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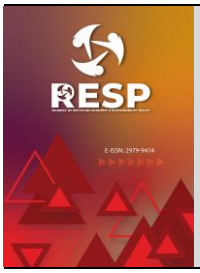

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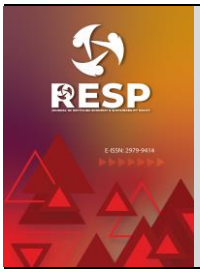

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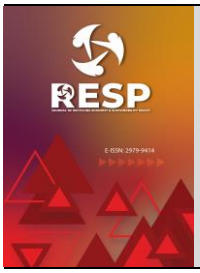

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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

RESP

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Araştırma Makalesi ● Research Article

The impact of education expenditures on economic growth in Turkey: Evidence from the ARDL bounds testing approach *

Türkiye'de eğitim harcamalarının ekonomik büyümeye etkisi: ARDL sınır testi yaklaşımından elde edilen kanıtlar

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ANAHTAR KELİMELER

Eğitim giderleri
Ekonomik büyüme
ARDL
Türkiye

ÖZ

Bu makale, Türkiye'de 1997-2020 dönemi için yıllık verileri kullanılarak kamu eğitim harcamalarının kişi başına düşen reel GSYİH üzerindeki etkisini ampirik olarak incelemektedir. Bu makale, değişkenler arasındaki uzun vadeli ve kısa vadeli ilişkiyi tahmin etmek için otoregresif gecikmeli dağıtma (ARDL) sınır testini benimser. ARDL sınır testi yaklaşımına ilişkin ampirik sonuçlar, eğitim harcamaları ile kişi başına düşen reel GSYİH arasında uzun dönemli bir ilişki olduğunu ve eğitime yapılan kamu harcamalarının Türkiye'nin kişi başına düşen reel GSYİH üzerindeki olumlu etkilerin uzun dönemde ortaya çıktığını göstermektedir. Bulgular, uzun vadede, eğitime yapılan kamu harcamalarının üretkenliği artırmaya ve ekonomik kalkınmayı hızlandırmaya yardımcı olduğunu göstermektedir.

KEYWORDS

Education expenditures
Economic growth
ARDL
Turkey

ABSTRACT

This paper empirically investigates the impact of public education expenditures on real GDP per capita using annual data for the period 1997-2020 in Turkey. This paper adopts the autoregressive distribute lagged (ARDL) bound test to estimate the long-run and short-run relationship between variables. Empirical results of the ARDL bound test approach reveal that there is a long-run relationship between education expenditures and real GDP per capita and that the positive effects of public expenditures on education on Turkey's real GDP per capita emerge in the long run. The findings point out that in the long run, public spending on education serves to promote productivity and accelerate economic development.

1. Introduction

The determinants of economic growth are among the most discussed and researched issues in every period of the historical development of economics. Although the economic literature focused mainly on the quantitative aspect of growth until the 1980s, attention was drawn to the effects of education on increasing the workforce's productivity and economic growth, together with the endogenous growth theories. From this point of view, human capital is needed to ensure economic growth. As important as the labor force is for economic growth, its effective and efficient use is just as important. Increasing efficiency in the economy is possible with a qualified workforce. This situation requires investing in humans,

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which is the basis of human capital to a large extent (Esen and Seren, 2022). Investments in the human element such as education, health, and nutrition make it possible to benefit from the human capital factor properly (Afşar, 2009). Changing the effectiveness of human capital, which is one of the main determinants of economic growth, through education is a necessity that needs to be examined in terms of economic growth.

It is accepted that the level of development of countries depends on their ability to produce information, technology, goods, and services and to transform them into economic and social benefits. Nowadays, it is known that education is a critical component that accelerates economic, social, and cultural development. In addition to contributing to the acquisition of the labor force in the quality and quantity needed in the development process, education also enables countries to follow, develop and apply contemporary production technologies to produce and disseminate information. As the education level rises, the increase in the productivity of the workforce also supports the competitiveness of countries and eases their outward expansion (Çalışkan et al., 2013). Moreover, increasing and developing human capital stock plays a key role in attracting foreign capital. As a result, education makes significant contributions to economic development and social welfare by increasing the knowledge and abilities of the labor factor and thus its productivity (Uçan and Yeşilyurt, 2016).

The effects of human capital on economic growth have been widely researched in the literature recently. In particular, researchers and policymakers closely follow the short- and long-term effects of investments in education on economic growth. Among these studies, Erdoğan and Yıldırım (2009) tested the link between education and economic growth for Turkey covering the 1983 - 2005 period using the ARDL method. They found a positive relationship between education expenditures and economic growth, and a negative relationship between investment in education expenditures and economic growth. Çalışkan et al. (2013) used data from Turkey covering the period 1923-2011 to examine the impact of education on economic growth. Based on the cointegration test results, they found evidence that improvements in education support economic growth. Similarly, Selim et al. (2014) examined the short- and long-run relationship between education expenditures and economic growth for G20 countries covering the 2000-2011 period using a panel cointegration and error correction model. They found a positive and statistically significant relationship between education expenditures and economic growth in both the long and short run. Uçan and Yeşilyurt (2016) examined the relationship between economic growth and education expenditures for the period 2006:Q1 and 2015:Q4 in Turkey using cointegration and causality analyses. They conclude that there is both a cointegration relationship and a bidirectional causality relationship between the variables. Addressing the subject in the context of the number of students, Gövdeli (2016) used unit root and cointegration tests with structural breaks and causality tests for Turkey covering the period of 1923-2014. Findings pointed out that there is a long-term positive relationship between the number of students in primary education, high school, and university and economic growth, and a unidirectional causality relationship from the number of students in primary education to economic growth and from growth to the number of students in high school. Yalçınkaya and Kaya (2016) examined the long-term effects of education on economic growth in low-, middle- and high-income countries for the period 1991-2011. They found that education contributed positively to economic growth in all country groups. In addition, the findings indicate that the positive effect of education on economic growth also increases, as the income levels of the countries increase. Karış (2019) examined the cointegration and causality relationship between education expenditures and economic growth for Turkey covering the period 2003:Q1-2018:Q2. The findings revealed that there is a cointegration relationship between the variables and that education expenditures are the cause of economic growth only in the long run. Yürük and Acaroğlu (2021) analyzed the relationship between education expenditures and economic growth for Turkey covering the 1980-2015 period using the Nonlinear Autoregressive Distributed Lags (NARDL) model. They found that positive shocks in education expenditures developed in favor of economic growth in both the short and long run, while negative shocks resulted only against economic growth in the short run. The findings support the positive externality of education.

In contrast, Pamuk and Bektaş (2014) examined the effects of education expenditures on economic growth in Turkey covering the period 1998:01-2013:02, employing the ARDL bounds test approach. The findings showed that there was no cointegration relationship between the variable. Similarly, Altun et al. (2018) examined the effect of education expenditures on economic growth using the Least Squares method for Turkey covering the period 1999-2017 and concluded that education expenditures do not have a significant effect on economic growth. Fendoğlu and Canpolat Gökçe (2021) used the Fourier ARDL approach to examine the relationship between economic growth and health and education expenditures in Turkey for the period 2006Q1-2021Q1. Findings revealed evidence that there is no long-term relationship between economic growth and education expenditures for Turkey.

To this end, this paper empirically studies the impact of public education expenditures on real GDP per capita for Turkey covering the period 1997-2020 using an autoregressive distribute lagged (ARDL) bound test. The rest of the paper is organized as follows. Section 2 briefly describes the data sets used in the analysis. Section 3 presents and discusses the empirical results. Subsequently, Section 5 provides some concluding remarks.

2. Model and Data

This paper examines the short- and long-term effects of

education expenditures on economic growth in the Turkish economy using the ARDL Boundary test approach. This study uses annual time series data covering the period 1997-2020 for Turkey. The availability of data is decisive in the selection of the sample period. The model used in this study to examine the relationship between education expenditures and economic growth is established in Equation (1). The data used in the analysis consists of time series data belonging to variables of education expenditures (EDU) and economic growth (GDP per). Data on education expenditures were compiled from the National Education Statistics database of the Ministry of National Education (MEB, 2007; 2021). The economic growth series was obtained from the World Bank's World Development Indicators (WDI) database (World Bank, 2022).

$$lnGDPper_t = \beta_0 + \beta_1 lnEDU_t + \varepsilon_t \quad (1)$$

The variables and the explanations for these variables in Eq. (1) are as follows; GDPper (GDP per capita) represents the real gross domestic product per capita and EDU (education expenditures) symbolizes the ratio of Turkey's Ministry of National Education (MEB) budget to GDP. Also, ε is the error term. In the calculations, the natural logarithm of each series is taken to reduce the skewness observed in the data distribution of the variables. Depending on taking the natural logarithms of all variables, the expression "ln" has been added to the model representations of the variables. The descriptive statistics of the variables are shown in Table 1.

Table 1. Descriptive statistics of the variables

Variables	Obs.	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis
lnGDPper	24	9.628	9.618	9.970	9.286	0.239	0.068	1.598
lnEDU	24	0.542	0.862	1.938	-2.606	1.168	-1.149	3.672

3. Empirical results

In this study, the ARDL bounds test approach developed by Pesaran and Shin (1995), Pesaran et al. (1996), Pesaran (1997), and Pesaran et al. (2001) is used to examine the long-run cointegration relationship between education expenditures and economic growth. ARDL cointegration approach has several advantages compared to other cointegration methods. Unlike other cointegration approaches, ARDL does not impose a restrictive assumption that all examined variables must be integrated at the same level. In other words, the ARDL approach can be used regardless of whether the variables are stationary at the same level (Odhiambo, 2010). Second, while other cointegration techniques are sensitive to sample size, the ARDL test can be applied to models with small sample sizes. Third, the ARDL technique can generally give unbiased estimates of the long-term model and can provide valid t-statistics even if some variables are endogenous (Harris and Sollis, 2003).

In the estimation of this study, which examines the effect of education expenditures on economic growth, the stationarity of the series must first be determined to examine the time series properties of each variable. Although the ARDL bounds test approach does not require unit root tests, these tests are required to ensure that variables are not integrated at the 2nd degree [I(2)] or higher. Therefore, the stationarity of the series is tested using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, and the results are reported in Table 3.

Table 2. Unit root tests results

Variables	ADF Tests			
	Level		1st Difference	
	Constant	Constant & trend	Constant	Constant & trend
lnEDU	-7.6967*	-7.6183*	-5.7990*	-4.0184**
lnGDPper	-0.0150	-3.2998	-4.2462*	-4.1547**
	PP Tests			
	Level		1st Difference	
	Constant	Constant & trend	Constant	Constant & trend
lnEDU	-7.3157*	-13.8372*	-4.6237*	-4.0949**
lnGDPper	-0.0373	-2.8340	-4.2379*	-4.1475**

* and ** indicate statistically significant at the 1% and 5% levels respectively.

For ARDL tests, the series should not be second-order stationary. Based on the results of both ADF and PP unit root tests in Table 2, it is seen that all series are stationary in difference. According to these findings, it is seen that lnEDU is stationary at I(0) and lnGDPper is stationary at the I(1) level. Within the scope of the study, it is evaluated that they can be modeled according to the ARDL bounds test approach, depending on the variables being stationary at different levels.

Firstly, the most appropriate lag length for the variables must be determined in the ARDL model. In this study, Akaike Information Criterion (AIC) was used to determine

the optimal lag length of the Model. ARDL (2,1) model corresponding to the smallest AIC value was chosen as the most suitable model. Accordingly, ARDL (2, 1) bounds test results are given in Table 3.

As reviewing Table 3 including the results of the ARDL bounds test, it is seen that the calculated F statistical value (5.032) is greater than the critical I(0) and I(1) bound values at the 5% significance level. Based on these findings, the H_0 hypothesis is rejected, and it is concluded that there is a long-term cointegration relationship between education expenditures and economic growth. After determining the existence of a long-term relationship between the variables, cointegration parameters reflecting the long-term relationship are estimated for the ARDL (2,1) model. Accordingly, the long-term estimation results of the ARDL approach are given in Table 4.

Table 3. ARDL results of cointegration

Test statistic		H_0: No cointegration relationship		
		Significance level	Lower I(0)	Upper I(1)
F-Statistic	5.032**	1%	6.027	6.760
k	1	5%	4.090	4.663
		10%	3.303	3.797

*, ** and *** indicate statistically significant at the 1%, 5% and 10% levels respectively.

Table 4. Long-run estimates based on the selected ARDL (2,1) model

Variables	Coefficients	t-Statistics	Prob.
lnEDU	0.240*	3.286	0.004
C	9.661*	49.423	0.000

*, ** and *** indicate statistically significant at the 1%, 5% and 10% levels respectively.

Table 4 shows the parameter estimation results of the long-run relationship between education expenditures and economic growth in Turkey. The findings show that education expenditures have a positive and significant effect on economic growth in the long run, that is, increases in education expenditures further increase real income per capita, which represents the level of welfare. From this point of view, an increase of 1 unit in education expenditures causes an increase in real income per capita by 0.24 units in Turkey in the long run. The short-run results with error correction representation are shown in Table 5.

Table 5. Short-run results with error correction representation for the selected ARDL (2,1) model

Variables	Coefficients	t-Statistics	Prob.
D(lnEDU (-1))	-0.061	-0.339	0.738
D(lnEDU)	-0.049	-1.230	0.235
ECM (-1)	-0.204*	-4.107	0.000

*, ** and *** indicate statistically significant at the 1%, 5% and 10% levels respectively.

Reviewing the short-term results in Table 5, it is seen that the ECT coefficient (-0.204) is negative and statistically significant. According to these results, it is understood that 6.2% of disequilibrium in the level of economic growth caused by education expenditures disappears or improves in the next period (one year). In other words, the deviations from the equilibrium in the short run converge to the equilibrium point in the long run. The short-term results show that, unlike the long-term, education expenditures have a statistically insignificant but negative effect on economic growth. The diagnostic tests related to the reliability of the model discussed in the study at a significance level of 0.05 are given in Table 6.

Table 6. Diagnostic test statistics

Diagnostic tests	F-stat. value (Prob.)
Breusch-Godfrey Serial Correlation LM Test	0.018 (0.974)
Heteroskedasticity Test: ARCH LM Test	0.045 (0.824)
Heteroskedasticity Test: Breusch-Pagan-Godfrey	0.271 (0.858)
Ramsey RESET Test	0.462 (0.506)

When the diagnostic test results of the model in Table 6 are evaluated, it is seen that there is no evidence of serial correlation and heteroskedasticity in the model, and finally there is evidence of a well-specified model. Therefore, these findings confirm the reliability and validity of the estimation results obtained in the study.

4. Conclusions

In this study, the effect of public education expenditures on real GDP per capita is examined with the help of the ARDL model, using annual data for the period 1997-2020 in Turkey. The study is based on the suggestions of the human capital and endogenous growth doctrines to provide investment in the education sector as a tool for economic development. The study provides evidence for the existence of a positive and statistically significant long-term effect of government education expenditures on economic growth for the examined period. The results of the long-term analysis reveal that a 1% increase in education expenditures causes an increase of 0.24 units in real income per capita in Turkey in the long run. In addition, it is concluded that the education

expenditures of the state have a non-significant negative effect on economic growth in the short run. As a result, it is understood that the positive effects of public expenditures on education on GDP per capita emerge in the long run. From this point of view, education offers people the opportunity to expand their knowledge and develop their skills. It can provide a fundamental incentive for research, development, and innovation, as well as the accumulation of human capital and skilled labor, which are decisive factors for growth. In other words, the findings indicate that in the long run, public spending on education serves to promote productivity and accelerate economic development. Therefore, it is concluded that policies aiming to invest more in education are important for more production and greater economic growth.

References

Afşar, M. (2009). Türkiye'de eğitim yatırımları ve ekonomik büyüme ilişkisi. *Anadolu Üniversitesi Sosyal Bilimler Dergisi, 9(*1), 85-98.

Altun, Y., İşleyen, Ş., & Görür, Ç. (2018). Türkiye'de eğitim ve sağlık harcamalarının ekonomik büyümeye etkisi: 1999-2017. *Yüzüncü Yıl Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, (39),* 223-244.

Çalışkan, Ş., Karabacak, M., & Meçik, O. (2013). Türkiye'de eğitim-ekonomik büyüme ilişkisi: 1923-2011 (Kantitatif bir yaklaşım). *Yönetim Bilimleri Dergisi, 11(*21), 29-48.

Erdoğan, S., & Yıldırım, D. Ç. (2009). Türkiye'de eğitim–iktisadi büyüme ilişkisi üzerine ekonometrik bir inceleme. *Bilgi Ekonomisi ve Yönetimi Dergisi, 4*(2), 11-22.

Esen, Ö., & Seren, G. Y. (2022). The impact of gender inequality in education and employment on economic performance in Turkey: evidence from a cointegration approach. Equality, Diversity and Inclusion. *An International Journal, 41*(4), 592-607. https://doi.org/10.1108/EDI-04-2021-0099

Fendoğlu, E., & Canpolat Gökçe, E. (2021). Türkiye'de eğitim ve sağlık harcamaları ile ekonomik büyüme arasındaki ilişki: Fourier yaklaşımı. *Ekonomi İşletme ve Maliye Araştırmaları Dergisi, 3(*2), 203-216.

Gövdeli, T. (2016). Türkiye'de eğitim-ekonomik büyüme ilişkisi: yapısal kırılmalı birim kök ve eşbütünleşme analizi. *Niğde Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 9*(3), 223-238.

Harris, R., & Sollis, R. (2003). *Applied time series modelling and forecasting*. Chichester, UK: Wiley.

Karış, Ç. (2019). Eğitim harcamaları ve ekonomik büyüme üzerine bir nedensellik analizi: Türkiye örneği. *Bingöl Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 9*(18), 1069-1090. https://orcid.org/0000-0002-7534-0494.

MEB (2007). *Millî Eğitim İstatistikleri Örgün Eğitim 2006/2007.* Ankara: Millî Eğitim Bakanlığı Strateji Geliştirme Başkanlığı. (Erişim Tarihi: 10.05.2022), https://sgb.meb.gov.tr/www/milli-egitim-istatistikleri-orgun-egitim-2010-2011/icerik/73

MEB (2021). *Millî Eğitim İstatistikleri Örgün Eğitim 2020/2021.* Ankara: Millî Eğitim Bakanlığı Strateji Geliştirme Başkanlığı. (Erişim Tarihi: 10.05.2022), https://sgb.meb.gov.tr/www/icerik_goruntule.php?KNO=424

Odhiambo, N. M. (2010). Interest rate reforms and credit allocation in Tanzania: An application of the ARDL bounds testing approach. *International Business & Economics Research Journal (IBER), 9*(5), 23-32.

Pamuk, M., & Bektaş, H. (2014). Türkiye'de eğitim harcamaları ve ekonomik büyüme arasındaki ilişki: ARDL sınır testi yaklaşımı. *Siyaset, Ekonomi ve Yönetim Araştırmaları Dergisi, 2*(2), 77-90.

Pesaran, M. H. (1997). The role of economic theory in modelling the long run. *The economic journal, 107*(440), 178-191.

Pesaran, M. H., & Shin, Y. (1995). An autoregressive distributed lag modelling approach to cointegration analysis. *DAE Working Paper Series No. 9514*. Cambridge: Department of Applied Economics, University of Cambridge.

Pesaran, M. H., Shin, Y., & Smith, R. J. (1996). Testing for the existence of a long-run relationship. *DAE Working Paper Series No. 9622.* Cambridge: Faculty of Economics, University of Cambridge.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics, 16(*3), 289-326. https://doi.org/10.1002/jae.616

Selim, S., Purtaş, Y., & Uysal, D. (2014). G-20 ülkelerinde eğitim harcamalarının ekonomik büyüme üzerindeki etkisi. *Optimum Ekonomi ve Yönetim Bilimleri Dergisi, 1*(2), 93-102

Uçan, O., & Yeşilyurt, H. (2016). Türkiye'de eğitim harcamaları ve büyüme ilişkisi. *Niğde Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 9*(2), 179-185.

