other hand, use the corporate structure, age, and scale of the firm as different constant coefficients in the regression equation, claiming that the efficiency of the firms will change according to their characteristics to determine the efficiency level of a single firm since they accept the industry as a whole. Therefore, it explains the source of inefficiency faced by firms with different fixed coefficients. In addition, Kumbhakar et al., (1991) found a statistically significant relationship between the effects of technical inefficiency the education level of farmers, and the scale of their activities. Reifschnider and Stevenson (1991) and Huang and Liu (1992) analyzed the relationship between technical inefficiency effects and firm characteristics using cross-sectional data.

Battese and Coelli (1995) examine the inefficiency frontier in the stochastic production function with a panel data set.

$$Y_{it} = \exp(x_{it}\beta + V_{it} - U_{it})$$

Here Y_{it}, represents the production of firm i (i = 1,2,…,N) in the observation period t (t = 1,2,…,T). x_{it}, is the value vector of the known functions of the inputs used in production and other explanatory variables related to the production of firm i in the observation period t. β is the unknown vector of the parameters to be estimated. V_{it} represents the random error term and is distributed independently of U_{it} in the form of $N(0, \sigma_V^2)$. U_{it} represents non-negative random variables and is independently distributed in the form of $N(z_{it}\delta, \sigma_u^2)$. z_{it} is defined as the vector of explanatory variables associated with technical inefficiency in the production of firms in a given period. δ represents the coefficient vector.

The technical inefficiency effects (U_{it}) of the stochastic frontier model in the equation are shown as follows.

$$U_{it} = z_{it}\delta + W_{it}$$

Here the random variable W_{it} is discretely and normally distributed with zero mean and σ^2 variance. The maximum likelihood method is proposed for simultaneous estimation of technical inefficiency and stochastic boundary parameters in the model, and the technical efficiency of firm i's production in observation period t is calculated as follows.

$$TE_{it} = \exp(-U_{it}) = \exp(z_{it}\delta - W_{it})$$ (Battese and Coelli, 1995: 326-328)

While x_{it} defined in the model represents economic variables (capital and labor), z_{it} represents economic and social variables that are thought to cause technical inefficiency.

3. Empirical Results

In the study, the 2000-2017 period data of OECD countries were used to analyze the effects of waste management styles on economic growth. Real gross domestic product values were obtained from the World Bank and waste data were obtained from the OECD website*. Using the Maximum Likelihood Estimation method based on the Cobb-Douglas production function, the effect of the variable causing technical inefficiency in the production function is calculated.

The production function used in the estimation follows;

$$lny_{it} = \beta_0 + \beta_1 lnK_{it} + \beta_2 lnL_{it} + v_{it} - u_{it}$$

The technical inefficiency effect is;

$$U_{it} = \delta_0 + \delta_1(lnRecoveryRate_{it}) + W_{it}.$$

* https://databank.worldbank.org/source/world-development-indicators ; https://data.oecd.org/waste/municipal-waste.htm

lny_{it} : Logarithm of real gross domestic product per capita

lnK_{it}: Logarithm of capital stock per capita

lnL_{it}: Logarithm of employment

$lnRecoveryRate_{it}$: The municipal solid waste (MSW) recovery rate is calculated by

$MSW\ recovery\ rate$: $\frac{Total\ MSW\ recovery}{Total\ MSW\ generated}$

where Total MSW generated = MSW recovery + MSW other treated + MSW disposal + MSW incineration; Total MSW recovery = recycling + composting waste[†].

Estimation Parameters for Stochastic Frontier Model

Variable	Parameter	Coefficient	z value
Constant	β_0	11,81*	213,4
logK	β_1	0,86*	93,12
LogL	β_2	0,32*	30,02
Inefficiency Effect			
Constant	δ_0	0,44*	138,22
logRecoveryRate	δ_1	-0,04*	-5,08
Variance Parameters			
γ		0,84	
Log-likelihood		770,05	
$LR = -2(lnH_0 - lnH_1)$**		1938,54*	

Variance Parameters: $\gamma = \sigma_u^2/\sigma_s^2$; $\sigma_s^2 = \sigma_u^2 + \sigma_v^2$,
(*): Statistically significant at the 1 per cent level
(**): Statistically significant at the 5 per cent level; Likelihood Ratio Test, where lnH_0 and lnH_1 represent Log-likelihood ratio values calculated from restricted generalized least squares model and unrestricted stochastic frontier model (Kumbhakar, Wang and Horncastle, 2015:65; Batesse and Coelli, 1995:330). The Critical value of X^2 for LR test is 5,41 (Kodde and Palm,1986: 1246).

