ACTA

INNOVATIONS

no. 49
December 2023

no. 49

December 2023

Content

UNLEASHING SUSTAINABLE RECOVERY AND DEVELOPMENT: ANALYZING EUROPEAN COUNTRIES' LABOR MARKET EXPERIENCE

Iryna Bashynska*
[1] Department of Enterprise Economics, Odessa Polytechnic National University, Odesa, Ukraine
[2] Department of Enterprise Management, AGH University of Krakow, Krakow, Poland
bashynska@agh.edu.pl
https://orcid.org/0000-0002-4143-9277

Hanna Smokvina
Department of Accounting, Analysis and Audit, Odessa Polytechnic National University
Odesa, Ukraine, smokvinann@gmail.com
https://orcid.org/0000-0001-6058-4720

Kseniia Bondarevska
Department of Social Security and Tax Policy, University of Customs and Finance
Dnipro, Ukraine, Kseny-8888@i.ua
https://orcid.org/0000-0001-8683-6834

Tetyana Semigina
National Qualifications Agency
Kyiv, Ukraine, t.semigina@nqa.gov.ua
https://orcid.org/0000-0001-5677-1785

Yevhen Tsikalo
Department of Accounting and Audit, Ivan Franko national University of Lviv
Lviv, Ukraine, yevhen.tsikalo@lnu.edu.ua
https://orcid.org/0000-0001-8051-9299

Viktoriia Terletska
Department of Management and International Entrepreneurship, Lviv Polytechnic National University
Lviv, Ukraine, Viktoriia.O.Terletska@lpnu.ua
https://orcid.org/0000-0002-9334-2557

This work was published free of charge as a publisher's support for Ukrainian authors struggling with wartime difficulties caused by Russian aggression against their country.

Highlights
The policies and strategies prioritizing employment opportunities and supporting social packages can lead to sustainable economic recovery.

Abstract
The study analyzes the labor market experience of European countries and evaluates the impact of unemployment rates, in-demand professions, and social packages on sustainable economic recovery. The authors use correlation-regression analysis and time-series analysis with Eviews 4.0 software package to identify trends and patterns in large amounts of data. The article's findings provide valuable insights into the labor market experience of European countries and can aid policymakers in developing sustainable policies and strategies for economic recovery, which can positively impact the European region. The economic impact of the article is significant, as it thoroughly analyzes European countries' labor market experience and evaluates the effects of various factors on sustainable economic recovery. By identifying the essential components of the labor market's structure and determining their impact on GDP, the article's findings can aid policymakers in developing sustainable policies and strategies for economic recovery, ultimately positively impacting the European region. The regional impact of the article is also noteworthy, as it focuses specifically on European

countries' labor market experience, making it particularly relevant to the region. By comparing individual European countries'. Positive and negative market features and providing comparative characteristics of labor market stakeholders, the article offers insights into the regional impact of the labor market on economic recovery. The article's evaluation of the impact of unemployment rates, in-demand professions, and social packages on sustainable economic recovery has social implications. The article suggests that policies and strategies prioritizing employment opportunities and supporting social packages can lead to sustainable economic recovery, ultimately benefiting individuals and society.

Keywords
Gross Domestic Product (GDP); in-demand professions; labor market; social packages; sustainable recovery; unemployment rates.

Introduction
The current state of Ukraine's economy has negatively affected the labor market [1,2]. Today, the institution of the labor market has almost been destroyed, and the issue of its effective functioning is becoming clear. First, it concerns the migration of the population to foreign countries, which led to a significant reduction in employment; another part of the population lost their jobs under the influence of the negative consequences of martial law. It is known that the labor market does not exist independently; it continuously interacts with the markets of production of goods, provision of services and other markets and institutions [3,4]. Therefore, secondly, the decrease in the population and the increase in unemployment also affected the reduction of the Gross Domestic Product (GDP) indicators of Ukraine in almost all sectors.

The purpose of the study is to examine the factors affecting the labor market, which will allow identifying weak points in the economic system; drawing on the best practices of European countries will help identify trends for the gradual revival of the labor market, improve the socio-economic situation, and reignite interest among the population in Ukraine's revitalization. Issues of regulation, functioning and improvement of the labor market are at the center of the attention of states, scientists and other subjects of economic activity. Since they cover the employed and unemployed population (economically active population); establishing robust contractual regulations in the field of labor relations and harnessing the country's intellectual potential are crucial for driving the development and efficiency of the national economy [5]. These unique characteristics of the labor market, combined with the diverse processes occurring within each country's labor market, serve as vital foundations for the reconstruction, reorientation, and sustainable development of Ukraine's economy (or any state in a post-crisis period).

Methods
In the article, the authors used both general scientific methods and special ones (Figure 1). Justify the use of special methods:
- to gain the article's goal, authors have chosen correlation-regression analysis as it allows considering the leading indicators of impact on GDP, identifying the most critical components of this structure and determining their effect on the performance indicator. The choice of GDP indicators for calculating the model is since it covers the final results of the production activity of economically active units of the labor market (labor force), which are reflected in the cost of manufactured goods and services provided for final use. Using this method, the authors can determine the most important components of the labor market's structure and their impact on the performance indicator (GDP), providing valuable insights into the labor market experience of European countries. Correlation-regression analysis also enables the authors to analyze large amounts of data and identify trends and patterns in the data, which would be challenging to do using other methods. Additionally, this method can help the authors to make predictions about future trends in the labor market, which is essential for developing sustainable policies and strategies for economic recovery.
- since this article analyses European countries' labor market experience over time, time-series analysis is particularly relevant. The authors considered that using the Eviews 4.0 software package is also appropriate for this article's research. Eviews allows the authors to analyze large amounts of time-series data and identify trends and patterns in the data, making it a valuable tool for analyzing the labor market experience of European countries. Furthermore, Eviews provides a range of statistical tools and features that enable the authors to perform regression analysis and other types of econometric analysis. These features make it easier for the authors to identify the relationship between the different factors affecting GDP, such as unemployment rates, in-demand professions, and social packages.