World Bank (2022). World Development Indicators. (Erişim Tarihi: 10.05.2022), https://databank.worldbank.org/source/world-development-indicators

Yalçınkaya, Ö., & Kaya, V. (2016). Eğitimin ekonomik büyüme üzerindeki etkileri: düşük, orta ve yüksek gelirli ülkeler üzerinde bir uygulama (1991-2011). *Bolu Abant İzzet Baysal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 16*(3), 27-60.

Yürük, B., & Acaroğlu, H. (2021). Türkiye'de eğitim harcamaları ve ekonomik büyüme arasındaki ilişkinin doğrusal olmayan analizi. *Yaşar Üniversitesi E-Dergisi*, *16*(63), 1301-1317.

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Derleme Makalesi ● Review Article

Understanding interactions between toxic waste and fungi: breaking down toxic materials and restore ecosystems

Toksik atık ve mantarlar arasındaki etkileşimleri anlamak: toksik malzemeleri parçalamak ve ekosistemleri eski haline getirmek

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A N A H T A R K E L İ M E L E R

Mantarların yeryüzü için rolü
Zehirli maddeleri parçalama
Ekosistemleri iyileştirme
Zehirli atık
Mantar
Mikoremediasyon

Ö Z

Son on yılda ikincil kirliliğe veya kirlilikle başa çıkmak için aşırı maliyet üzerine önemli bir baskı uygulandı. Birçok çalışma, dünya kirliliğiyle başa çıkmak için uygun maliyetli yöntemleri keşfetmeye çalıştı. Doğada, herhangi bir ikincil kirlilik olmadan doğal olarak kirlilikle mücadelede hayati rol oynayabilecek birkaç tür vardır. Mikoremediasyon bu günlerde dikkat çekiyor, çünkü bu, mantarların değerli bir etki için bir şeyleri parçalama yeteneğini kullanma sürecidir. Sanayide biyoenerji, biyomalzemeler, biyokimyasallar ve biyogübre, biyoatık ve tarımsal ürün artıkları bu tür mantar ürünleri yardımıyla dönüştürülmektedir. Bu nedenle mantarlar her alanda daha fazla ilgi görmektedir. Çoğu mantarın birincil işi, dünyayı sürdürülebilir kılmaktadır. Bakteriler kadar mantarlar da dünya için önemlidir. Bu çalışma, mantarların farklı sektörlerdeki faydalarını incelemektedir. Ayrıca mantarların toksik maddelerle savaşmadaki rolünü de vurgulamaktadır. Bu çalışma aynı zamanda, mantarların biyoremediasyon aracı olarak potansiyelinin kullanılmasına yönelik daha fazla araştırma yapılmasını önermektedir.

K E Y W O R D S

Role of Fungi for earth
Breaking down toxic materials
Restore ecosystems
Toxic waste
Mushroom
Mycoremediation

A B S T R A C T

Significant pressure has been applied to the secondary pollution or over costing to deal with pollution over the past decade. Several studies have tried to explore cost-effective methods to deal with earth's pollution. There are several species in the nature which can play vital role to fight with pollution naturally without any secondary pollution. Mycoremediation is getting attention these days, because this is process of harnessing fungi's ability to break down things for a valuable effect. In industry, bioenergy, biomaterials, biochemicals, and bio-fertilizer are converted from bio-waste and agricultural crop residues with the help of such fungal products. This is the reason fungi is getting more attention in every field. The prime job of most fungi is to sustain the natural world. Along with bacteria, fungi are important for the earth. This study reviews the benefits of fungi in different sectors. It also highlights the role of fungi to fight with toxic materials. This study also recommends further research towards the exploitation of potential of fungi as bioremediation tool.

1. Introduction

Recently, environmental issues need green response because many practices which we apply have secondary pollution (M Akram, 2010; Muhammad Akram et al., 2022; Dan et al., 2020). In developing countries, environmental issues related to waste are being solved by different methods, sometimes they have secondary pollution (Gadd, 1994) and it creates several problems. A biological method is recommended to deal this issue. As several studies are looking to conversion from fossil to bio-based resources with the help of fungi

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because they are attractive vital biodegradable building blocks. In addition, fungi are useful for pollutant removal from the waste (Jones, Mautner, Luenco, Bismarck, & John, 2020). Fungi exposed a higher progression rate than bacteria during 150 year's succession (Wang et al., 2019). Easy ways for removing man-made contaminants from the environmental bodies by fungi have been discovered because they use their enzymatic power to degrade these unwanted chemicals (Akhtar & Mannan, 2020). They are also able to break down waste plastics (which persist in the environment for years) within few weeks (Zimmermann, 2021), and produce sustainable building materials (Ferrari et al., 2015). There should be new advanced study to understand fungal biology and diversity. Aspergillus tubingensis is one of the types, which is typically found in soil. Researchers continue to look at the broad ways fungi can probably redevelop soils and keep moisture in the ground (Buil, Renison, & Becerra, 2021). Recent study found that it can also thrive on the surface of plastics (Lange, 2010). In addition, species of indigenous fungal isolates: A. candidus, , A. clavatus A. iizukae, A. niger, A. ochraceus and A. westerdijkiae, were used for bioaccumulation (Vašinková, Dlabaja, & Kučová, 2021).

Mycoremediation is getting attention these days, because this is process of harnessing fungi's ability to break down things for a valuable effect. In industry, bioenergy, biomaterials, biochemicals, and bio-fertilizer are converted from bio-waste and agricultural crop residues with the help of such fungal products (M Akram, 2010; Muhammad Akram et al., 2022; Inam, Khan, Akram, Khan, Park, et al., 2019; Inam, Khan, Akram, Khan, & Yeom, 2019; Inam et al., 2021). Several projects around the globe are looking to manipulate fungi to break down toxic waste and other man-created contaminants in a lab. Those projects will work effectively in industries, since they feed on trash, they can detoxify global waste and convert it into usable and valuable materials that are non-extractive. This process offer a neat way out for closing the loop on unrecyclable plastic (Meyer et al., 2020). Increased mycological research efforts are needed to unlock this potential (Lange, 2010). This papers focus on fungi, its role of breaking down toxic materials such as waste which create problems to the environment and human. It is very expensive to deal with this problem but this study will review how and where fungi play its role for solving this issue.

2. Role of fungi for breaking down toxic materials

In the past few years, recent studies and new projects have highlighted a very old natural process and role of fungi for cleaning the environment. Some innovations in existing studies (M Akram, 2010; Muhammad Akram et al., 2022; Inam, Khan, Akram, Khan, Park, et al., 2019; Inam, Khan, Akram, Khan, & Yeom, 2019; Inam et al., 2021; Nairn, 2021) have demonstrated that fungus species can save planet so that there should be deep research. Chinese scientists from Kunming Institute of Botany, Chinese Academy of Sciences have found a fungus Aspergillus tubingensis on a rubbish dump in Islamabad, Pakistan. Study has documented that fungus can possibly help us to address the issues of non-biodegradable (Scientists Find Fungus with an Appetite for Plastic in Rubbish Tip, 2017). There are many types of fungi with useful properties (See table 1), which play vital role such as White-Rot Fungi, Marine Fungi, Extremophilic Fungi, Symbiotic Fungi with Plants and Bacteria, Bioremediation Potential of Fungi etc. There are so many more that we don't yet know about them but as human activities and deforestation have destroyed habitats. If this continues then we might never gain access to such species.

Table 1: Role of Fungi/mushroom

Fungi / Mushroom	**Role**	**References**
Pleurotus, Agaricus,	Keep antimutagenic or antigenotoxic power against cancer	(Gameiro, 2013) (Kang, Rico, & Lee, 2012)
Pleurotus pulmonarius	Degredation for crude oil	(Olusola & Anslem, 2010)
Pleurotus ostreatus	Oxo-Biodegradable plastic was degraded by Mushrooms	(da Luz, Paes, Nunes, da Silva, & Kasuya, 2013)
Pleurotus pulmonarius	Radioactive cellulosic-based waste with mushroom mycellium was solidified with portland cement	(skander SB, 2012)
Pleurotus florida	Cultivation and Bioconversion of Handmade paper and cardboard industrial waste	(Shweta Kulshreshtha, Mathur, Bhatnagar, & Jain, 2010)
Ganoderma lucidum, Phellinus rimosus, Pleurotus florida and *Pleurotus pulmonaris*	Used as antioxidant and antitumor agent	(Ajith & Janardhanan, 2007)
Pleurotus citrinopileatus	Bioconversion of Handmade paper and cardboard industrial waste	(Shweta Kulshreshtha, Mathur, Bhatnagar, & Kulshreshtha, 2013)
Grifola frondosa Coriolus versicolor, Ganoderma Schizophyllan	Used as medicine to increase immune responses against cancer	(Maehara et al., 2012), (Gao, Dai, Chen, Ye, & Zhou, 2003)

commune,
Ganoderma
lucidum,
Pleurotus,
Agaricus,

Applications of fungi and their surprising characteristics for construction materials and degrade pollutants while making circularity truly "biological". Fungi have natural function and it is considered as super-powered decomposers and nutrient dispersers. Their mycelial "root systems" help to almost all ecosystems as the backbone by ingesting nutrients from the plant matter (Deshmukh, Khardenavis, & Purohit, 2016). They decompose and re-dispersing them to other plants and trees (M Akram, 2010; Muhammad Akram et al., 2022; Deshmukh et al., 2016; Inam, Khan, Akram, Khan, Park, et al., 2019; Inam, Khan, Akram, Khan, & Yeom, 2019; Inam et al., 2021; Nairn, 2021). Remediation through fungi is also known as mycoremediation. Mycoremediation tool generally refers to mushrooms and their enzymes because they have natural ability to degrade several types of environmentally persistent contaminants, and convert industrial and agro-industrial wastes into products for a beneficial effect. Mycoremediation through fungi play vital role for waste disposal and ecosystem restoration (Nairn, 2021). Mushrooms have ability to work with waste through mycoremediation (Deshmukh et al., 2016; S. Kulshreshtha, Mathur, & Bhatnagar, 2014).

3. Mycoremediation today: Fungal products and benefits

Mycocycle purposes to support in the change to zero waste by decontaminating toxic building materials such as asphalt and petrochemical-based waste that previously could not be reused. Fungi may be engaged in different types of work for the environment. Earthen building materials have a variety of fascinating characteristics, for example their ability to induce natural regulation of the indoor air humidity. They reduce environmental impact and their low cost. Existing ecological concerns are leading us to contribute greater attention to the environmental impact of building materials. Mycocycle claims that its trash-fed mycelium is fire and water-resistant and can be manufactured into a host of new products such as styrofoam, insulation, packaging and building materials. Fungi may even be able to restore habitat destroyed by wildfire, a vital possibility in an age of climate change. Mycoremediation, particularly through the use of native fungi, is one of many tools for community restoration projects aimed at regenerating areas hit hard by human-made hazards, where erosion, decay, disaster, pollution or mismanagement have caused the ecosystems to falter (Deshmukh et al., 2016). . It's both water-retardant and fire-resistant, making it a perfect intermediary for environmental recovery and disaster prevention. In addition, bioremediation of toxic organics by fungi is considered as the most sustainable and green route for cleanup of contaminated sites. It is an excellent tools in our hands as genomics and bioinformatics. Several studies have discussed the multiple modes employed by fungi for detoxification of several toxic and recalcitrant compounds including prominent fungal enzymes viz., laccases, peroxidases catalases, and cyrochrome P450 monooxygeneses (Deshmukh et al., 2016).

In addition, both bacterial and fungal have been used in several industries such as their microflora throughout the manufacturing process and the impact of extreme humidity, simulating a hydric accident, on microflora development analyzed on the surface of and inside earthen bricks. These results provide a better understanding of microbial proliferation on these materials. Some other industries get benefits from mycoremediation such as decolourisation of dyes in greywater by mycoremediation (Noman, Talip, Al-Gheethi, Mohamed, & Nagao, 2020), Mycoremediation of industrial dyes by laccases (Bhuvaneswari, Subashini, Winny Fred Crossia, & Vijayalakshmi, 2020), Mycoremediation: Expunging environmental pollutants (Akhtar & Mannan, 2020) and for Pharmaceuticals (Dai et al., 2018).

4. Benefits of Fungi for the Environment and Humans

There are several benefits of Fungi for the environment and humans. Fungi are known to be very diverse groups of organisms; about 100,000 species have already been identified. Some of them are microscopic and some of them have large fruiting bodies with underground systems that extend for miles or even hectares. They have a wide range of life forms e.g single celled to very complex multicellular organisms. In addition, some of them are detrimental to humans, animals and plants, such as mildews, canker, ringworm or thrush. Fungi can help tackle global challenges, including climate change and hunger because they are in diverse group of organisms. However, due to its vast diversity, they are are responsible for important ecosystem services, which benefit humans and the overall environment and ecosystem. They are also an important part of soil biodiversity. Fungi are closely interlinked with vegetation and carbon and nutrient cycling. As a result, they are major drivers of soil health and carbon sequestration, among other ecosystem functions. Benefits are given in the table 2.

Table 2 Benefits of Fungi for the Environment and Humans

S.No	Benefits	Remarks	Reference
1	*Human Health*	• Fungi provide health benefits for humans. • Mushrooms possess medicinal properties, which can help prevent diseases • Mushrooms boost our immune system. • Fungi produce antibiotics such as penicillin • Mushrooms figure prominently in the human diet • Mushrooms are rich in nutrients such as vitamin B, C and D, • Shiitake, for example, present antiviral properties and can reduce serum cholesterol. • Other species are known to possess a number of other benefits such as anti-oxidative property and antidiabetic effect.	(Pérez, 2021; Rather, Shahid ul, & Mohammad, 2015; Viana, 2021)
2	*Environmental protection*	• Fungi help in degradation of various pollutants from the environment, such as plastic, pharmaceuticals, personal care products, and other petroleum-based products. • Fungi can act as a powerful tool to reduce environmental pollution. • Fungi help in breaking down organic matter and releasing carbon, oxygen, nitrogen, and phosphorus into the soil and the atmosphere. • Fungi can help in ecosystem restoration by advancing reforestation in degraded soils and act as pest control. • Fungi could play a huge role in sustainability by remedying existing environmental damage.	(Falandysz & Treu, 2017; Kües, 2015; Ohmiya, Sakka, Kimura, & Morimot, 2003; Tortella, Diez, & Duran, 2005; Viana, 2021; Zhao et al., 2019)
3	*Nutrient Cycling*	• Fungi have the ability to transform nutrients in a way that makes them available for plants. • They can also propel nitrogen fixation and phosphorus mobilization, two of the main nutrients required for plant development and productivity. • Some fungi (e.g *Saprotrophic Fungi*) are decomposers which mean that they break down plant and animal debris, thus cycling nutrient and increasing their availability in the soil. • *Ectomycorrhizal fungi* (EcMF) are involved in soil nutrient cycling in forest ecosystems.	(Liu, Li, & Kou, 2020; "Nutrient Cycling by Saprotrophic Fungi in Terrestrial Habitats," 2007; Read & Perez-Moreno, 2003; Viana, 2021)
4	*Carbon Cycling and Climate regulation*	• Fungi are heterotrophic organisms; therefore, they rely on photosynthetic carbon to produce energy. • They break down organic material to get nutrients and energy. • Fungi are important contributors to the soil carbon stock. • Fungi are an integral part of the global carbon cycle. • They play a major part in the carbon cycle through the soil food web (i.e., *mycorrhizal fungi*). • They can move carbon from decomposing material into the atmosphere as carbon dioxide. • Together, plants and fungi perform a process called soil carbon sequestration, capturing carbon from the atmosphere and storing it into the soil for decades.	(Verbruggen, Struyf, & Vicca, 2021; Viana, 2021; Zhao et al., 2019)
5	*Sustainable materials*	• Mycelium, which is the root structure of mushrooms are now being used to replace unsustainable materials, such as plastic, leather-like material biofabrication using fungi, sustainable textiles made from fungi, disposable healthcare products, compostable packaging, synthetic and animal-based products. • The products from Mycelium are biodegradable and require less water and land resources to be produced.	(Alemu, Tafesse, & Mondal, 2022; Heisel et al., 2017; Jones et al., 2020; Joshi, Meher, & Poluri, 2020; Maximino C. Ongpeng,

• Some of the mycelium-based products already in the market include packaging, clothes, shoes, sustainable leather, skincare products and others.	Inciong, Sendo, Soliman, & Siggaoat, 2020; Travaglini, Dharan, & Ross, 2014; Viana, 2021)

5. Conclusion

This study concluded that Fungi are green response to the earth. Benefits of fungi for the environment and humans have been highlighted such as human health, environmental protection, nutrient cycling, carbon cycling and climate regulation, sustainable materials. In addition, it is a tremendous boon to the idea of using this for mycoremediation process as a real-world solution. Mycoremediation through mushroom cultivation will alleviate two of the world's major problems i.e. waste accumulation and production of proteinaceous food simultaneously. Mycoremediation is getting attention these days, because this is process of harnessing fungi's ability to break down things for a valuable effect. In industry, bioenergy, biomaterials, biochemicals, and bio-fertilizer are converted from bio-waste and agricultural crop residues with the help of such fungal products. Besides producing nutritious mushroom, it reduces genotoxicity and toxicity of mushroom species. Thus, there is a need for further research towards the exploitation of potential of mushroom as bioremediation tool and its safety aspects for consumption as product.

References

Ajith, T. A., & Janardhanan, K. K. (2007). Indian Medicinal Mushrooms as a Source of Antioxidant and Antitumor Agents. *Journal of Clinical Biochemistry and Nutrition, 40*(3), 157-162. doi:10.3164/jcbn.40.157

Akhtar, N., & Mannan, M. A.-u. (2020). Mycoremediation: Expunging environmental pollutants. *Biotechnology Reports, 26*, e00452. doi:https://doi.org/10.1016/j.btre.2020.e00452

Akram, M. (2010). Adsorptive removal of phosphate by the bimetallic hydroxide nanocomposites embedded in pomegranate peel. *Journal of Environmental Sciences.*

Akram, M., Gao, B., Pan, J., Khan, R., Inam, M. A., Xu, X., . . . Yue, Q. (2022). Enhanced removal of phosphate using pomegranate peel-modified nickel-lanthanum hydroxide. *Science of the Total Environment*, 809, 151181. doi:https://doi.org/10.1016/j.scitotenv.2021.151181

Alemu, D., Tafesse, M., & Mondal, A. K. (2022). Mycelium-Based Composite: The Future Sustainable Biomaterial. *International Journal of Biomaterials*, 2022, 8401528. doi:10.1155/2022/8401528

Bhuvaneswari, M., Subashini, R., Winny Fred Crossia, J., & Vijayalakshmi, S. (2020). Chapter 18 - *Mycoremediation of industrial dyes by laccases.* In J. Singh & P. Gehlot (Eds.), New and Future Developments in Microbial Biotechnology and Bioengineering (pp. 235-243): Elsevier.

Buil, P. A., Renison, D., & Becerra, A. G. (2021). Soil infectivity and arbuscular mycorrhizal fungi communities in four urban green sites in central Argentina. *Urban Forestry & Urban Greening, 64*, 127285. doi:https://doi.org/10.1016/j.ufug.2021.127285

da Luz, J. M. R., Paes, S. A., Nunes, M. D., da Silva, M. d. C. S., & Kasuya, M. C. M. (2013). Degradation of Oxo-Biodegradable Plastic by Pleurotus ostreatus. *PloS one, 8(*8), e69386. doi:10.1371/journal.pone.0069386

Dai, W., Chen, X., Wang, X., Xu, Z., Gao, X., Jiang, C., . . . Han, G. J. F. i. m. (2018). The algicidal fungus Trametes versicolor F21a eliminating blue algae via genes encoding degradation enzymes and metabolic pathways revealed by transcriptomic analysis. 9, 826.