Considering the results of the analysis, the γ coefficient, which indicates the presence of technical inefficiency obtained from the variance of the error terms, was calculated as 0,84. Thus, the average efficiency value of the countries is determined as 0,85, it can be said that there is technical inefficiency in the production function. In addition, since the Likelihood Ratio Test result related to the presence of technical inefficiency is higher than the X^2 table value of 5,41, statistically significant at the 5 per cent level, Therefore, the presence of technical inefficiency is considered statistically.

[†] Giovannis, (2012) used MSW recycling rate with a similar ratio, see details,

The sign of the lnK_{it} variable is positive and statistically significant at the 1 per cent level. In this case, it can be said that the increase in the capital amount of the countries increases the technical efficiency. Although it had a lower value compared to the coefficient of the capital variable, the sign of the lnL_{it} variable was positive and statistically significant at 1 percent level. Therefore, it is thought that the increase in the use of the labor force also increases technical efficiency.

Although the existence of technical inefficiency in the production function is accepted, it is seen that a variable that reduces this inefficiency is $lnRecoveryRate_{it}$. The sign of this variable is negative and statistically significant at 1 percent level. Finally, It has been found that as $lnRecoveryRate_{it}$ increases, technical inefficiency decreases.

Conclusion

The concept of circular economy is defined as the recycling of wastes generated in the production process into resources. CE, which aims to achieve a sustainable balance between economy, environment, and society, is seen as an opportunity for the effective use of resources. CE is widely known as the 3R's principle. However, 3R and waste management policies may differ between countries due to each country's unique circumstances or political strategies. While some countries focus on reducing waste and its damages, some countries focus on recycling wastes into resources and bringing them into the economy. The 3R strategy is defined more broadly in the literature, and the 5R and 10R waste hierarchy is recommended. It is technically more about how countries will consider the relationships between the R stages and whether they have sufficient capacity to realize all stages, rather than the expansion of the hierarchy.

Although CE analyzes have been discussed using different methods, DEA is preferred more intensely in the literature. While DEA has advantages in multi-input and multi-output situations, they rank the efficiency scores according to the highest level among the existing decision-making units and facilitate the development of policy recommendations for performance improvement. These analyzes are insufficient since they do not take into account the error term, are a static analysis, and reliability tests cannot be performed. For all these reasons, SFA models, which provide statistically more successful and robust results, have started to see more preference for efficiency analysis. Although SFA studies are limited, the results are considered more reliable because it is a superior approach to DEA and theoretically uses a functional form.

In this study, the production inefficiency effect was calculated with the SFA model based on the Cobb-Douglas production function. The recovery rate variable was added to the production function as an input variable to represent the situation in which the wastes were converted back into resources, and the inefficiency effect of the recovery rate variable was obtained by calculating the inefficiency value in the production process. As a result, it was seen that the efficiency value calculated for OECD countries was 0,84 and the inefficiency in the production process decreased as the recovery rate increased.

The recovery variable used in the study was defined as the sum of recycling and composting waste. Municipal waste treated consists of recovery operations (recycling, composting, incineration with energy recovery and another recovery) and disposal operations (incineration without energy recovery, landfill, and other disposals) in the OECD Database. Further studies can determine the importance and economic contribution of the recovery process by redefining the recovery variable according to the waste management policies of the countries.

Even though the economic contribution of the recovery process is accepted by local governments, the initial costs of carrying out this process may require significant expenditures. Therefore, the financing of these expenditures stands before us as an important area.

The full cost of recovery policy includes up-front costs, operation costs, and back-end costs in total. Up-front costs cover the initial investments and expenses required to implement MSW services. Operating costs are the expenses of managing MSW daily. Back-end costs include completing operations smoothly at the end of their useful life, covering maintenance and repair costs of landfills and facilities, and securing costs such as health and retirement benefits for MSW workers.

Considering these defined costs of the MSW process, it is seen that not all municipalities can spend enough for a successful MSW. MSW has the potential to become a problem, especially for municipalities in small cities. While recovery has a positive effect on the economy of the country, new policies should be developed by considering the potential costs and the capacities of the municipalities.

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