Dan, H., Li, N., Xu, X., Gao, Y., Huang, Y., Akram, M., Yue, Q. (2020). Mechanism of sonication time on structure and adsorption properties of 3D peanut shell/graphene oxide aerogel. *Science of the Total Environment, 739*, 139983. doi:https://doi.org/10.1016/j.scitotenv.2020.139983

Deshmukh, R., Khardenavis, A. A., & Purohit, H. J. (2016). Diverse Metabolic Capacities of Fungi for Bioremediation. *Indian J Microbiol, 56*(3), 247-264. doi:10.1007/s12088-016-0584-6

Falandysz, J., & Treu, R. (2017). Fungi and environmental pollution. *Journal of Environmental Science and Health, Part B, 52*(3), 147-147. doi:10.1080/03601234.2017.1261535

Ferrari, C., Santunione, G., Libbra, A., Muscio, A., Sgarbi, E., Siligardi, C., & Barozzi, G. S. (2015). Review on the influence of biological deterioration on the surface properties of building materials: Organisms, materials, and methods. *International Journal of Design & Nature and Ecodynamics, 10*, 21-39. doi:10.2495/DNE-V10-N1-21-39

Gadd, G. M. (1994). Interactions of Fungi with Toxic Metals. In K. A. Powell, A. Renwick, & J. F. Peberdy (Eds.), *The Genus Aspergillus: From Taxonomy and Genetics to Industrial Application* (pp. 361-374). Boston, MA: Springer US.

Gameiro, P. H. (2013). Antimutagenic Effect of Aqueous Extract from Agaricus brasiliensis on Culture of Human *Lymphocytes. 16*(2), 180-183. doi:10.1089/jmf.2012.0068

Gao, Y., Dai, X., Chen, G., Ye, J., & Zhou, S. (2003). A Randomized, Placebo-Controlled, Multicenter Study of Ganoderma lucidum (W.Curt.:Fr.) Lloyd (Aphyllophoromycetideae) Polysaccharides (Ganopoly<big>^{®</big>}) in Patients with Advanced Lung Cancer. 5(4), 14. doi:10.1615/InterJMedicMush.v5.i4.40

Heisel, F., Schlesier, K., Lee, J., Rippmann, M., Saeidi, N., Javadian, A., . . . Block, P. (2017). *Design of a load-bearing mycelium structure through informed structural engineering.* Paper presented at the World Congress on Sustainable Technologies (WCST-2017),(ss. 45-49).

Inam, M. A., Khan, R., Akram, M., Khan, S., Park, D. R., & Yeom, I. T. (2019). Interaction of Arsenic Species with Organic Ligands: Competitive Removal from Water by Coagulation-Flocculation-Sedimentation (C/F/S). 24(8), 1619.

Inam, M. A., Khan, R., Akram, M., Khan, S., & Yeom, I. T. (2019). Effect of Water Chemistry on Antimony Removal by Chemical Coagulation: *Implications of ζ-Potential and Size of Precipitates. 20*(12), 2945.

Inam, M. A., Khan, R., Yeom, I. T., Buller, A. S., Akram, M., & Inam, M. W. (2021). Optimization of Antimony Removal by Coagulation-Flocculation-Sedimentation Process Using Response Surface Methodology. 9(1), 117.

Jones, M., Mautner, A., Luenco, S., Bismarck, A., & John, S. (2020). Engineered mycelium composite construction materials from fungal biorefineries: A critical review. *Materials & Design, 187,* 108397. doi:https://doi.org/10.1016/j.matdes.2019.108397

Joshi, K., Meher, M. K., & Poluri, K. M. (2020). Fabrication and Characterization of Bioblocks from Agricultural Waste Using Fungal Mycelium for Renewable and Sustainable Applications. *ACS Applied Bio Materials, 3*(4), 1884-1892. doi:10.1021/acsabm.9b01047

Kang, M. Y., Rico, C. W., & Lee, S. C. (2012). In vitro antioxidative and antimutagenic activities of oak mushroom (Lentinus edodes) and king oyster mushroom (Pleurotus eryngii) byproducts. *Food Science and Biotechnology, 21*(1), 167-173. doi:10.1007/s10068-012-0021-5

Kües, U. (2015). Fungal enzymes for environmental management. *Current Opinion in Biotechnology, 33,* 268-278. doi:https://doi.org/10.1016/j.copbio.2015.03.006

Kulshreshtha, S., Mathur, N., & Bhatnagar, P. (2014). Mushroom as a product and their role in mycoremediation. *AMB Express, 4,* 29. doi:10.1186/s13568-014-0029-8

Kulshreshtha, S., Mathur, N., Bhatnagar, P., & Jain, B. J. J. o. e. b. (2010). *Bioremediation of industrial waste through mushroom cultivation. 31*(4), 441-444.

Kulshreshtha, S., Mathur, N., Bhatnagar, P., & Kulshreshtha, S. (2013). Cultivation of Pleurotus citrinopileatus on handmade paper and cardboard industrial wastes. *Industrial Crops and Products, 41*, 340-346. doi:https://doi.org/10.1016/j.indcrop.2012.04.053

Lange, L. (2010). The importance of fungi for a more sustainable future on our planet. *Fungal Biology Reviews, 24*(3), 90-92. doi:https://doi.org/10.1016/j.fbr.2010.12.002

Liu, Y., Li, X., & Kou, Y. (2020). Ectomycorrhizal Fungi: Participation in Nutrient Turnover and Community Assembly Pattern in Forest Ecosystems. *Forests, 11*, 453. doi:10.3390/f11040453

Maehara, Y., Tsujitani, S., Saeki, H., Oki, E., Yoshinaga, K., Emi, Y., . . . Baba, H. (2012). Biological mechanism and clinical effect of protein-bound polysaccharide K (KRESTIN®): review of development and future perspectives. *Surgery Today, 42(*1), 8-28. doi:10.1007/s00595-011-0075-7

Maximino C. Ongpeng, J., Inciong, E., Sendo, V., Soliman, C., & Siggaoat, A. (2020). Using Waste in Producing *Bio-Composite Mycelium Bricks. 10*(15), 5303.

Meyer, V., Basenko, E. Y., Benz, J. P., Braus, G. H., Caddick, M. X., Csukai, M., . . . Wösten, H. A. B. (2020). Growing a circular economy with fungal biotechnology: a white paper. *Fungal Biology and Biotechnology, 7(*1), 5. doi:10.1186/s40694-020-00095-z

Nairn, C. (2021). *Mycoremediation brings the fungi to waste disposal and ecosystem restoration*. In: Mongabay.

Noman, E., Talip, B. A., Al-Gheethi, A., Mohamed, R., & Nagao, H. (2020). Decolourisation of dyes in greywater by mycoremediation and mycosorption process of fungi from peatland; primary study. *Materials Today: Proceedings, 31,* 23-30. doi:https://doi.org/10.1016/j.matpr.2020.01.078

Nutrient Cycling by Saprotrophic Fungi in Terrestrial Habitats. (2007). In C. P. Kubicek & I. S. Druzhinina (Eds.), *Environmental and Microbial Relationships* (pp. 287-300). Berlin, Heidelberg: Springer Berlin Heidelberg.

Ohmiya, K., Sakka, K., Kimura, T., & Morimot, K. (2003). Application of microbial genes to recalcitrant biomass

utilization and environmental conservation. *Journal of Bioscience and Bioengineering*, *95*(6), 549-561. doi:https://doi.org/10.1016/S1389-1723(03)80161-5

Olusola, S., & Anslem, E. (2010). Bioremediation of a crude oil polluted soil with Pleurotus pulmonarius and Glomus mosseae using Amaranthus hybridus as a test plant. *J Bioremed Biodegr 1*: 113. In: OMICS Publishing Group J Bioremed Biodegrad ISSN.

Pérez, J. C. (2021). Fungi of the human gut microbiota: Roles and significance. *Int J Med Microbiol, 311*(3), 151490. doi:10.1016/j.ijmm.2021.151490

Rather, L. J., Shahid ul, I., & Mohammad, F. (2015). Acacia nilotica (L.): A review of its traditional uses, phytochemistry, and pharmacology. *Sustainable Chemistry and Pharmacy*, *2*, 12-30. doi:https://doi.org/10.1016/j.scp.2015.08.002

Read, D. J., & Perez-Moreno, J. (2003). Mycorrhizas and nutrient cycling in ecosystems – a journey towards relevance? , *157(*3), 475-492. doi:https://doi.org/10.1046/j.1469-8137.2003.00704.x

Scientists Find Fungus with an Appetite for Plastic in Rubbish Tip. (2017). Retrieved from China: https://english.cas.cn/newsroom/archive/research_archive/rp2017/201703/t20170330_175543.shtml

skander SB, A. E.-A. S., El-Sayaad H, Saleh HM. (2012). Cementation of bioproducts generated from biodegradation of radioactive cellulosic-based waste simulates by mushroom. *ISRN Chemical Engineering.* doi:doi:10.5402/2012/329676

Tortella, G. R., Diez, M. C., & Duran, N. (2005). Fungal diversity and use in decomposition of environmental pollutants. *Crit Rev Microbiol*, *31*(4), 197-212. doi:10.1080/10408410500304066

Travaglini, S., Dharan, C., & Ross, P. (2014). *Mycology matrix sandwich composites flexural characterization*. Paper presented at the Proceedings of the American Society for Composites.

Vašinková, M., Dlabaja, M., & Kučová, K. (2021). *Bioaccumulation of toxic metals by fungi of the genus Aspergillus isolated from the contaminated area of Ostramo Lagoons.* IOP Conference Series: Earth and Environmental Science, 900(1), 012048. doi:10.1088/1755-1315/900/1/012048

Verbruggen, E., Struyf, E., & Vicca, S. (2021). Can arbuscular mycorrhizal fungi speed up carbon sequestration by enhanced weathering? , 3(5), 445-453. doi:https://doi.org/10.1002/ppp3.10179

Viana, C. (2021). *Benefits of Fungi for the Environment and Humans.* In: Chloridefree.

Wang, J., Liu, G., Zhang, C., Wang, G., Fang, L., & Cui, Y. (2019). Higher temporal turnover of soil fungi than bacteria during long-term secondary succession in a semiarid abandoned farmland. *Soil and Tillage Research*, *194*, 104305. doi:https://doi.org/10.1016/j.still.2019.104305

Zhao, M., Sun, B., Wu, L., Wang, F., Wen, C., Wang, M., Yang, Y. (2019). Dissimilar responses of fungal and bacterial communities to soil transplantation simulating abrupt climate changes. *Mol Ecol*, *28*(7), 1842-1856. doi:10.1111/mec.15053

Zimmermann, W. (2021). Degradation of Plastics by Fungi. In Ó. Zaragoza & A. Casadevall (Eds.), *Encyclopedia of Mycology* (pp. 650-661). Oxford: Elsevier.

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RESP

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Araştırma Makalesi ● Research Article

An Analysis of Employee's Perception Regarding the Impact of Corporatization: A Study of PSPCL And PSTCL

Kurumsallaşmanın Etkisine İlişkin Çalışan Algısının Analizi: PSPCL ve PSTCL Üzerine Bir Araştırma

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ANAHTAR KELİMELER

PSPCL
PSTCL
İş memnuniyeti
şirketleştirme
Yapısal Reformlar

ÖZ

İnsan kaynakları, herhangi bir sektörün temel bileşeni olarak kabul edilir ve insan kaynaklarının önemli davranışsal çıktılarından biri de çalışan memnuniyetidir. Çalışanların yenilikçiliğinin ve üretkenliğinin ancak daha yüksek düzeyde iş tatmini ile geldiği anlaşılmaktadır. İnsanlar, çalışma ortamlarındaki değişikliği kabul etmeye isteksizdir; Örgüt yapısal reformlara girerse, örgütün çalışma kültürünü mutlaka etkiler. Punjab'ın enerji sektöründe olduğu gibi, Punjab Devlet Elektrik Kurulunu iki kısma ayıran yapısal reformlar 2010 yılında başladı: Punjab State Power Corporation Ltd (PSPCL) ve Punjab State Transmission Corporation Ltd (PSTCL). Bu araştırma, şirketleşmenin çalışanlar üzerindeki etkisine ilişkin çalışan algısına odaklanmaktadır. Bunun için, her iki kuruluştan yeterli sayıda katılımcı, ilgili kuruluşlara bağlı olarak orantılı olarak seçilmiştir. Çalışma, çoğu çalışanın, ister PSPCL ister PSTCL olsun, kuruluşun kendilerine adil ücret ve terfi fırsatı sağladığı konusunda hemfikir olduğunu gösteriyor. Çalışmada yer alan tüm faktörlerden, "beceri ve yeteneklerin kullanımından memnuniyet" adlı faktörün, tüm faktörler arasında puanı en düşüktür; bu, çalışanların çoğunluğunun becerilerini ve yeteneklerini geliştirme fırsatı için yönetimin daha fazla olanak sağlaması gerektiğini düşündüğünü göstermektedir.

KEYWORDS

PSPCL
PSTCL
Job Satisfaction
Corporatization
Structural Reforms

ABSTRACT

Human resources are considered to be the main constituent of any sector and one of the significant behavioural outcomes of human resources is employee satisfaction. It is perceived that the innovation and productivity of employees only come with a higher level of job satisfaction. Humans are reluctant to accept change in their working environment; if the organization goes under structural reforms, it definitely affects the work culture of an organization. As in the case of Punjab's power sector, the structural reforms started in the year 2010, which divides the Punjab State Electricity Board into two parts: Punjab State Power Corporation Ltd (PSPCL) and Punjab State Transmission Corporation Ltd (PSTCL). The present research focuses on the perception of employees regarding the impact of corporatization upon them. For this, an adequate number of respondents from both organizations was selected proportionately depending on their respective organizations' total strength. The study shows that most employees agreed that the organization is providing them equitable pay and promotional opportunity, whether it is PSPCL or PSTCL. Out of all the factors concerned in the study, there is one factor named "satisfaction with use of skills and abilities" in which the mean score is the lowest among all factors, which represents that the majority of employees feel that management should provide more facility and opportunities to enhance their skills and abilities.

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1. Introduction

Professionals have long contended that the upper hand is a benefit over competitors acquired by offering a more prominent worth to customers. In other words, competitive advantage is what separates a firm from its opponents. Drawing on the asset-based theory, the upper hand can be accomplished when a firm has a bunch of unfaltering assets. Wright et al. (1994) added that "a sustained upper hand exists just when different firms are unequipped for copying the advantages of an upper hand." with regards to HR arranging, work and other representative-related issues are basic factors that should be thought of.

Specifically, the HR arranging process should include human resources and possible abilities of representatives, as well as hierarchical preparation concerning staffing. The logical current of the hypothetical underpinnings of the executives (Taylor, 1911), puts more accentuation on the plan of occupations to proficiently and properly utilize the human abilities being referred to. Wright et al. (1994) noticed that "HR can be portrayed as a product as opposed to an uncommon asset; in any case, to the degree that positions require abilities that consider variety in individual commitments (i.e., when it is as of now not aware), these abilities ought to typically be dispersed in the populace." Further, the associations disregarded the job of HRM in the development cycle which is vital for giving the association an upper hand; to do as such, the association ought to take on an imaginative way of behaving in HRM arranging connected with a system of reward to raise the satisfaction level of employee (Amarakoon et al., 2018; Elrehail et al., 2018).

2. Literature Review

In order to discover the conceptual framing behind the human behavioural outcome, appropriate literature has been assessed and synthesized. A number of national and international studies have been reviewed and major resources enlightening about the theoretical foundation of human resources have been studied. The review of related literature is as follows:

Emmerik et al. (2005) the study conducted on 178 respondents out of which 101 are males and 77 are females. The researcher uses a web questionnaire technique. The study is conducted in three different types of organizations i.e., a city council, a university, and a bank. The researcher examines the relationship between burnout and altruism. The results show that OCB and burnout are affected by altruism but OCB was negatively linked with personnel objectives.

Rao (2005) while describing how employees can participate in management it is described by the International Institute for Labour Studies that involvement brought about by procedures that broaden the employee share's potential of power in the decision-making process at various organisational levels with simultaneous acceptance of responsibility.

Kesar Singh Bhangoo (2008) the regional pattern of industrial dispute in the state of Punjab from 1967 to 2003 through secondary data based on various government reports, revealed that in the pre-economic reform era i.e., from 1967 to 1990 that the number of disputes raised by the employees and the man-days lost was much higher than in the post-economic era i.e. 1991 to 2003. Adjudication remained the most dominant method for the settlement of 42 disputes indicating the inefficiency of the dispute settlement machine.

Asha Prassad (2006) grasps the relationship between the restructuring system and representative change in two power circulation organizations of Delhi, BSES (Dependence) and NDPL (Goodbye Power). The discoveries uncovered that employees were not kept very much informed about the rebuilding brought about uneasiness, associations didn't get a lot of warm greetings subsequently leaving the worker shaky, and representatives have fears in regards to their government-managed retirement benefits being given by the association in a long run. The VRS scheme has been a finished disappointment and the representative were not given their contribution on time.

Kundu and Mishra (2012) concentrated on the effect of change and privatization on workers it is a contextual analysis of power sector reforms in Orissa, India. Before Delhi, it is Orissa and the main Indian state where power sector reforms occurred. The state power board was unbundled and separate organizations were framed for the generation, transmission, and dispersion of electricity. The 11 factors were concentrated on specific costs to the organization per unit of time, learning experience, cooperation, working climate, and employer stability equipped for making sense of and anticipating representative benefits. The outcome showed them this large number of factors have expanded and moved along, subsequently reasoned that workers have been helped by the changes.

3. Research Methodology

Research is a precise, huge, basic, and logical quest for critical data embraced to find realities or approve open proposals. Great exploration observes methodical guideline conventions and rules. It alludes to a coordinated methodology by which examinations, perceptions, and correlations are made in the mission of truth. It refers to an exact report by which an exploration issue is distinguished and information is gathered and assessed involving logical strategies and methods to make derivations and arrive at a resolution (Chawla and Sondhi, 2011; Kothari, 1990).

Objective of Research

To analyze employees' perceptions regarding the impact of structural reforms in the power sector of Punjab.

Sampling Design

Sampling is the technique of statistical practice, which is intended to draw some inferences about the population with the selection of individual observations. To know the perception of employees regarding the impact of corporatization upon them, an adequate number of respondents from both organizations was selected on a proportionate basis depending upon the total strength of their respective organizations. The sample size of a minimum of 373 employees was calculated by the formula given by Godden, B. (2004) for a population of 33,272 employees. Initially, 400 questionnaires were distributed from which 22 questionnaires were rejected in a screening stage due to wrong and ambiguous answers. The responses of 378 employees from both organizations were gathered from which 308 and 70 belong to PSPCL and PSTCL respectively.

Data Analysis and Interpretation

To study the perception of employees regarding the impact of corporatization upon them, sequential steps have been taken.

As the study is exploratory and qualitative in nature, on the basis of content validity, a schedule containing 17 items was finalized to gather responses from 400 employees, resulting in a response rate of 94.5% (378 employees). Using a judgemental sampling, responses were gathered on a five-point Likert Scale varying between Strongly Disagree to Strongly Agree. Internal consistency of 0.921 was shown by Cronbach's Alpha which is higher than the minimum acceptance value of 0.70 (Nunally, 1978). There were no impressions of inconsistent data due to zero missing frequency and properly engaged respondents. As the nature of the study is exploratory, therefore various items were asked to check the satisfaction level of employees under various factors.

Exploratory Factor Analysis

Purification of the construct was done using SPSS (version 20.00). A total of 17 items were used to assess employees' perception regarding the impact of corporatization upon them in form of their satisfaction level. After applying EFA, five factors have been extracted under the construct to assess the perception of employees with Cronbach's Alpha Reliability Coefficient varying from 0.891 to 0.971 for all the underlying 17 items in the construct. The Alpha coefficient of F1 (α=0.912), F2 (α=0.971), F3 (α=0.925), F4 (α=0.903), and F5 (α=0.891), which shows good internal consistency against the minimum acceptable value is α=0.70 (Nunally, 1978). The overall score of Alpha (α= 0.921) is very much satisfactory and the Kaiser-Meyer-Ohlin sample adequacy measure is 0.864 with a minimum factor loading value of 0.778, which indicates a significant validity and reliability of construct to assess the perception of employees (Hair et al., 2014).

Employee's views on the impact of corporatization

There are some assumptions for the application of Exploratory Factor Analysis, that the nature of data, adequate sample size, and there should be multi-co linearity in the data to identify the interrelated sets of variables ((Hair et al., 2014). There is a thumb rule that observations are at least five times the number of variables (Hair et al., 2014). After considering these assumptions, raw data used in this study is suitable for factor analysis as examined through KMO value, Bartlett Test for sphericity, and p-value as represented in table 1.1 (Dess et al., 1997 and Field, 2000).

Table 1.1: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.864
Bartlett's Test of Sphericity	Approx. Chi-Square	6.103
	Df	136
	Sig.	.000

Source: Survey

Bartlett's Test of Sphericity disproves the null hypothesis that the population correlation matrix is an identity matrix. The approximate value of chi-square is 6.103 with a degree of freedom 136, which is found to be significant at a five percent level. The KMO statistics value is .864 which is more than the minimum acceptable value of 0.5 as recommended by Kaiser, 1974 (Hutcheson & Sofroniou, 1999; Malhotra & Birks, 2006). Thus, Factor Analysis is an appropriate technique for the analysis.

Five components were extracted using Principal Components Analysis in rotation mode with the Varimax Rotation Method and Kaiser's Criterion of keeping the factors with Eigen values $\geq$1 and suppressing the factor loading of 0.5. (Field, 2009). After rotation, the relative importance of the five factors is equalized and a cumulative variance of 84.35% has been explained by all the five factors taken together which is higher than the minimum of 60% (Malhotra & Birks, 2006). From all the statements, 17 statements under the construct were retained after rotation as the communality of these statements ranges from 0.709 to 0.947 demonstrating a moderate to the strong linear connection between the variables. The mean, standard deviation, factor loading, and communalities of all the variables are represented in table 1.2 and 1.3.

Table 1.2: Output of Exploratory Factor Analysis using RCM

Factor Wise Dimension	Mean	Standard Deviation	Factor Loading	Communality
FACTOR 1: Satisfaction with Pay and Promotional Opportunities (Eigen Value- 7.629, Variance Explained-22.557, Cumulative Variance Explained-22.557, Alpha-0.912)				
I am satisfied with the pay I receive	3.71	1.036	0.877	0.804
I am satisfied with the promotional opportunities	3.44	1.171	0.817	0.709
I am satisfied with the security my job provides me	3.94	0.923	0.828	0.766
I am satisfied with the benefits I receive	3.71	0.983	0.881	0.859
I am satisfied with my organisation that	3.72	1.010	0.778	0.754
FACTOR 2: Satisfaction With Work Relationships (Eigen Value- 2.536, Variance Explained-16.755, Cumulative Variance Explained-39.313, Alpha- 0.971				
Relationship with my co-workers has improved	3.80	0.858	0.904	0.947
Relationship with my subordinates has improved	3.82	0.855	0.899	0.946
Relationship with my superiors has improved	3.75	0.861	0.895	0.931
FACTOR 3: Satisfaction with Work Activities (Eigen Value- 1.706, Variance Explained-15.449, Cumulative Variance Explained-54.762, Alpha- 0.925)				
Management provided me with enough degree of independence associated with my work roles	3.57	0.925	0.882	0.914
Management provided me with various job responsibilities	3.66	0.869	0.868	0.859
Management provided me with adequate opportunity for periodic changes in my duties	3.49	0.953	0.844	0.851
FACTOR 4: Satisfaction with Working Hours (Eigen Value- 1.359, Variance Explained- 15.114, cumulative Variance Explained- 69.876, Alpha- 0.903)				
I am satisfied with my current working hours	3.92	0.937	0.810	0.799
My organization has provided me with enough flexibility for scheduling my work	3.70	0.998	0.870	0.877
Working beyond duty hours has decreased	3.60	1.061	0.868	0.851
FACTOR 5: Satisfaction with the Use of Skills and Abilities (Eigen Value- 1.110, Variance Explained- 14.479, Cumulative Variance Explained- 84.355, Alpha- 0.891				
My organization has provided me with enough opportunity to utilize my skills	3.42	0.968	0.857	0.775
My organization has provided me with enough opportunity to learn new skills	3.37	0.956	0.834	0.872
My organization has provided me with enough support for additional training and education	3.19	1.004	0.782	0.826

Source: Survey, Note: RCM- Rotated Component Method

Table 1.3: Descriptive Statistics

Factor	N	Minimum	Maximum	Mean	Std. Dev.
Satisfaction with Pay and Promotional Opportunities	378	3.442	3.942	3.703	0.891
Satisfaction With Work Relationships	378	3.753	3.824	3.792	0.833
Satisfaction with Work Activities	378	3.495	3.661	3.575	0.854
Satisfaction with Working Hours	378	3.603	3.918	3.740	0.915
Satisfaction with the Use of Skills and Abilities	378	3.189	3.424	3.327	0.884

Source: Survey

Factor 1 (Satisfaction with Pay and Promotional Opportunities)

This factor consists of five items which are "I am satisfied with the pay I receive", "I am satisfied with the promotional opportunities ", "I am satisfied with the security my job provides me", "I am satisfied with the benefits I receive", "I am satisfied with my organization that recognizes my work accomplishment", with standard deviation ranging from 0.923 to 1.171, mean values varying from 3.44 to 3.94, factor loading ranging from 0.778 to 0.881 and commonality between 0.709 to 0.859. This factor represents the satisfaction level of employees with pay and promotional opportunities in the power sector of Punjab after its corporatization. This factor has an imputed mean of 3.703, which indicates the majority of employees are satisfied with the pay and promotional opportunities they are getting from their organization. It shows that the pay and promotion policy proves to be satisfactory after the corporatization of the power sector in Punjab.

Factor 2 (Satisfaction with Work Relationships)

This factor represents three items such as "Relationship with my co-workers has improved", "Relationship with my subordinates has improved", and "Relationship with my superiors has improved" with the standard deviation ranging from 0.855 to 0.861, mean values varying from 3.75 to 3.82, factor loading values between 0.895 to 0.904 and commonalities between 0.931 to 0.947. This factor indicates the satisfaction level of employees with their work relationships with an imputed value of a mean of 3.792, which accounts for the maximum mean among all the factors extracted. This represents the maximum satisfaction level of employees with regards to their work relationships whether it is with their superiors, co-workers, and subordinates, which indicates policy measures of the power sector in Punjab after its corporatization provides an environment of a healthy relationship between the employees.

Factor 3 (Satisfaction with Work Activities)

It comprises three items such as "Management provided me enough degree of independence associated with my work roles", "Management provided me various job responsibilities" and "Management provided me with an adequate opportunity for periodic changes in my duties" with a standard deviation ranging from 0.869 to 0.953, mean values varying from 3.49 to 3.66, factor loading value between 0.844 to 0.882 and communalities between 0.851 to 0.914. This factor indicates the satisfaction level of employees regarding work-related activities with an imputed value of mean is 3.575, which shows that majority of employees are inclined towards satisfaction from work-related activities in their organization after these structural reforms took place in the power sector of Punjab.

Factor 4 (Satisfaction with Working Hours)

This factor comprises three items, namely "I am satisfied with my current working hours", "Working beyond duty hours has decreased" and "My organization has provided me with enough flexibility for scheduling my work", with a standard deviation ranging from 0.937 to 1.061, mean value varying between 3.60 to 3.92, factor loading between 0.810 to 0.870 and commonalities between 0.799 to 0.877. This factor illustrates the satisfaction level of employees with their working hours with an imputed value of mean is 3.740, which is the second highest mean value from all the factors extracted. This analysis represents that most of the employees are satisfied with their working hours and their management provides them autonomy in scheduling their work.

Factor 5 (Satisfaction with the Use of Skills and Abilities)

This Factor consists of three items such as "My organization has provided me enough opportunity to utilize my skills", "My organization has provided me enough opportunity to learn new skills", and "My organization has provided me enough support for additional training and education" with a standard deviation varying from 0.956 to 1.004, mean value ranging from 3.19 to 3.42, factor loading value between 0.782 to 0.857 and communalities between 0.775 to 0.872. This factor indicates the satisfaction level of employees regarding the use of their skills and abilities in the organization with an imputed mean value of 3.327, which is the lowest among all factors extracted. This represents that majority of employees feel satisfaction under this factor but not as much compared to other factors. The satisfaction of employees can be increased in this facto if management provides them with an adequate facility of training and education.

4. Limitations

Data is the foundation stone of every study in the field of research but in presenting primary data there is always a chance of deviation and biasness. Due to the busy work schedule and prior engagements of employees of different organizations in the power sector, frequent visits were to be made for filling up questionnaires. The other limitation due to the primary data has been the attitude and sincerity of the employees of the power sector in filling up questionnaires. Since this job demands a high level of seriousness from the respondents but due to their official priorities the process of data collection was not far from limitations. Despite of above-mentioned limitations the conclusions of the present study are quite useful. Further, the findings recommend certain improvements in various areas of the power sector in Punjab.

5. Suggestions

- It has been observed during the interaction with concerned respondents of the study that employees are not getting the work according to their skills and abilities. So proper screening channel must be installed in the board to fix the job description and job specification.

- The electricity demand of Punjab is increasing day by day but installed electricity generation plants could not meet this demand due to the shortage of engineers ‟s staff. Many times, PSEB Engineers Association demanded more manpower to run all the public sector thermal units at Ropar and Lehra Mohabbat. PSPCL should consider their demands for the productive utilization of their infrastructure facilities.
- By enhancing work-related activities and varieties, management can improve altruism behaviour of the employees, which will increase job satisfaction and employees can be encouraged to work with more devotion and passion.

References

Amarakoon, U., Weerawardena, J. and Verreynne, M.L. (2018), Learning capabilities, human resource management innovation and competitive advantage. *The International Journal of Human Resource Management, 29* ,10, 1736-1766.

Chawla, Deepak & Sondhi, Neena (2011). *Research Methodology Concepts and Cases.* Vikas Publishing House Pvt.

Dewan, U. (2010, November 21). *Post-PSEB unbundling, tripartite pact inked PSPCL and PSTCL to remain govt companies; no retrenchment.* The Tribune.

Dess, G.G., Lumpkin, G.T., & Covin, J. G. (1997). Entrepreneurial Strategy Making and Firm Performance: Tests of Contingency and Configurational Models. *Strategic Management Journal, 18*(9),677-695.

Elrehail, H., Emeagwali, O.L., Alsaad, A. and Alzghoul, A. (2018), The impact of transformational and authentic leadership on innovation in higher education: the contingent role of knowledge sharing. *Telematics and Informatics, 35* (1), 55-67.

Field, A.P. (2000). *Discovering Statistics using SPSS for Windows.* Sage Publications.

Hair, J. F., Black, W. C., Babin, B. J. & Anderson, R. E. (2014). *Multivariate Data Analysis.* Pearson Education.

Hutcheson, G. and Sofroniou, N. (1999). *The Multivariate Social Scientist: Introductory Statistics using Generalized Linear Models*. Sage Publication.

Malhotra, N. K. & Birks, David. (2006). *Marketing Research: An Applied Orientation* (2nd European Education). Prentice Hall Publications.

Nunnally, J. C. (1978). *Psychometric Theory*. McGraw-Hill.

Prasad, A. (2006). Power Sector Reforms in Delhi: Human Resource Perspective. *Indian Journal of Industrial Relations, 42*, (2), 203-226.

Rao, V. S. P. (2005). *Human Resource Management.* New Delhi: Excel Books.

Wright, P.M., McMahan, G.C. and McWilliams, A. (1994), Human resources and sustained competitive advantage: a resource-based perspective. *The International Journal of Human Resource Management, 5*(2),301-326, DOI: 10.1080/09585199400000020.

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Araştırma Makalesi ● Research Article

Artificial Intelligence in a Transforming Labour Market – New Skills are Needed?

Dönüşen İşgücü Piyasasında Yapay Zeka – Yeni Becerilere İhtiyaç Var mı?

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ANAHTAR KELİMELER

Yapay zeka
Gelecek
İşgücü piyasası
İstihdam
Yetenekler

ÖZ

Yapay zekanın (AI) yaygınlaşmasıyla birlikte yakın gelecekte belirli iş aşamalarının ve hatta tüm mesleklerin yerini alması ve bunun da işgücü piyasasını yeniden yapılandırması bekleniyor. Açık ve öngörülebilir bu yakın gelecek için sadece eğitim sistemlerinin değil, İK yöneticilerinin de zamanında ve bilinçli bir şekilde hazırlanmaları gerekmektedir. Dolasıyla bu çalışma, yukarıdaki konulara odaklanarak yapay zekanın kavramsal kapsamını ve gelişimini özetlemeyi amaçlamaktadır ve ardından yenilik, yapay zeka ve istihdam arasındaki bağlantıları da kapsayarak dönüşüm sırasında değer verilen becerilere genel bir bakış sunmaktadır.

KEYWORDS

Artificial intelligence
Future
Labour market
Employment
Skills

ABSTRACT

With the spread of artificial intelligence (AI) certain work phases and even entire professions will be replaced in the near future, which is expected to restructure the labour market. Not only education systems, but also HR managers must prepare in time and consciously for this near future, which can be predicted with certainty and predictability. The present study therefore aims to outline the conceptual scope and development of artificial intelligence, focusing on the above topics, and then also covers the connections between innovation, artificial intelligence and employment, also to give an overview of the skills that are valued during the transformational employment.

1. Introduction

For Management as a profession, it is essential to accurately anticipate the future and how these changes may affect its effectiveness. In the business environment to identify and accurately plan changes in the business environment, coping with these changes will be difficult. Strategies cannot be proactive only reactive moreover they can be much more costly. Given the accelerated pace of change in today's workplace and labour market, any HR leaders who want to provide strategic support need to pay attention to the future labour market trends more accurately than ever before. There is no such thing as a glass globe and the unprecedented acceleration of digitalisation, automation, artificial intelligence and the proliferation of robots will also bring significant changes in the field of employment. The paper's aim is to study the possible future of artificial intelligence (AI) in the labour market.

In accordance with Hungary's Artificial Intelligence Strategy, it also presents worldwide forecasts and explores the temporal waves of the application of artificial intelligence, followed by an examination of whether the application of artificial intelligence can be a solution to the shortage of skilled workers. Finally, there is an overview of the skills that are valued during the transformational employment.

In order to thoroughly examine the the background of the topic, it is first necessary to clarify the concept of artificial intelligence. Although there are several approaches in the literature, some of them synonymously scrutinize the definition of the topic. The following quote also shows the

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uncertainty of the issue: *"Many studies have attempted to answer this question, but no scientific consensus has been reached. The results of these studies are varied (according to which 9-54% of jobs are at risk). The predictions are uncertain because factors other than the technical potential of automation also arise: political, legislative, economic, demographic changes, as well as social acceptability. It is not enough for a technology to be used and spread that it is advanced."* (European Economic and Social Committee /EESC/, 2018)

2. Theoretical principles of artificial intelligence

2.1. The concept of artificial intelligence

Artificial intelligence is the English artificial intelligence, analogously to the common notation (AI), in many cases it is denoted by the Hungarian terminology as AI. Defining it is not such an easy task, given the approaches found in the literature. Studying the definitions, starting from engineering and mathematical foundations, conceptual networks that also process the similarity of human thinking included. If we take these approaches into account, we can be sure of only one thing, namely that the study of AI encompasses several scientific fields, i.e. its interdisciplinary feature cannot be ignored. In most cases, when studying artificial intelligence, we try to discover attributes similar to human intelligence. However, Russell and Norvig (2005) provide an interesting grouping of the definitions by processing the wording of several different textbooks, distinguishing thought processes and conclusions from behaviour. Similarity to human behaviour and ideal behaviour and rationality are considered as further organizing principles. Based on this, the following trends are distinguished.

- A system that thinks in a human way: Considers systems that model the functioning of the human mind and cognition as artificial intelligence. AI and cognitive science constantly interact, and this can be considered a strong relationship especially in the case of vision and natural language.
- A system that acts in a human way: based on the Turing-test, if the behaviour is human, then the machine is intelligent. To do this, the computer must have natural language processing, knowledge representation, automated inference, and machine learning capabilities.
- Rational thinking system: Machines and software more perfect and rational than human thinking.
- A rationally acting system: The ability to represent knowledge and draw conclusions is necessary in order to reach the right decision in a wide spectrum of situations. Then act accordingly, rationally. The authors draw attention to the fact that it is impossible to achieve perfect rationality in a complex environment.

Although all four schools of thought have followers, it should be noted that strong disagreements between their different approaches colour the research.

The mature, simplified approach to the concept of AI is given by the European Union, according to which artificial intelligence refers to the human-like abilities of machines, such as reasoning, learning, planning and creativity. It allows the tech to sense its environment, deal with what it perceives, solve problems, and plan its actions to achieve a specific goal. The computer not only receives data, but also processes it and reacts to it. It is an essential declaration that the discussed systems are capable of modifying their behaviour to a certain degree, by analyzing the effects of their previous steps and working independently (European Parliament, 2021).

Emphasizing the importance of the topic, they draw attention to the fact that artificial intelligence is a central element of today's digital revolution and one of the main priorities of the EU. Future applications are expected to bring enormous changes, but artificial intelligence is already present in our daily lives. It distinguishes between the main types of artificial intelligence in software-based and physical aspects where the software-based are categorized as virtual assistants, image analysis software, search engines, speech and face recognition systems, and the physical as robots, self-driving cars, drones, and the Internet of Things.

According to the European Parliament's resolution on the comprehensive European industrial policy for artificial intelligence and robotics, "artificial intelligence and robotics can transform several industries and lead to greater production efficiency, and also make European industry and SMEs more competitive on a global level; whereas the availability of large data sets and testing and experimental facilities is of great importance for the development of artificial intelligence" (European Parliament, 2019).

2.2. Philosophical development of the concept of artificial intelligence

According to Russell and Norvig's approach, we should distinguish between weak and strong artificial intelligence. Weak AI, i.e. weak artificial intelligence hypothesis systems (weak AI) that act as if they are intelligent (it is not known whether they have real intelligence). IBM's Deep Blue software managed to defeat Garry Kasparov, an international grandmaster, multiple world chess champion, eight-time team and seven-time Olympic chess champion, two-time Soviet champion, champion of Russia, 11-time Chess Oscar winner, master coach. In this, the machine was assisted by brute force, but it still worked based on algorithms with pre-stored steps (Keene & Goodman, 1997).

Strong AI, i.e. strong artificial intelligence hypothesis systems (strong AI), which really think, have an independent consciousness. The test for achieving strong AI is the Turing test, the essence of which is that a machine must answer

questions about any topic in such a way that the questioner cannot determine that it is not communicating with a human. Simply put, if the machine makes at least 30 percent of the people in the experiment believe that it is human, after it shows a level of intelligence that clearly proves that there is an artificial intelligence in which the machine thinks (Turing, 1950). Although the test was invented decades earlier, it is still not easy to pass. First, in 2014, a supercomputer with the pseudonym Eugene Goostman, who pretended to be a 13-year-old Ukrainian boy, succeeded, but this has been disputed ever since. However, in a broad presentation, Google Duplex was able to pass the test in some respects (Szilágyi, 2018).

The Turing-test is applicable only for identifying systems that imitate human behaviour however this still makes them weak AI (Eszteri, 2015).

2.3. Consequences of technological development

The literature on economics emphasises the significance of examining and comprehending the factors that facilitate growth, especially sustainable growth (Bayrak & Esen, 2014). There can emerge a possible future event in which the emergence of "superhuman" intelligence accelerates technological development and social change modifying the environment at a rate that pre-singularity humans cannot fathom or reliably predict. Raymond Kurzweil (2000) sees an exponential pattern of technological development in which current progress will eventually lead to the singularity.

An analysis of the history of technology indicates that technological change is exponential, contrary to current intuitive-linear views. Therefore, in the 21st century, we will not experience 100 years of development, but - at the current rate - 20,000 years. The benefit and results of development, such as chip speed and cost efficiency, will also increase exponentially. Even exponential growth will change exponentially (Kurzweil, 2014).

He generalized Moore's Law to development. Moore's Law stated the empirical observation in technological development that the complexity of integrated circuits doubles approximately every 18 months. Its generalization means that it will be true for all technologies.

It can be considered trivial that the singularity also affects society to a great extent, especially with regard to employment.

3. The effects of the application of artificial intelligence on employment

3.1. Employment forecasts

Cyber-physical systems are making millions of jobs redundant worldwide. Manual labor is rapidly disappearing from Industry 4.0. However, the spread of artificial intelligence applications affects not only blue-collar jobs, but also white-collar ones. Routine, uncomplicated cognitive tasks will be replaced by robotic intelligence that never gets tired and communicates in natural language (Csepeli, 2020).

According to an Oxford study, about half of the workers in the United States can expect to lose their jobs in the next decade or two because artificial intelligence applications will do the work done by humans cheaper, faster and more efficiently (Frey & Osborne, 2013). The study shows with concrete numbers the impact of automation, artificial intelligence and machine learning on industries.

These technologies will affect employment not only in the case of profit-oriented companies, but also in the case of non-profit companies. 8.5% of the workforce in the global manufacturing industry, i.e. 20 million workers, will be displaced by the evolving technologies of robots by 2030 (Lardieri, 2019).

According to another study, the use of robots costs only a third as much as in the case of human labour, which is obviously an additional motivation for their use (Tilley, 2017).

It is estimated that for the 36 million jobs in the USA, more than 70% of the functions are at risk of being replaced by artificial intelligence (Associated Press, 2019).

The motivation for the use of artificial intelligence is obviously driven by profit-oriented business interests. The retail industry will spend $7.3 billion annually on AI through 2022 (Juniper Research, 2018). In the case of the healthcare industry, this represents $150 billion worth of AI activity by 2026 (Collier, Fu, Yin & Christiansen, 2017).

According to estimates, the rise of artificial intelligence in the world economy can result in an increase of 15.7 trillion dollars, and the benefits provided by artificial intelligence will also rearrange the balance of power in the world economy. The projected trends are as follows. North America can initially expect faster productivity growth than China, thanks to its readiness for artificial intelligence and the fact that it has many jobs that can be replaced by new, more productive technologies. After bringing in the disadvantages of slower technology adoption and lack of expertise, China will overtake the United States within ten years. Developed parts of Europe and Asia can also expect significant economic benefits thanks to artificial intelligence. (by 2030, GDP growth may reach 9-12%). Developing countries, including Latin America and Africa, can forecast a much more modest improvement (less than 6% of GDP) due to lower adoption of artificial intelligence (PWC, 2017).

It is easy to see that the above estimates always assume that automation can affect all jobs that consist of constantly repeating activities and minimal decision-making or judgment (Wheeler & Buckley, 2021).

The EU treats the development of artificial intelligence as a top priority, regardless of this it draws attention to the dangers of its use. The use of artificial intelligence is

expected to lead to the elimination of many jobs. Although it also presumably creates better jobs, 60 million new jobs could be created worldwide by 2025 thanks to robotics and artificial intelligence.

The creation of the position of the European Parliament on the regulation of artificial intelligence is currently taking place in the framework of a preparatory work of a specialist committee. The investigations focus on building trust in artificial intelligence. This also includes the management of possible effects on individuals, society and the economy (European Parliament, 2020).

3.2. Uncertainties inherent in the application of artificial intelligence

The singularity also affects the evolution of society. Although this is trivial, there is not complete agreement on the details of the subject. Leaders of technology companies leading the way in the use of artificial intelligence do not agree. Tesla CEO Elon Musk thinks everyone should be concerned about the long-term effects. On the other hand, according to the founder of Facebook, Mark Zuckerberg, since they are developing this area, they can optimize it in the direction of bringing only the positives out of it. The owner of Microsoft, Bill Gates, doesn't understand how someone who doesn't worry can exist at all. According to his opinion, the application of artificial intelligence will be good at the beginning, but after that the processes can get out of control.

According to researcher and inventor Ray Kurzweil, 2029 is the date he predicts when an artificial intelligence will reach the level of human intelligence. He set 2045 as the date of the singularity, when we will multiply our effective intelligence a billion times by merging with the artificial intelligence we have created. Kurzweil believes that intelligent machines will make us smarter. Although they are not yet in our bodies, by the 2030s the part of our brain where we think can be connected to the cloud.

The idea is similar to Musk's controversial neural chip, who recently announced that in 2022, a chip called Neurolink will be implanted in the brains of disabled people to restore the ability to walk (Futurism, 2021).

The following are the uncertainties inherent in the widespread use of artificial intelligence.

- People may lose their jobs to automation.
- People have too much (or too little) free time.
- People may lose their sense of uniqueness.
- People may lose some of their privacy rights.
- The use of artificial intelligence systems can eliminate accountability.
- The success of artificial intelligence could mean the end of the human race (Russell & Norvig, 2005.

4. The problem of the lack of skilled labour

4.1. Losses due to the lack of skilled labour

Based on research conducted by PWC, which included 2,993 structured interviews with key decision-makers of family and small businesses with a turnover of more than 10 million Euros in 53 countries, the loss due to the lack of skilled labour was mapped. According to the research results, the countries participating in the survey are affected to varying degrees. Overall, the magnitude of the losses is 12.6% of the GDP of Central and Eastern Europe. Based on the survey, Ukraine, Russia and Bulgaria are in the lead. Hungary is the least affected, but here too we can talk about a loss of 4.1%. Collectively, the losses due to the lack of skilled labour in Central and Eastern Europe exceed 2,831 billion Euros. The lack of professionals also affects growth prospects. Among the spill-over effects, the higher-than-expected increase in human capital costs, the failure to take advantage of market opportunities, the deterioration of the quality of products and services, and the related customer experience are among the most important. 79% of foreign managers and 92% of domestic managers consider the lack of professionals to be a concern. Regarding the management of the problem area, the company managers agreed that there is no quick solution, but among the current alternatives, they prefer the following resources (PWC, 2019).

Table 1. Ideas related to filling the shortage of professionals

Source	Hungarian answers %	Foreign answers %
from the education system	27	17
retraining/further training	23	46
from competitors	19	14
from another industry	16	18
modification of the proportion of casual labour	9	5

Source: Own edition based on the results of PWC (PWC, 2019).

Interestingly, the leaders do not take into account that these resources are partially exhausted, and on the other hand, cumulatively, mathematically, they result in a solution corresponding to a zero-sum game.

4.2. Robot technology and digital solutions in the labour market

If certain conditions are met, automation, artificial intelligence and robotisation could also be a solution to the problem of the lack of skilled workers. According to the missing skills research findings, the preferred order of occupations and skills in short supply is: technicians (37%), sales specialists (33%), engineers (31%), support staff (28%), interns (17%), digital experts (15 %), financial experts and even senior managers (10 %).

So, overall, CEE companies are mainly looking for technical specialists and sales specialists, and surprisingly, 10% of them even lack senior managers.

The research pointed out the relevant digital solutions, i.e. the special, most important "eight" such as internet devices, network of machines (IOT), the application of robots, the application of artificial intelligence, 3D printing, virtual reality, augmented reality, block-chain and drones. For Central and Eastern European entrepreneurs, the use of controllable equipment available on the Internet is the most relevant of the digital solutions.

Artificial intelligence and robotisation could also be a solution to fill the shortage of skilled workers. Among the international responses, as well as in Hungary, the majority opinion is that artificial intelligence will significantly change the business activities of companies in the next five years. Despite the optimistic views, some of the managers interviewed in the research are not currently planning any initiatives related to artificial intelligence, 35% of them are thinking about it in the next three years, but are not completely convinced (PWC, 2019).

5. Artificial intelligence and the labour market

5.1. Waves of the use of artificial intelligence in employment

Automation will spread in employment in three waves, which are markedly separated from each other by the degree of machine autonomy.

- First wave: Algorithmic wave (from the early 2020s)

People make decisions. Structured data analysis and the automation of simpler digital tasks (e.g. credit assessment).

- Second wave: Expansion wave (until the end of the 2020s)

Humans make decisions with the help of robots. Repetitive tasks and the automation of information exchange, drones, warehouse robots and self-driving vehicles with conditional automation (in some cases they require human intervention).

- Third wave: Autonomy wave (until the mid-2030s)

The robot makes the decisions. Artificial intelligence will increasingly be able to analyze data from multiple sources, make decisions, and perform physical operations with minimal or no human intervention. E.g.: driverless vehicles (PWC, 2019). From a legal point of view, the question of liability appears (Józwiak & Falus, 2022/A; Józwiak & Falus, 2022/B). The regulatory background for this has not yet developed (Józwiak & Falus, 2022/B), despite the fact that, for example, in such cases, the question of intent, which is the basis for establishing criminal liability, would also reasonably arise (Józwiak & Falus, 2022/C). Jurisprudence will soon face the theoretical question of where legislation draws the regulatory boundary between real and virtual reality (Falus, Józwiak & Kővári, 2022).

5.2. Hungarian forecasts

Hungary's artificial intelligence strategy defines mobilizing goals with high social utility, which bring direct benefits to all citizens. According to minister László Palkovics (2020), there can be no doubt about the fact that artificial intelligence as a technology has become part of everyday life. The integration of applications based on artificial intelligence into economic and social conditions is accelerating. "From the point of view of the future of Hungary, this strategy and the successful implementation of the social, technological, economic and personal changes included in it will be of great importance."

Hungary's Artificial Intelligence Strategy was prepared for the period between 2020 and 2030. By the end of the 2030s, automation and artificial intelligence are expected to affect 900,000 workers. According to some expert estimates, more than 40% of jobs can be automated in Hungary.

In this process, three consecutive waves can be identified as presented in the previous chapter, during which the following changes are likely.

Algorithmic wave: Sectors based on data processing, such as the financial sector, IT-related and administrative jobs. The affected workers are typically young and female. This wave is expected to affect 5-10% of jobs on average.

Expansion wave: Affects sectors that provide services and are based on office work, such as the financial sector, education, public administration and IT-based services. It will affect 15-20% of the jobs in the affected industries. The difference compared to the first wave is that the proportion of affected women and men is expected to be the same, and among those affected there will be a higher proportion of more experienced, middle-aged workers.

Autonomy wave: On the one hand, it will affect production, and on the other, it will also affect highly complex and responsible jobs. It is expected that this wave will have the greatest impact, affecting 25-30% of jobs, mostly men and more experienced workers. (Artificial Intelligence Strategy of Hungary, 2020).

Automation in Hungary can accelerate economic growth by 0.8-1.4% through productivity growth. With the available technologies, 49% of domestic working hours can be

automated (McKinsey, 2018).

5.3. Skills that will increase in value in the future

If we consider the technological applications of artificial intelligence and the possibilities of endless automation of technical tasks, the most difficult human skills to reproduce will be the “soft” skills. Unlike "hard" or technical skills, which are usually measured by the quality of work, "soft" skills are less tangible or related to personality. In some businesses and professions, individuals with strong technical skills can get away with lacking soft skills. While other businesses focus more on how things are done than just looking at the end result. Many people are willing to put up with highly productive performers, even if they don't really get along with others. The era of strong technical skills and weak "soft skills" is estimated to be coming to an end. As artificial intelligence becomes a priority, employers will value the following “soft” skills more for those who remain employed:

- Creativity
- Curiosity
- Compassion
- Cooperation
- Critical thinking (Eubanks, 2020).

6. Conclusions and evaluation

During the study of the main domestic and foreign literature and sources, we presented the process of the development and rise of artificial intelligence. In the study, we wanted to review the worldwide forecasts regarding the development of artificial intelligence and employment, including presenting the relevant details of Hungary's Artificial Intelligence Strategy. In accordance with all this, we explored the temporal waves of the application of artificial intelligence. We also examined whether the use of artificial intelligence could be a solution to the shortage of skilled workers. Finally, there was an overview of the skills that are valued during the transformational employment.

The transformation of the labour market and employment does not affect men and women equally. In the future, competence will determine suitability, so artificial intelligence and digitalization can reduce the gender gap. On the other hand, mathematical, physical, IT and engineering skills are currently more favourable for male employees. In jobs not affected by the transformation, compassion and solidarity will continue to be important, which is more favourable for the weaker sex than employment. Those whose workplaces are affected by the rise of artificial intelligence may not be suitable and capable of performing new types of tasks, as a result of which a large number of employees affected by the digital transformation of the economy may appear on the labour market as a surplus. The world of work will produce significantly different standards than before. Working can be freer and more flexible.

Since the development of artificial intelligence and the scope of its fields of application are rapidly growing, it can be recommended to increase also the intensity and scope of related research in the near future, in all scientific fields.

References

Bayrak, M., Esen, Ö. (2014). “Forecasting Turkey’s Energy Demand Using Artificial Neural Networks: Future Projection Based on an Energy Deficit”. *Journal of Applied Economic Sciences. IX*, (2)(28), 191-204.

Collier, M., Fu, R., Yin, L., & Christiansen, P. (2017). Artificial intelligence: Healthcare’s new nervous system. (Accessed: 2021.12.05), https://www.accenture.com/t20171215T032059Z__w__/us-en/_acnmedia/PDF-49/Accenture-Health-Artificial-Intelligence.pdf.

Csepeli, Gy. (2020). *Ember 2.0 – A mesterséges intelligencia gazdasági és társadalmi hatásai.* Budapest: Kossuth Kiadó.

Digitális Jóléti program, Innovációs és Technológiai Minisztérium & Mesterséges intelligencia Koalíció. (2020). Magyarország Mesterséges Intelligencia Stratégiája 2020–2030. (Accessed: 2021.08.21), Innovációs és Technológiai Minisztérium: https://ai-hungary.com/api/v1/companies/15/files/137203/view

Eszteri, D. (2015). A mesterséges intelligencia fejlesztésének és üzemeltetésének egyes felelősségi kérdései. (Accessed: 2021.08.21), REAL - az MTA Könyvtárának Repozitóriuma: https://real.mtak.hu/eszteri.mi.felelosseg.final.pdf

Eubanks B. (2020). *Artificial intelligence for HR: Use AI to Support and Develop a Successful Workforce.* London: Kogan Page.

European Economic and Social Committee (2018). A mesterséges intelligencia munkavégzésre gyakorolt hatásainak előrejelzése a méltányos átállás biztosítása érdekében. (Accessed: 2021.12.06), forrás: Európai Gazdasági és Szociális Bizottság: https://eur-lex.europa.eu/legal-content/HU/TXT/PDF/?uri=CELEX:52018IE1473&from=BG

European Parliament (2019). A mesterséges intelligenciára és a robotikára vonatkozó átfogó európai iparpolitika (Accessed: 2021.09.10), https://www.europarl.europa.eu/doceo/document/TA-8-2019-0081_HU.html

European Parliament (2020). A mesterséges intelligencia szabályozása: az EP álláspontja (Accessed: 2021.09.10), European Parliament: https://www.europarl.europa.eu/news/hu/headlines/society/20201015STO89417/a-mesterseges-intelligencia-szabalyozasa-az-ep-allaspontja

European Parliament (2021). What is artificial intelligence and how is it used? (Accessed: 2021.09.10), European Parliament: https://www.europarl.europa.eu/news/en/headlines/society/20200827STO85804/what-is-artificial-intelligence-and-how-is-it-used

Falus, O. & Jóźwiak, P. & Kővári, Attila (2022). "Gólyakalifa" a 21. században: Joghézag és analógia a virtuális valóság jogában" *JOGELMÉLETI SZEMLE ,2,* 20-32.

Frey, C. B., & Osborne, M. A. (2013). *The future of employment: how susceptible are jobs to computerisation*. Oxford: Martin School.

Futurism. (2021). Kurzweil Claims That the Singularity Will Happen by 2045. (Accessed: 2021.12.07), Futurism: https://futurism.com/kurzweil-claims-that-the-singularity-will-happen-by-2045

Jóźwiak, P. & Falus, O. (2022A). Criminal liability of associations in Polish and Hungarian law. Poznan: Wydawnictwo Rys. DOI: 9788367287340

Jóźwiak P. & Falus O. (2022 B). "Legal Regulations on Autonomous Cars in Poland and Hungary". *DUNAKAVICS 10 :* 8, 45-58.

Jóźwiak, P. & Falus, O. (2022C). "Legal Regulations on Autonomous Vehicles in Poland and Hungary: The Issue of Criminal Liability" in László Balázs, Mónika Rajcsányi-Molnár, István (eds.) *Elektromobilitás és társadalom. Dunaújváros.* 125-136.

Juniper Research. (2018). Retailer Spending on AI to Grow Nearly Fourfold, Reaching $7.3 Billion by 2022. (Accessed: 2021.12.07), https://www.businesswire.com/news/home/20180131005068/en/Juniper-Research-Retailer-Spending-AI-Grow-Fourfold.

Keene, R. & Goodman, D. (1997). *Man Versus Machine: Kasparov Versus Deep Blue*. Cambridge: H3 Publications.

Kurzweil, R. (2000). *The Age of Intelligent Machines When Computers Exceed Human Intelligence.* Harmondswoorth: Penguin Books.

Kurzweil, R. (2014). *A szingularitás küszöbén. Amikor az emberiség meghaladja a biológiát.* Budapest: Ad Astra.

Lardieri, A. (2019). Robots will replace 20 million jobs by 2030, oxford report finds. (Accessed: 2021.12.06) https://www.usnews.com/news/economy/articles/2019-06-26/report-robots-will-replace-20-million-manufacturing-jobs-by-2030.

Marketwach.(2019). Over 30 million U.S.workers will lose their jobs because of AI. (Accessed: 2021.12.07). https://www.marketwatch.com/story/ai-is-set-to-replace-36-million-us-workers-2019-01-24

McKinsey & Company. (2018). Átalakuló munkahelyek: az automatizálás hatása Magyarországon. (Accessed: 2021.12.06), https://www.mckinsey.com/~/media/McKinsey/Locations/Europe%20and%20Middle%20East/Hungary/Our%20Insights/Transforming%20our%20jobs%20automation%20in%20Hungary/Automation-report-on-Hungary-HU-May24.ashx.

PWC. (2017). A mesterséges intelligencia a produktivitás és a személyre szabhatóság javításával 15,7 billió dollárral növelheti a GDP-t. (Accessed: 2021.08.21), https://www.pwc.com/hu/hu/sajtoszoba/2017/ai.html

PWC. (2019). Magyarországi Vezérigazgató Felmérés A cselekvés ideje Visszafogott növekedés, fókuszban a belső folyamatok. (Accessed: 2020.12.21), https://www.pwc.com/hu/hu/kiadvanyok/assets/pdf/PwC_CEO_survey_kiadvany_HU_2019.pdf

Russell, S. J. & Norvig, P. (2005). *Mesterséges Intelligencia - Modern megközelítésben.* Budapest: Panem Könyvkiadó.

Szilágyi Sz. (2018). Átmegy a Turing-teszten a Google MI-je. (Accessed: 2021.08.30), https://bitport.hu/atmegy-a-turing-teszten-a-google-mi-je.html

Tilley, J. (2017). Automation, robotics, and the factory of the future. (Accessed: 2021.12.06), https://www.mckinsey.com/business-functions/operations/our-insights/automation-robotics-and-the-factory-of-the-future.

Turing, A. M. (1950). Computing Machinery and Intelligence. *Mind. 59*, 433–460.

Wheeler A. R. & Buckley M. R. (2021). *HR Without People?: Industrial Evolution in the Age of Automation, Ai, and Machine Learning* (Future of Work). Bingley: Emerald Publishing.

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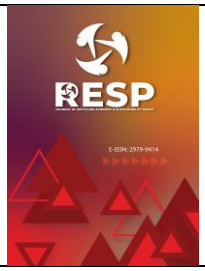

RESP

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Araştırma Makalesi ● Research Article

The Effect of Economic Freedom and Human Development on Economic Growth: Panel Data Analysis for G7 Countries

Ekonomik Özgürlük ve İnsani Gelişmenin Ekonomik Büyümeye Etkisi: G7 Ülkeleri İçin Panel Veri Analizi

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ANAHTAR KELİMELER

Ekonomik büyüme
Ekonomik özgürlük
İnsani gelişimi

ÖZ

Ülkelerin daha iyi ekonomik koşullara ulaştığının önemli bir göstergesi ekonomik büyümedir. Ekonomik büyüme, makroekonomik bir olgu olması nedeniyle birçok durum ve faktörden etkilenebilmektedir. Bu çalışmada bu faktörlerden ekonomik özgürlük ve insani gelişmenin ekonomik büyümeye etkisi ele alınmaktadır. Analizde, Heritage Foundation tarafından her yıl yayınlanan Ekonomik Özgürlük Endeksi verileri ile Birleşmiş Milletler Kalkınma Programı tarafından yayınlanan İnsani Gelişme Endeksi verileri ve Dünya Bankası veri tabanından elde edilen kişi başına Gayri Safi Yurtiçi Hasıla verileri kullanılmıştır. 1995-2021 döneminde G7 ülkeleri için panel veri regresyon yöntemi uygulanmıştır. Ekonomik Özgürlük Endeksi ve İnsani Gelişme endeksleri ekonomik büyümeyi istatistiksel olarak anlamlı ve pozitif şekilde etkilediği sonucuna varılmıştır.

KEYWORDS

Economic Growth
Economic Freedom
Human Development

ABSTRACT

An important indicator of countries achieving better economic conditions is economic growth. Economic growth can be affected by many situations and factors due to the fact that it is a macroeconomic phenomenon. In the study, the effect of economic freedoms and human development on economic growth were examined from these factors. In the analysis, the Index of Economic Freedom data published every year by the Heritage Foundation and the Human Development Index data published by the United Nations Development Program and the Gross Domestic Product per capita data obtained from the World Bank's database were used. In the period of 1995-2021, panel data regression method was applied with the data of G7 countries. It was concluded that there is a statistically significant and positive relationship between the independent variables of the Economic Freedom Index and the Human Development Index and the dependent variable of economic growth expressed by GDP per capita.

1. Introduction

Economic growth is defined as a continuous increase in real income per capita. For its requirement for continuity, growth is a long-term phenomenon. The increase in the amount of production or real output depends on the combination rates and efficiency of the factors of production. The combination of factors of production forms the production function. According to Rostow (1990), economic growth theories from the 18th century to the present are based on the production function, which is a general formulation.

Undoubtedly, factors of production constitute the dynamics of economic growth; however, studies have shown that institutions and public policies also have influence in economic growth. In many studies on the subject, it has been revealed that money and price stability, secure property rights and openness to international trade have independent effects on economic growth (Gwartney et al., 1999). At this point, rights and freedoms comes to the spotlight within the institutional structure. Under the heading of freedoms, economic freedoms refer to an individual's ability to form their own decisions regarding labor and property. The

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concept of economic freedoms has become one of the main axes of neo-liberal economic policies implemented since the 1980s (Akıncı et al., 2013). The ability of economic agents operating in free market conditions to make decisions freely is necessary for efficiency in production processes and consumption. Efficiency in production and consumption shows that resources are used effectively. Effective use of resources also positively affects the processes of economic growth and income distribution. The findings of the studies show that there is a strong correlation between economic freedom and its sub-components and the variability in economic growth (Heckelman, 2000).

On the other hand, the concept of human development is defined as the process of increasing the options for people (Ranis et al., 2006). The increase in the interaction between countries in the world due to developments in the field of communication and technology has shown that the development of a country cannot be evaluated only with economic growth, and it is necessary to develop human-oriented methods (Uçan & Koçak, 2018). At this point, the Human Development Index (HDI), published every year since 1990 by the United Nations Development Program (UNDP), presents a brief measurement of the average success in basic dimensions of human development. These dimensions can be listed as a healthy life, being knowledgeable and having good living conditions. The Human Development Index is the geometric mean of the indices created for each of these three dimensions (UNDP, 2023).

Economic freedoms and human development are among the focal points of global development policies. While the increase in economic freedoms allows a country to increase its economic growth potential; human development also contributes to facilitating people's access to basic needs such as health and education, and to creating an environment of welfare.

The study examines the correlation between the Index of Economic Freedom and the Human Development Index and the real Gross Domestic Product per capita as an indicator of economic growth. The period between 1995 and 2021 and the G7 countries constitute the scope of the analysis. It is aimed to reveal the effect of economic freedoms and human development on economic growth.

The study consists of four parts, including the introduction. After the introduction, in the second part, the studies in the literature on the subject are examined; In the third section, information about the data set and the method is given. In the fourth chapter, the empirical findings obtained as a result of the analysis are explained. In the last part, there is the conclusion section where the evaluation of the estimation results is included.

2. Literature Survey

When the relevant literature is examined, there are many studies in which the relationship between human development and economic freedoms on economic growth are evaluated separately. There are few studies on the relationship between both concepts and economic growth, and no study examining G7 countries has been found.

Gwartney et al. (1999) researched the effect of economic freedoms on economic growth. Their results show that economic freedom is an important determinant of growth, even when considering human capital, physical capital and demographic characteristics.

De Haan and Sturm (2000) researched the effect of economic freedoms on economic growth with data from 80 countries between 1975 and 1990. In the model which is established, both the level of economic freedom and the change in economic freedom over time were used as explanatory variables. Finally, it was concluded that economic freedoms feed economic growth, but there is no relation between the level of economic freedom and growth.

Carlsson and Lundström (2002) examined the effect of economic freedoms on economic growth with data from 74 countries between the years 1970-1990 in their study. In the study, the effects of the changes in the economic freedom index on growth were estimated and the results were found to be statistically significant. The relationship between them is positive and the increase in economic freedoms increases economic growth. However, the fact that some categories in the index are unimportant and that some of the important variables have negative effects does not mean that the increase in economic freedom in general is good for economic growth.

Justesen (2008) examined the causality relationship between economic freedoms and economic growth in their study. The results indicate that some aspects of economic freedom affect economic growth as well as investment. However, there is no strong evidence that growth affects economic freedom.

Compton et al. (2011) examined the nature of the correlation between economic freedoms and economic growth. All 50 US states in the period from 1981 to 2004 were included in the analysis. It has been determined that there is a positive and statistically significant relationship between economic freedoms and economic growth; however, the effects of the sub-components of economic freedoms differ.

Akinci et al. (2013) examined the relationship between economic freedoms and economic growth with panel data analysis. 144 countries for the period from 1995 to 2012 were included in the analysis. The results of the applied cointegration analysis reveal the existence of a long-term relationship between economic freedoms and economic

growth. The causality analysis results applied afterwards show that economic freedoms are the cause of economic growth. According to the results obtained, it can be easily determined that economic freedom accelerates the economic growth process.

Tunçsiper and Biçen (2014), in their study, examined the relationship between economic freedoms and economic growth in the framework of nine emerging market economies, including Turkey. Data between 2000 and 2012 were used in the study and panel data analysis was applied. As a result of the analysis, it was concluded that there is a negative relationship between the property rights index and the freedom to invest index and economic growth, as well as a positive relationship between the freedom to work index and the freedom to trade index and economic growth. No significant relationship was found between the general economic freedom index and economic growth.

Çetenak and Işık (2016) analyzed the causal relationship between economic growth and economic freedoms in their studies. Along with the effect of economic freedoms on growth, the effect of growth on economic freedoms has also been examined. For the period between 1995 and 2014, panel VAR method was applied with ten sub-components and growth data representing the economic freedom index of 32 OECD member countries. The results show that all the components of economic freedom are effective on economic growth. In addition, it was concluded that economic growth is the Granger cause of financial freedoms, monetary freedoms and commercial freedoms, which are the sub-components of economic freedoms.

Uçan and Koçak (2018) conducted panel data analysis between Turkey and Germany, USA, Norway and Italy, which are countries with high human development index, for the period between 1990 and 2015. In this context, the relationship between economic growth and economic growth was examined by using human development index data. According to the results of the applied cointegration analysis, a long-term relationship was determined between the sub-components of economic growth and human development.

Çoban (2020) examined the period between 1995 and 2014 for the countries of Czechia, Hungary, Slovakia and Poland, which are described as the Visegrad quartet. The Human Development Index and the Index of Economic Freedom and its sub-components the Monetary Freedom Index and the Property Rights Index were included in the analysis. The share of public health expenditures in national income, the share of public education expenditures in national income and the inflation rate were also used as control variables. According to the results obtained, it was found that economic freedoms affect the level of human development positively.

Göcen (2021) examined the relationship between economic freedoms and economic growth in the period between 1996 and 2019 and within the scope of D8 countries. The causality test was applied and it was concluded that economic freedom was the cause of economic growth in seven countries. Expanding economic freedoms plays a critical role in achieving higher levels of economic prosperity in these countries. In Bangladesh, a bidirectional causality relationship was determined. These results reveal the importance of improving economic freedoms for better economic performance.

Türkmen and Tıraş (2022), in their study, examined the correlation between human development and urbanization and economic growth for BRICS-T countries. Panel cointegration analysis was performed with the data of the period between 1990 and 2019. According to the results obtained, the human development index variable is statistically significant in the long run; It was concluded that the urbanization rate was not significant.

Ahmed et al. (2023) examined the effect of the Index of Economic Freedom and its sub-components on economic growth for the period between 1995 and 2021. The analysis covers four South Asian countries: Bangladesh, India, Pakistan and Sri Lanka. The results show that economic freedoms have a strong impact on growth. In addition, most of the sub-components of economic freedoms were found to be statistically significant.

3. Data and Methodology

The data included in the analysis consists of Index of Economic Freedom, Human Development Index and GDP per capita. The abbreviations of the variables, their definitions and the sources from which the data are accessed are shown in Table 1.

Table 1. Definitions and Sources of Variables

Abbreviations	Definitions	Sources
gdp	Real Gross Domestic Product adjusted by Puchasing Power Parity	https.//databank.worldbank.org/
hdi	Human Development Index	https://hdr.undp.org/
efi	Economic Freedom Index	https://www.heritage.org/

The GDP per capita dependent variable representing economic growth is shown by "gdp", and the independent variables of the Economic Freedoms Index and the Human Development Index are shown by "hdi" and "efi", respectively. The values taken by the GDP dependent variable are logarithed because they are high quantitative

quantities relative to the index values. The index values that make up the independent variables are included as is. Thus, the established regression model becomes a semi-logarithmic model. The regression equation established for analysis is given below:

$lngdp_{it} = ß_0 + ß_1 hdi_{it} + ß_2 efi_{it} + u_{it}$ (i: 1,2,….,N; t: 1,2,….,T)

In the model, i represents the cross-section dimension and t represents the time dimension. The dependent variable is the logarithmic equivalent of the Gross Domestic Product (GDP) of country i in year t. The independent variable "hdi" denotes the Human Development Index value of country i in year t, and "efi" denotes the Economic Freedom Index value of country i in year t. The error term is represented by u.

The model was tried to be estimated by panel data regression analysis. Panel data regression analysis can be estimated by three methods: classical, fixed effects and random effects. The classical (pooled) model ignores unit and time effects. However, unit and time effects may occur with the use of panel data. "Random effects" if the resulting effects cannot be observed and are assumed to be a random variable; "fixed effects" occur if they are assumed to be the estimated parameter for each observation (Yerdelen Tatoğlu, 2020). The Hausman test is frequently used to select the appropriate one between fixed effects and random effects models. After selecting the appropriate method and performing the analysis, diagnostic tests are applied. Diagnostic tests are used to detect problems such as cross-section dependence, heteroscedasticity and autocorrelation. In the presence of these problems, estimators that produce resistant standard errors are resorted to, since the estimation results cannot be trusted.

4. Empirical Results

In the analysis part, descriptive statistics of the variables in the regression established first are included. In the first column of Table 2, the logarithm of the GDP per capita adjusted by Purchasing Power Parity, respectively, as the dependent variable, the abbreviations "lngdp", the Human Development Index "hdi", and the Economic Freedom Index, "efi".

Table 2. Summary of Statistics

Variables	Mean	Std.Dev.	Min.	Max.
lngdp	10.688	0.130	10.426	11.061
hdi	0.894	0.029	0.810	0.948
efi	70.968	6.693	57.4	81.2

The Human Development Index (hdi) takes values between 0 and 1. From 0 to 1, the level of human development increases. The Economic Freedom Index, on the other hand, takes a value between 0 and 100, and the level of economic freedom increases from 0 to 100. As seen in the table, the average values of the human development and economic freedom indexes are closer to the maximum point than the minimum point. This is because the countries in the sample are developed countries. Based on the data we have, it can be said that there is a relationship between high human development and economic freedoms.

Before the analysis phase, the validity of the classical (pooled) model was tested. At this point, the existence of unit and time effects is examined. The existence of the unit effect was found, but it was seen that there was no time effect. For this reason, the classical model is not suitable and it is necessary to choose between fixed or random effects models. The appropriate model was decided by the Hausman test.

Table 3. Hausman Test

	Test stat.	P-value
Hausman Test	0.140	0.9304

According to the Hausman test result in Table 3, the null hypothesis stating that the variability in the coefficients is not systematic could not be rejected. Therefore, the appropriate model is the random effects model. After selecting the appropriate model, diagnostic tests were started. First, the heteroscedasticity test was applied.

Table 4. Heteroscedasticity Test Results

	df(6, 180)	P-value
W0	16.030	0.000
W50	11.845	0.000
W10	15.676	0.000

According to Levene, Brown and Forsythe varying variance test results, the constant variance null hypothesis was rejected. It was found that the variance of the error terms in the estimated model differed. There is a problem of heteroscedasticity in the model.

Then, the existence of autocorrelation was tested. The applied test is a modified version of the test statistic developed by Baltagi and Wu (1999) and the test statistic of Bhargava, Franzini, and Narendranathan (1982).

Table 5. Autocorrelation Test Results

	Test statistics value
Bhargava et.al. Durbin-Watson Test	0.250
Baltagi-Wu LBI Test	0.461

Looking at the results in Table 5, it was found that the test values were less than 2. The null hypothesis indicating the existence of autocorrelation could not be rejected. There is also an autocorrelation problem in the model. Finally, the

cross-section dependency test was applied.

Table 6. Cross-Section Dependence Test

	Test stat.	P-value
Pesaran CSD Test	5.087	0.000

The test can be applied for balanced and unbalanced panels in the existence of standard normally distributed error terms developed by Pesaran (2004). The null hypothesis of "cross-section independence" is rejected. It is seen that there is a cross-section dependency in the model.

In the diagnostic tests, heteroscedasticity, autocorrelation and cross-sectional dependence were tested and it was concluded that each of them is present in the model. In the presence of these problems, it will be necessary to apply estimators that produce robust standard errors. In the presence of all three problems together, the Driscoll-Kraay estimator can be used. The method produces robust estimators even when the time dimension has bigger value than the cross section (T>N) (Driscoll & Kraay, 1998).

Table 7. Driscoll-Kraay Random-Effects Estimator (Robust Standart Errors)

Variables	Coeff.	Std.Err.	t-value
hdi	2.600 *	0.203	12.790
efi	0.004 **	0.002	2.620
constant	8.074 *	0.194	41.540
$R^2 = 0.40$		Wald chi2 = 254.00	
corr(u_i, Xb) = 0		Prob > chi2 = 0.0001	

Note: (*), (**), (***) denote 1%, 5% and 10% significance levels, respectively.

According to the estimation results, it is seen that there is a positive and statistically significant relationship between the human development and economic freedom indices and economic growth. Independent variables are significant both individually and as a whole. The power of the independent variables to explain the variability in the dependent variable was 40%. The increase in human development and economic freedom in G7 countries contributes positively to economic growth.

5. Conclusion

Efficiency of the markets is possible with conditions of full competition and full employment. The creation of a competitive environment will lead to the sprouting of new enterprises and expand employment opportunities. The view advocated in mainstream economics that the role of the state in the economy should be minimal and that it should play a role in allocating the competitive environment instead of intervening in the economy is related to the efficient functioning of the markets. Optimisation in the markets will lead to efficient use of resources; Thus, production will be positively affected and an increase in economic growth will be experienced.

A competitive environment can be created when economic agents can carry out their activities freely. A high level of economic freedom will contribute positively to the economy. At this point, it was possible to make quantitative analyzes with the measurable level of economic freedom. On the other hand, human development consisting of sub-components such as health and education will be high in economies with employment opportunities and easy access to basic rights and needs. The Human Development Index is a measure of the well-being of individuals in society.

The expectation in the study is that the increase in economic freedoms and human development levels will contribute positively to economic growth. In this direction, panel data regression method was applied between the Index of Economic Freedom published by the Heritage Foundation and the Human Development Index data published by the United Nations Development Program (UNDP) and GDP per capita data obtained from the World Bank database. The analysis includes the G7 countries for the period between 1995 and 2021. According to the results obtained, a positive and statistically significant relationship was found between economic freedoms and human development and economic growth. These results seem to be compatible with similar studies in the literature.

Achieving economic growth is seen as one of the most important conditions for the improvement of living conditions and the creation of a welfare environment in countries. In societies where economic freedoms are ensured and human development is aimed, both economic growth and welfare will be created. In the welfare environment, individuals will strive for the continuity of good economic conditions. It can easily be said that these processes feed each other. It is essential for growth to be sustainable that states invest in human development and create an environment in which economic agents can act freely. Developing policies to increase economic freedoms and human development levels will be beneficial for states.

References

Ahmed, S., Mushtaq, M., Fahlevi, M., Aljuaid, M., & Saniuk, S. (2023). Decomposed and composed effects of economic freedom on economic growth in South Asia. *Heliyon*, *9*(2), e13478. https://doi.org/10.1016/j.heliyon.2023.e13478

Akıncı, M., Yüce, G., & Yılmaz, Ö. (2013). Ekonomik özgürlüklerin iktisadi büyüme üzerindeki etkileri: Bir

panel veri analizi. *Anadolu Üniverstesi Sosyal Bilimler Dergisi.*

Carlsson, F. (t.y.). *Economic freedom and growth*: Decomposing the effects.

Compton, R. A., Giedeman, D. C., & Hoover, G. A. (2011). Panel evidence on economic freedom and growth in the United States. *European Journal of Political Economy, 27*(3), 423-435. https://doi.org/10.1016/j.ejpoleco.2011.01.001

Çetenak, Ö., & Işık, M. (2016). Ekonomik özgürlükler ile ekonomik büyüme arasındaki nedensellik ilişkisi: OECD ülkeleri üzerine bir uygulama. *Nevşehir Hacı Bektaş Veli Üniversitesi SBE Dergisi*.

Çoban, M. N. (2020). Ekonomik özgürlüklerin insani gelişmişlik üzerine etkisi: Visegrad dörtlüsü kapsamında panel veri analizi. *TESAM Akademi Dergisi*, 143-162. https://doi.org/10.30626/tesamakademi.696203

de Haan, J., & Sturm, J.-E. (2000). On the relationship between economic freedom and economic growth. *European Journal of Political Economy, 16*(2), 215-241. https://doi.org/10.1016/S0176-2680(99)00065-8

Driscoll, J. C., & Kraay, A. C. (1998). Consistent Covariance Matrix Estimation with Spatially Dependent Panel Data. *Review of Economics and Statistics, 80(*4), 549-560. https://doi.org/10.1162/003465398557825

Göcen, S. (2021). Gelişen ülkelerde ekonomik özgürlük ve ekonomik büyüme ilişkisi: Bootstrap panel Granger nedensellik testi. A*tatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi.* https://doi.org/10.16951/atauniiibd.797849

Gwartney, J. D., Lawson, R. A., & Holcombe, R. G. (1999). *Economic freedom and the environment for economic growth.*

Heckelman, J. C. (2000). Economic freedom and economic growth: A short-run causal investigation. *Journal of Applied Economics, 3*(1), 71-91. https://doi.org/10.1080/15140326.2000.12040546

Justesen, M. K. (2008). The effect of economic freedom on growth revisited: New evidence on causality from a panel of countries 1970–1999. *European Journal of Political Economy, 24*(3), 642-660. https://doi.org/10.1016/j.ejpoleco.2008.06.003

Ranis, G., Stewart, F., & Samman, E. (2006). Human development: Beyond the Human Development Index. *Journal of Human Development, 7(*3), 323-358. https://doi.org/10.1080/14649880600815917

Rostow, W. W., & Kennedy, M. (1990). *Theorists of economic growth from David Hume to the present: With a perspective on the next century* (1. issued as an Oxford University Press paperback). Oxford Univ. Press.

The Heritage Foundaiton (2023). Index of Economic Freedom. https://www.heritage.org/

Tunçsiper, B. ve Biçen, Ö. F. (2014). Ekonomik özgürlükler ve ekonomik büyüme arasındaki ilişkinin panel regresyon yöntemiyle incelenmesi. *Eskişehir Osmangazi Üniversitesi İİBF Dergisi, 9(*2), 25- 45.

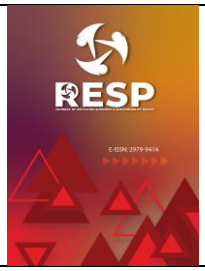
Türkmen, S., & Tiraş, H. H. (2022). BRICS-T Ülkelerinde Ekonomik Büyüme ve İnsani Gelişme İlişkisinin Ekonometrik Analizi. *Journal of Economics and Research*. https://doi.org/10.53280/jer.1156790

Uçan, O., & Koçak, E. (2018). İnsani gelişme endeksi ile büyüme ilişkisi: Pedroni eşbütünleşme örneği. *Journal of Politics, 1(*2).

UNDP (2023). United Nations Development Programme. Retrieved from https://www.undp.org/

World Bank (2023). World Bank Open Data. Retrieved from https://data.worldbank.org/

Yerdelen Tatoğlu, F. (2020). *Panel Veri Ekonometrisi* (Genişletilmiş 5.Baskı). Beta Basım Yayım Dağıtım.



RESP

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Araştırma Makalesi ● Research Article

Impact of Plastic waste on the environment and humans health in Pakistan: Effective Waste Management Strategies and sustainable solutions

Pakistan'da Plastik atıkların çevre ve insan sağlığı üzerindeki etkisi: Etkili Atık Yönetimi Stratejileri ve sürdürülebilir çözümler

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ANAHTAR KELİMELER

Plastik kirliliği
Sağlık tehdidi ve Çevresel problem
Sürdürülebilir çözüm
Geri dönüşüm
Enerji geri kazanımı

ÖZ

Son zamanlarda atıklar ciddi çevre sorunlarından biridir. Plastik okyanusa atılıyor ve insan, hayvan ve su yaşamı için tehlikeli. Plastiğin açık bir şekilde yakılması veya atılması hava kirliliği yaratır. Ayrıca suyu ve toprağı da etkiler. Bu uygulama genel çevreyi ve ekolojik döngüyü bozmaktadır. Mikro-plastik canlıların vücuduna besin zinciri yoluyla geldiği için sağlık tehditleri fark ediliyor. Birçok ülke plastiğin kullanımına kısıtlamalar getirdi ancak bu, plastik kirliliğini ortadan kaldırmak için yeterli değil. Plastik yeniden kullanılabilir ve geri dönüştürülebilir. Bu sorunu çözmek ve başta enerji geri kazanımı olmak üzere plastik atık yönetimi için sürdürülebilir bir çözüm bulmak için çeşitli çalışmalar yapılmıştır. Bu çalışma, çevre veya insan sağlığı sorunları da dahil olmak üzere Pakistan'daki plastik atık sorunlarına odaklanmaktadır. Bu çalışma aynı zamanda Pakistan'da başlatılması gereken sürdürülebilir çözümleri de göstermiştir. Bu çalışma, atıkların yeni teknolojilerle enerjiye dönüştürülmesi konusunda en önemli çözümleri önermektedir.

KEYWORDS

Plastic pollution
Health threat and Environmental problem
Sustainable solution
Recycling
Energy recovery

ABSTRACT

Recently waste is one of the serious environmental issues. Plastic is being thrown into ocean and it is dangerous to human, animal and aquatic life. Burning or dumping plastic openly creates air pollution. It also affects water and soil. This practice disturbs overall environment and ecological cycle. Health threats are recognized due to micro-plastic because it comes to living things' body through food chain. Several countries have put limitations to use plastic but it is not enough to eliminate plastic pollution. Plastic can be reused and recycled. Several studies have been conducted to tackle this issue and find sustainable solution for plastic waste management, especially energy recovery. This study is focused to plastic waste issues in Pakistan including environmental or human health issues. This study also demonstrated sustainable solutions which need to be initiated in Pakistan. This study recommends the most important solutions that waste should be converted into energy with new technologies.

1. Introduction

Waste and its management are universal issues around the globe. Several types of waste have been recognized which are the big threat to environment and health of living things. Plastic waste is one of the serious global challenges that are increasing day by day. Recently, it is one of the most highlighted issues because plastic waste has been found around the beaches due to lack of social awareness (Hina et al. 2020, Cook and Halden 2020). Every year,

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approximately 8000000000 kilograms of plastic waste is discarded into the oceans and this action is destroying aquatic life (Chawla et al. 2022). If it continues, it is predicted that there will be more plastic in the oceans than fish by 2050 (Cook and Halden 2020). Scholars have been striving to tackle this issue that why plastic and rubber wastes is thrown away in the environmental bodies (Alyousef et al. 2021). Plastic waste is social and environmental issue. In addition, it is not only ocean problem; it pollutes the whole environment because plastic waste is burned in several countries (Yusuf et al. 2022, Kanellopoulos et al. 2021). People do not care about it. The social awareness about the environment is important to be given with different medium especially regarding plastic and rubber wastes disposal that cause serious issues around the globe.

Pakistan is one the country where people do not care about environment because of social awareness. Pakistan alone generated about 3900000000 kilograms of plastic waste in 2020 (Batool and Ch 2009). Exactly 70% of this plastic waste is sent to landfills, improper dumps into environmental bodies which results in soil and water pollution across the country (Khan 2021, WWF 2022, Jabeen et al. 2022). The Pakistani government has put restriction in different plastic products and allows the manufacture to usage of Oxo-biodegradable shopping bags because these types of bags cannot fly here there with air pressure and most important things is that they are also reusable. Though, there was no proper implementation on these agreements. There is another program, where it was set that only particular substance will be used for this purpose in Pakistan, including Karachi (Desk 2019, Longsheng et al. 2022), but it was also not followed accordingly. Karachi city is one of the largest cities where a large number of locally manufactured plastic products are being used. It is very difficult to manage such huge amount of plastic in a short time (Desk 2019).

Globally, wide-ranging studies have been conducted to improve MSW management system that includes proper treatment before discarding (Das et al. 2021, Zhu et al. 2021, Yukalang, Clarke, and Ross 2018). There are several technologies are being adopted by developing countries to manage plastic waste such as reduce; reuse, recycle. It is also documented that waste can be resources for energy recovery. Several methods are being used for energy recovery from solid waste (Malamis et al. 2016). At the moment, urban areas are considered as 56% of the total global-population. It is accountable for producing momentous amount of municipal solid waste (MSW) (Hemidat et al. 2022). Landfills get approximately 70%, whereas, very low percentage of waste is documented for energy production (Vergara and Tchobanoglous 2012). Plastic waste is generated in huge percentage in Pakistan because several companies are using plastic for their production. If this waste is utilized for energy recovery then Pakistan can tackle several deficiencies such as electricity. This study is focused to plastic waste issues in Pakistan including environmental or human health issues. This study also demonstrated sustainable solutions which need to be applied in Pakistan. One of the most important solutions is that waste has potential to recover energy with certain technologies.

2. Sources of plastic waste in Pakistan

Pakistan is one of the regions with high percentage of plastic waste mismanagement in South Asia (Ferronato and Torretta 2019). Plastic is widely used because it is cheap and convenient. Recently, plastic used in electrical and electronic equipment (EEE) is more in highly developed countries than other countries (Goosey and Goosey 2019). Such waste can be reused and also can be recycled. Such electrical appliances are computers, screens, mobile phones, TVs, etc. (Herreras-Martínez and Leroy 2019, Goosey and Goosey 2019, Ijomah and Danis 2019, Townsend 2011). In addition, more waste is found in big cities due to urbanization because they use plastic for interior design. Except plastic, some of them are not liable to decompose; they are known as inert waste such as construction waste (dirt, debris, rocks, etc.) and demolition (Ehrig and Stegmann 2018, El-Haggar 2007, Osmani and Villoria-Sáez 2019). Industrial sector has different types of waste. Composite wastes are under tetra packs, clothing, waste plastic, etc. Other types of waste such as chemicals, paints, spray cans, shoe polish, bulbs, fluorescent tubes, fertilizers and pesticides belong to domestic hazardous waste and toxic waste. They all also connected with plastic waste (Kundariya et al. 2021, Vignesh, Rajadesingu, and Arunachalam 2021, Woodard and Curran 2006, Artiola 2019, Sam and Barik 2019).

In Pakistan, biggest plastic sources and polluters are Coca-Cola, PepsiCo, Unilever, and Nestle (Maryam Arshad 2020). It needs strict legislation to tackle their plastic pollution. Plastic bottles, plastic bottle caps, plastic straws, stirrers, plastic grocery bags, and food wrappers are the next most common item. In addition, other sources such as Cigarette butts, whose filters have tiny plastic fibers (Belzagui et al. 2021). They are the most common kinds of plastic waste in the environment. Pakistani people are not realizing the facts that, it is difficult to manage the waste because it adversely affects overall environment and living things especially humans (Khan 2021, Ahmed et al. 2020). It affects more wildlife, wildlife habitat (Akram 2010). In addition, it does not decompose on its own easily. Even though Pakistan has become one of 128 countries with a single-use plastic (polythene) bag ban in place in 2019 (Khan 2021) but no one follows the rules and regulations. In Pakistan, sources of plastic waste vary city to city but mostly it comes from industries and home usage products, see fig 1.

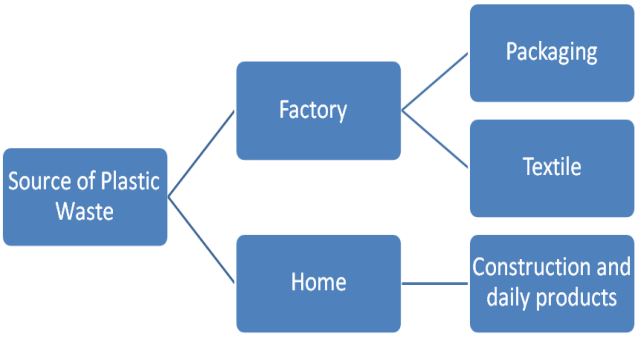

Figure 1. Main sources of plastic waste in Pakistan

Pakistan Plastic Manufacturers Association (PPMA) reported that the use of plastic per capita is 5.5 kilograms in Pakistan and the country imports 1070 kilograms of polymers annually (Desk 2019). Regrettably, plastics waste is considered as 65% of the total waste in Pakistan; with an estimated annual increase of 15% of plastic bag usage (WWF 2022). Pakistan banned some plastic production and it affects 600,000 kg annually. The achievement of the ban is determined by social awareness. State should take steps (especially Ministry of Climate Change) such as educational campaigns for citizens and manufacturers. In addition, there should be the free distribution of alternative bags for a limited time so that people should be habitual. This program should be taken by the Pakistan Environmental Protection Agency (EPA) and special attention should be given by media coverage agencies. Approach to reusable bags and social awareness should be given to the citizens (Khan 2021, Ahmed et al. 2020). These practices can tackle this plastic pollution.

3. Impact of plastic waste on environment and human health

Indeed there is no any engineered way of disposal in Pakistan (Siddiqi et al. 2019). Several technologies have been introduced to deal with waste. Those technologies propose best solution to tackle public health and environmental problems in Pakistan. Implementation of those technologies may reduce amount of waste and it will improve uncontrolled manner of management regarding waste (Longsheng et al. 2022). Main problem is to implement properly. Plastic recyclers are working in several cities of Pakistan but their methods are not eco-friendly and that's the reason it is threat to the environment or on public health. They just melt the plastic and make new plastic for further usage (Desk 2019). Problems due to plastic waste are increasing day by day. All problems should be highlighted so that authorities and nation should take some steps to deal with them.

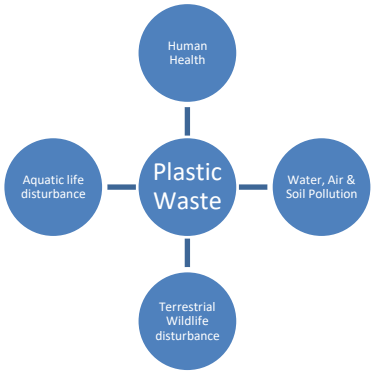

Figure 2. Impact of Plastic Waste

In Pakistan, condition of solid waste management is a problem of crucial concern because waste-related diseases is responsible for death around 5 million people each year (Akmal and Jamil 2021). Several health hazards caused by solid waste have been documented such as diseases like diarrhea, dysentery, typhoid, hepatitis, cholera, skin, eye infections etc. (Jerie 2016, Ankit et al. 2021). Inhalation problems in children and adults are caused due to dust in the air at dumpsites (Njoku, Edokpayi, and Odiyo 2019). Due to improper disposal, several species such as mosquitoes, flies, bacteria, dogs, cats and rats spread several types of diseases such as malaria, flea born fever, yellow fever, plague, intestinal, parasitic and skin diseases etc. (Mataloni et al. 2016). Pakistan is working for solid waste management including all types of wastes but immediate steps should be taken to avoid such health issues. Due to proper waste management, several problems including health and pollution will be solved.

4. Transportation of solid waste in Pakistan

Transportation plays a prominent role in waste management. It is used to transfer the waste from collection point to recycling or disposal destination (Hina et al. 2020). Inefficient waste management and inadequate waste collection system negatively impacts the environment, leading to socio-environmental and serious health issues (Batool and Ch 2009). Developed countries have organized system of transportation for waste collection but developing countries or poor countries have improper way which adversely impact. Similar to other developing countries, Pakistan is also having poor waste management infrastructure so it is leading to serious environmental challenges (Marshall and Farahbakhsh 2013). Donkey carts or tractor trolleys are used for waste collection and transportation from the societies and streets. Huge amount of waste is dropped out from those transportation means on the roads. Smell spreads in the air and citizens feel disturbance (Shah et al. 2019). Waste is dumped on the common roads and streets in several areas and proper waste collection system is not available. In urban areas, there is no appropriate system for waste collection separately for different types of waste as other countries had initiated this system long ago (Khan 2021, Ahmed et al. 2020). Key issues

concerning solid waste management in Pakistan are needed to be solved.

In addition, landfill sites in Pakistan are not sanitary controlled so this thing brings environmental issues such as soil, water and air pollution. Moreover, Citizens are not aware of risks and they do not know the ways of disposing of wastes. Improper disposals, lack of appropriate discarding techniques and resources for solid waste management have created environmental and public health issues (Siddiqi et al. 2019, Ahmed et al. 2021, EPA 2022, Maria et al. 2020). Pakistan government needs to take steps for proper waste management and Pakistani nationals are required social awareness about it, including reduce, reuse, recycle and energy recovery from waste.

5. Sustainable solutions to decrease the plastic waste in Pakistan

In many regions of Pakistan, solid waste is generally discarded in open places (Masood, Barlow, and Wilson 2014). Management of Solid waste and its methods are varied province to province and city to city. Sometimes Pakistan's waste is reused and recovered for recycling, mostly by scavengers (Majeed, Batool, and Chaudhry 2017). There should advance-technology to manage MSW from the time it is generated to its safe-disposal. The local and public municipal authorities need to work together for managing overall cities waste every day. There are landfill sites in major cities of Pakistan but poor waste management has been noticed. Usually, waste management costs more than US$20 per tonne of waste, and this cost is generally for waste collection from the spot only (Masood, Barlow, and Wilson 2014). Pakistan's biggest city Karachi uses three big sanitary landfill sites, whereas, Lahore is second-largest city uses two landfill sites. Pakistan's Other big cities are still planning to build proper sanitary landfill sites (Ahmed et al. 2021). Bahawalpur is a region with pre-dominant rural-urban infusion; its current waste management system is classified by straining resources, prominent source separation, little production rates (0.424 kg/capita/day), and open discarding system. The waste composition analysis revealed that organic wastes as the bigger constituent (64%), recyclables (27%) and inert (9%) (Majeed, Batool, and Chaudhry 2018).

Pakistan needs strict environmental laws regarding solid waste management issues and there should be immediate implementation. Though, Pakistan has reported that environmental laws and government agencies have been developed to overcome environmental problem (Siddiqi et al. 2019). Pakistan is receiving technical support from donors, including the World-Bank. Notwithstanding the environmental institutes, laws, and other initiatives, Pakistan could not resolve the all issues. Environmental-legislation is not yet mature in Pakistan, comparing to those developed countries (Jabeen et al. 2022). There should be strict rules in public and street for waste disposal and implementation is important especially in big cities. Ministry of environment around the globe are recognizing the need to change national action plans and coordinate action to accelerate circular plastic solutions (Khan 2021). Pakistani Government should do so. Awareness should be given to people to practice different to avoid waste generation.

5.1. Shop Friendly

Plastic bags were considered as a modern convenience several years ago but recently they are burden. Due to plastic pollution, people should change their behavior to avoid this problem around the world. Pakistani government should take actions. They can be efficiently replaced by other reusable bags. In some countries, consumers are supposed to bring own shopping bags instead of using plastic bags (Nguyen 2021). Consumers may understand the importance of sustainability and are willing to accept a greener option. Everyone should think about how many bags you mostly carry out of a grocery store, you will know your contribution to plastic pollution and multiply that by the number of times you visit the grocery shop. It is really huge plastic pollution you are contributing and it's destruction of environment and economy (Chang and Chou 2018). It is recommended that everyone should carry a bag and always reuse plastic bags as much as possible if you have them. There are some other ways to adopt reduce and reuse policies.

5.2. Reduce, Reuse and Recycling Policy

Several countries have taken measure to reduce the use of plastic bags. In some countries, these measure entailed partial bans on the use of plastic bags. In some countries, they have resorted to different fees and taxes on plastic bags to tackle this issue (Senturk and Dumludag 2021). Reusing method is also good option. In some countries, consumers are supposed to bring own shopping bags instead of using plastic bags (Nguyen 2021). However, currently, recycling rates are very low. The majority of plastic waste is transported to landfills or the sea. In every country there are some technical limitations to overcome but there should be strategy for increasing recycling and up-cycling rates for addressing the problems caused by plastic pollution. (Jung et al. 2023). Plastic waste and utilizing it in a sustainable aggregate in concrete has been recognized as better strategy (Alyousef et al. 2021). Recycling is generally at the forefront, but now it is at the last minute (Kumar, Pali, and Kumar 2023). Recent advancements have been noticed in recycling industries. It should be adopted by every country especially low-income countries. (Jung et al. 2023). It is better option; it should be adopted by countries around the world.

In Pakistan, well managed recycling on a large scale or small scale, even in big cities does not exist (Akmal and Jamil 2021, Ahmed et al. 2020, Siddiqi et al. 2019). Municipal solid waste is increasing every year with some percentage over the last four decades, due to over population and their rising standard of living, industrialization and urbanization

(Korai, Mahar, and Uqaili 2017, Safar et al. 2021, Ahmed et al. 2021). In Lahore, the recycling activities exert a important impact on resource conservation, provision of economic opportunity, creation of jobs, and reduction in the problems related to waste disposal. Lot of money can be saved if we own recycling industries (Batool, Chaudhry, and Majeed 2008). Municipal solid waste is managed by the municipal authorities or contractors who are responsible for waste collection, transport and disposal but there is no proper waste recycling system over all Pakistan. There is no system of waste collection from rural areas (Batool, Chaudhry, and Majeed 2008, Batool and Ch 2009, Shah et al. 2019, Ali 2018). Pakistan needs proper waste knowledge, its related problems and social awareness.

6. Plastic biodegradation in Pakistan

A fungus has been discovered in a rubbish dump in Pakistan that could support to save the planet and it could potentially give benefit to us to get rid of the issues of plastics which are non-biodegradable (Nannan 2017). The fungi are proficient to break down plastic waste few weeks that would otherwise stick for years in the environment (Kumari et al. 2022). *Aspergillus tubingensis* is generally found in soil (Barratt et al. 2003), but the study revealed that it can also grow on the surface of plastics (Kumari et al. 2022). New studies actually demonstrated that it was found on a rubbish dump in Islamabad, Pakistan (Nannan 2017). It secretes enzymes which break down the molecules and then use its mycelia to break them apart. It is documented that all kinds of fungi have good properties that are not yet discovered. If deforestation and other human activities which continue to abolish habitats, then such species maybe destroyed and cannot be used for solving environmental issues (Nannan 2017). The performances of fungus are affected by many environmental parameters such as pH, temperature and the type of culture medium used. It could cover the method for large-scale usage of the fungus in several treatment plants, such as, waste treatment plants, solid waste treatment plants. It is also utilized for application in soils already polluted by plastic waste (Nannan 2017). There are several other microorganisms which can be useful to solve environmental issues. There should be deep study by environment and biotechnology specialists.

7. Energy Recovery:

Electricity demand is increased because population growth, economic development and industrialization. The rapid buildup of municipal, industrial and agricultural wastes is caused by these same factors. In developing countries, these all types of wastes generally end up in open landfills. This system creates severe environmental problems. Waste management is still one of the critical issues. Apart from other reuse or recycling technologies, waste-to-energy technology is an effective method to decrease the waste and help to minimize fossil fuels usage and mitigate environmental related issues. Biomass waste is one of the best energy sources in terms of economy and emissions which is abundantly available in Pakistan in the forms of plastic waste, agriculture waste, poultry waste, animal manure and kitchen waste (Yaqoob et al. 2021, Korai, Mahar, and Uqaili 2017). If it is properly managed then the solid waste produced in Pakistan has huge potential to generate energy by thermo-chemical and bio-chemical process up-to 50.35 million m3/year and 265 million m3/year respectively (Korai, Mahar, and Uqaili 2016). Waste-to-energy (WtE) methods present sustainable solutions for transforming waste into clean energy (Longsheng et al. 2022). Determining the key components of solid waste is critical to produce any sort of energy from it. The input of energy resources from solid-waste is predictable like 0.07% by bio-chemical and 0.34% by thermo-chemical in the total main energy supply of the country (Korai, Mahar, and Uqaili 2017). Pakistani government should work on it, especially agricultural waste because Pakistan has huge agricultural waste due to agricultural country.

8. Conclusion and Recommendations:

Plastic disposal on the land and micro-plastic in ocean has been declared a serious problem around the globe. This issue has been found more in developing countries than developed countries. This study concluded that plastic pollution is dangerous to human, animal and aquatic life. Several diseases are recognized due to improper disposal. In addition, micro-plastic in ocean has wide-range impact on living things because its food chain. It also pollutes the ocean water and may cause disturbance in aquatic life. Burning or dumping plastic openly cause air pollution. It also affects water and soil. Several countries have banned plastic but it is not enough to eliminate plastic pollution. It is recommended that creative and sustainable solutions should be implemented to prevent and mitigate plastic waste and pollution. In Pakistan, waste management system is not organized. Transportation of waste and dumping system are not proper. Open dumping and burning are common. It causes serious environmental issues. In addition, People need awareness. Pakistani government should run campaigns to create awareness regarding not throwing plastic here there and using these eco-unfriendly products. It is also recommended that small entrepreneurs should work on city waste management. Surveys and research studies have documented that Pakistan has huge potential of waste. Plastic waste can be recycled and energy can be recovered. Pakistan should look to bring in laws that can help the industry grow safely and at the same time mitigate the environmental problem. Companies may convert plastic into other products, especially energy recovery. It can be beneficial for national economy and overall country environment.

References

Ahmed, A., Hussain, A., Thahrani, S., Ahmed, S., Khoso, A. Q., & Soomro, B. (2021). Municipal solid waste

management and waste to energy in karachi pakistan. *Engineering Proceedings*, *12*(1), 19.

Ahmed, S., Mahmood, Q., Elahi, N., & Nawab, B. (2020). Current practices and futuristic options in plastic waste management in Pakistan. *Central Asian Journal of Environmental Science and Technology Innovation*, *1*(4), 237-244.

Akmal, T., & Jamil, F. (2021). Assessing health damages from improper disposal of solid waste in metropolitan Islamabad–Rawalpindi, Pakistan. *Sustainability*, *13*(5), 2717.

Akram, M., Xu, X., Gao, B., Yue, Q., Yanan, S., Khan, R., & Inam, M. A. (2020). Adsorptive removal of phosphate by the bimetallic hydroxide nanocomposites embedded in pomegranate peel. *journal of environmental sciences*, *91*, 189-198.

Alyousef, R., Ahmad, W., Ahmad, A., Aslam, F., Joyklad, P., & Alabduljabbar, H. (2021). Potential use of recycled plastic and rubber aggregate in cementitious materials for sustainable construction: A review. *Journal of Cleaner Production*, *329*, 129736.

Saha, L., Kumar, V., Tiwari, J., Rawat, S., Singh, J., & Bauddh, K. (2021). Electronic waste and their leachates impact on human health and environment: Global ecological threat and management. *Environmental Technology & Innovation*, *24*, 102049.

Artiola, J. F. (2019). Industrial waste and municipal solid waste treatment and disposal. In *Environmental and pollution science* (pp. 377-391). Academic Press.

Barratt, S. R., Ennos, A. R., Greenhalgh, M., Robson, G. D., & Handley, P. S. (2003). Fungi are the predominant micro-organisms responsible for degradation of soil-buried polyester polyurethane over a range of soil water holding capacities. *Journal of applied microbiology*, *95*(1), 78-85.

Batool, S. A., & Ch, M. N. (2009). Municipal solid waste management in Lahore city district, Pakistan. *Waste management*, *29*(6), 1971-1981.

Batool, S. A., Chaudhry, N., & Majeed, K. (2008). Economic potential of recycling business in Lahore, Pakistan. *Waste management*, *28*(2), 294-298.

Belzagui, F., Buscio, V., Gutierrez-Bouzan, C., & Vilaseca, M. (2021). Cigarette butts as a microfiber source with a microplastic level of concern. *Science of the Total Environment*, *762*, 144165.

Chang, S. H., & Chou, C. H. (2018). Consumer intention toward bringing your own shopping bags in Taiwan: An application of ethics perspective and theory of planned behavior. *Sustainability*, *10*(6), 1815.

Chawla, S., Varghese, B. S., Chithra, A., Hussain, C. G., Keçili, R., & Hussain, C. M. (2022). Environmental impacts of post-consumer plastic wastes: Treatment technologies towards eco-sustainability and circular economy. *Chemosphere*, 135867.

Cook, C. R., & Halden, R. U. (2020). Ecological and health issues of plastic waste. In *Plastic waste and recycling* (pp. 513-527). Academic Press.

Das, A. K., Islam, M. N., Billah, M. M., & Sarker, A. (2021). COVID-19 and municipal solid waste (MSW) management: a review. *Environmental Science and Pollution Research*, *28*, 28993-29008.

Desk, W. (2019). *Karachi's Uncontrollable Plastic Monster- Facts, Figures and Solution*. Pakistan.

Ehrig, H. J., Stegmann, R., & Robinson, T. (2018). Biological Leachate Treatment. *Solid Waste Landfilling [Internet]*. *Elsevier*, 541-74.

El-Haggar, S. M. (2007). Sustainability of construction and demolition waste management. *Sustainable Industrial Design and Waste Management Cradle-to-cradle for Sustainable Development*, 261-292.

EPA (2022). *Solid Waste in Pakistan*. Lahore: Environment Protection Department, Government of The Punjab, Pakistan.

Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. *International journal of environmental research and public health*, *16*(6), 1060.

Goosey, E., & Goosey, M. (2019). The materials of waste electrical and electronic equipment. In *Waste Electrical and Electronic Equipment (WEEE) Handbook* (pp. 231-262). Woodhead Publishing.

Hemidat, S., Achouri, O., El Fels, L., Elagroudy, S., Hafidi, M., Chaouki, B., Ahmed, M., Hodgkinson, I. & Guo, J. (2022). Solid waste management in the context of a circular economy in the MENA region. *Sustainability*, *14*(1), 480.

Herreras-Martínez, L., & Leroy, P. (2019). The WEEE forum and the WEEE label of excellence project. In *Waste Electrical and Electronic Equipment (WEEE) Handbook* (pp. 185-205). Woodhead Publishing.

Hina, S. M., Szmerekovsky, J., Lee, E., Amin, M., & Arooj, S. (2020). Effective municipal solid waste collection using geospatial information systems for transportation: A case study of two metropolitan cities in Pakistan. *Research in Transportation Economics*, *84*, 100950.

Ijomah, W. L., & Danis, M. (2019). Refurbishment and reuse of waste electrical and electronic equipment. In *Waste Electrical and Electronic Equipment (WEEE) Handbook* (pp. 263-282). Woodhead Publishing.

Jabeen, F., et.al. (2022). Trash to Energy: A Measure for the Energy Potential of Combustible content of Domestic solid waste generated from an industrialized city of

Pakistan. *Journal of the Taiwan Institute of Chemical Engineers*, *137*, 104223.

Jerie, S. (2016). Occupational risks associated with solid waste management in the informal sector of Gweru, Zimbabwe. *Journal of Environmental and Public Health*, *2016*.

Jung, H., Shin, G., Kwak, H., Hao, L. T., Jegal, J., Kim, H. J., ... & Oh, D. X. (2023). Review of polymer technologies for improving the recycling and upcycling efficiency of plastic waste. *Chemosphere*, 138089.

Kanellopoulos, P. G., Verouti, E., Chrysochou, E., Koukoulakis, K., & Bakeas, E. (2021). Primary and secondary organic aerosol in an urban/industrial site: Sources, health implications and the role of plastic enriched waste burning. *Journal of Environmental Sciences*, *99*, 222-238.

Khan, M.A.A. (2021). 4 ways Pakistan is tackling plastic waste and pollution. Geneva, Switzerland

Korai, M. S., Mahar, R. B., & Uqaili, M. A. (2016). Optimization of waste to energy routes through biochemical and thermochemical treatment options of municipal solid waste in Hyderabad, Pakistan. *Energy Conversion and Management*, *124*, 333-343.

Korai, M. S., Mahar, R. B., & Uqaili, M. A. (2017). The feasibility of municipal solid waste for energy generation and its existing management practices in Pakistan. *Renewable and Sustainable Energy Reviews*, *72*, 338-353.

Kumar, A., Pali, H. S., & Kumar, M. (2023). A comprehensive review on the production of alternative fuel through medical plastic waste. *Sustainable Energy Technologies and Assessments*, *55*, 102924.

Kumari, A., Rajput, V. D., Mandzhieva, S. S., Rajput, S., Minkina, T., Kaur, R., ... & Glinushkin, A. P. (2022). Microplastic pollution: An emerging threat to terrestrial plants and insights into its remediation strategies. *Plants*, *11*(3), 340.

Kundariya, N., Mohanty, S. S., Varjani, S., Ngo, H. H., Wong, J. W., Taherzadeh, M. J., ... & Bui, X. T. (2021). A review on integrated approaches for municipal solid waste for environmental and economical relevance: Monitoring tools, technologies, and strategic innovations. *Bioresource technology*, *342*, 125982.

Longsheng, C., Shah, S. A. A., Solangi, Y. A., Ahmad, M., & Ali, S. (2022). An integrated SWOT-multi-criteria analysis of implementing sustainable waste-to-energy in Pakistan. *Renewable Energy*, *195*, 1438-1453.

Majeed, A., Batool, S. A., & Chaudhry, M. N. (2017). Informal waste management in the developing world: Economic contribution through integration with the formal sector. *Waste and biomass valorization*, *8*, 679-694.

Majeed, A., Batool, S. A., & Chaudhry, M. N. (2018). Environmental quantification of the existing waste management system in a developing world municipality using EaseTech: The case of Bahawalpur, Pakistan. *Sustainability*, *10*(7), 2424.

Malamis, S., Katsou, E., Inglezakis, V. J., Kershaw, S., Venetis, D., & Folini, S. (2016). Urban environment. In *Environment and Development* (pp. 287-362). Elsevier.

Majeed, A., Batool, S. A., & Chaudhry, M. N. (2018). Environmental quantification of the existing waste management system in a developing world municipality using EaseTech: The case of Bahawalpur, Pakistan. *Sustainability*, *10*(7), 2424.

Malamis, S., Katsou, E., Inglezakis, V. J., Kershaw, S., Venetis, D., & Folini, S. (2016). Urban environment. In *Environment and Development* (pp. 287-362). Elsevier.

Manzoor, M., Gul, I., Iqrar, I., & Arshad, M. (2020). Solid waste management practices in Pakistan. In *Sustainable Waste Management Challenges in Developing Countries* (pp. 248-269). IGI Global.

Marshall, R. E., & Farahbakhsh, K. (2013). Systems approaches to integrated solid waste management in developing countries. *Waste management*, *33*(4), 988-1003.

Maryam, A. & Farah, R. 2020. *Scoping Study For Pet Waste Management In Pakistan*. In Nazifa Butt. Pakistan: WWF-Pakistan.

Masood, M., Barlow, C. Y., & Wilson, D. C. (2014). An assessment of the current municipal solid waste management system in Lahore, Pakistan. *Waste Management & Research*, *32*(9), 834-847.

Mataloni, F., Badaloni, C., Golini, M. N., Bolignano, A., Bucci, S., Sozzi, R., ... & Ancona, C. (2016). Morbidity and mortality of people who live close to municipal waste landfills: a multisite cohort study. *International journal of epidemiology*, *45*(3), 806-815.

Nannan, Z. (2017). *Scientists Find Fungus with an Appetite for Plastic in Rubbish Tip*. edited by ZHANG Nannan. China.

Nguyen, T. P. (2021). A dataset of factors influencing consumer behavior towards bringing own shopping bags instead of using plastic bags in Vietnam. *Data in Brief*, *37*, 107226-107226.

Njoku, P. O., Edokpayi, J. N., & Odiyo, J. O. (2019). Health and environmental risks of residents living close to a landfill: A case study of Thohoyandou Landfill, Limpopo Province, South Africa. *International journal of environmental research and public health*, *16*(12), 2125.

Osmani, M., & Villoria-Sáez, P. (2019, January). Current and emerging construction waste management status, trends and approaches. In *Waste* (pp. 365-380). Academic Press.

Safar, K. M., Bux, M. R., Faria, U., & Pervez, S. (2021). Integrated model of municipal solid waste management for energy recovery in Pakistan. *Energy*, *219*, 119632.

Sam, A., & Barik, D. (2019). Toxic waste from municipality. In *Energy from Toxic Organic Waste for Heat and Power Generation* (pp. 7-16). Woodhead Publishing.

Senturk, G., & Dumludag, D. (2021). An evaluation of the effect of plastic bag fee on consumer behavior: Case of Turkey. *Waste Management*, *120*, 748-754.

Shah, S. Z. A., Nawaz, Z., Nawaz, S., Carder, G., Ali, M., Soomro, N., & Compston, P. C. (2019). The role and welfare of cart donkeys used in waste management in Karachi, Pakistan. *Animals*, *9*(4), 159.

Siddiqi, M. M. et.al. (2019). Evaluation of municipal solid wastes based energy potential in urban Pakistan. *Processes*, *7*(11), 848.

Townsend, T. G. (2011). Environmental issues and management strategies for waste electronic and electrical equipment. *Journal of the Air & Waste Management Association*, *61*(6), 587-610.

Vergara, S. E., & Tchobanoglous, G. (2012). Municipal solid waste and the environment: a global perspective. *Annual Review of Environment and Resources*, *37*, 277-309.

Vignesh, K. S., Rajadesingu, S., & Arunachalam, K. D. (2021). Challenges, issues, and problems with zero-waste tools. In *Concepts of Advanced Zero Waste Tools* (pp. 69-90). Elsevier.

Woodard, C. I. (2006). 5-waste characterization. *Industrial waste treatment handbook, 2nd edn. Butterworth-Heinemann, Burlington*, 83-126.

Yaqoob, H., Teoh, Y. H., Din, Z. U., Sabah, N. U., Jamil, M. A., Mujtaba, M. A., & Abid, A. (2021). The potential of sustainable biogas production from biomass waste for power generation in Pakistan. *Journal of cleaner production*, *307*, 127250.

Yukalang, N., Clarke, B., & Ross, K. (2018). Solid waste management solutions for a rapidly urbanizing area in Thailand: Recommendations based on stakeholder input. *International journal of environmental research and public health*, *15*(7), 1302.

Yusuf, A. A., Ampah, J. D., Soudagar, M. E. M., Veza, I., Kingsley, U., Afrane, S., ... & Buyondo, K. A. (2022). Effects of hybrid nanoparticle additives in n-butanol/waste plastic oil/diesel blends on combustion, particulate and gaseous emissions from diesel engine evaluated with entropy-weighted PROMETHEE II and TOPSIS: Environmental and health risks of plastic waste. *Energy Conversion and Management*, *264*, 115758.

Zhu, Y., Zhang, Y., Luo, D., Chong, Z., Li, E., & Kong, X. (2021). A review of municipal solid waste in China: characteristics, compositions, influential factors and treatment technologies. *Environment, Development and Sustainability*, *23*, 6603-6622.