The methodology of empirical and theoretical analysis of the labor market, which includes theoretical research and practical use, is presented in Figure 1.
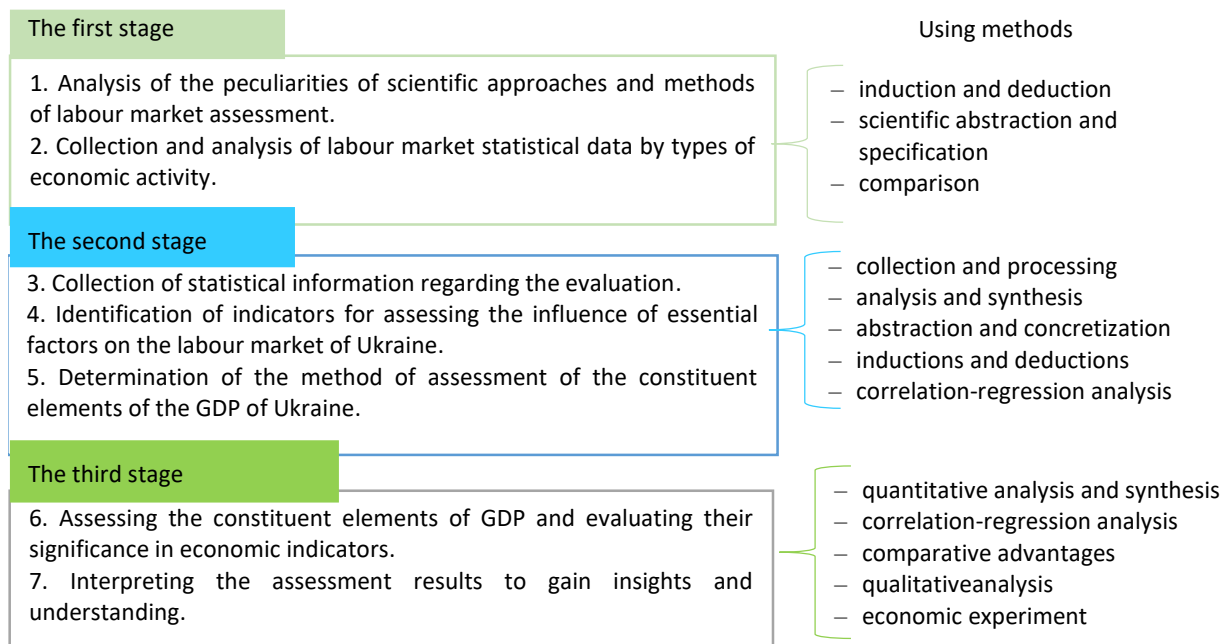

The first stage	Using methods
1. Analysis of the peculiarities of scientific approaches and methods of labour market assessment. 2. Collection and analysis of labour market statistical data by types of economic activity.	− induction and deduction − scientific abstraction and specification − comparison
The second stage	
3. Collection of statistical information regarding the evaluation. 4. Identification of indicators for assessing the influence of essential factors on the labour market of Ukraine. 5. Determination of the method of assessment of the constituent elements of the GDP of Ukraine.	− collection and processing − analysis and synthesis − abstraction and concretization − inductions and deductions − correlation-regression analysis
The third stage	
6. Assessing the constituent elements of GDP and evaluating their significance in economic indicators. 7. Interpreting the assessment results to gain insights and understanding.	− quantitative analysis and synthesis − correlation-regression analysis − comparative advantages − qualitativeanalysis − economic experiment

Figure 1. Research methodology. Source: Authors.

Results

The state of the labor market and employment processes are crucial socio-economic parameters that significantly influence social development and the competitiveness of the national economy. On one hand, the labor market is an integral part of the economic system, shaping the direction and pace of macroeconomic dynamics. On the other hand, it serves as a medium through which macroeconomic policies and developments impact the well-being of the population and various social processes [2,6]. Given recent events in Ukraine, the labor market is undergoing a transformation accompanied by negative consequences and trends. These include the emigration of labor force, mass mobilization of men during a full-scale invasion, declining labor productivity due to population demoralization, a rise in informal employment, and an increase in non-standard employment opportunities, among others. The primary criteria used to gauge the efficiency of the labor market are the economically active and inactive population, as well as the employed and unemployed individuals. (Table 1).

Table 1. Labor force aged 15-70 for 2018-2021. *Source: Calculated by the authors based on [7,8].*

Indicator	Population			
	2018	2019	2020	2021
Labor force (thousands of people)	17957.8	18155.7	17643.4	17321.6
The level of participation of the population in the labor force (%)	62.6	56.3	62.0	60.8
Employed population, thousands of people	16408.5	16668.0	15974.4	15610.0
Employment rate, %	57.2	51.7	56.1	55.7
Unemployed population (according to the ILO methodology), thousands of people	1549.3	1487.7	1669.0	1711.6
Unemployment rate (according to the ILO methodology), %	8.6	8.2	9.5	9.9

Thus, after conducting an end-to-end analysis of the data of the State Statistics Service of Ukraine [8], during the studied period, there has been a concerning trend in the workforce numbers (18,155.7 thousand people in 2019 and a gradual reduction to 17,321.6 thousand people in 2021) is observed. Other indicators, such

as the number of employed populations, employment level, etc., show a comparable scenario. Considering the indicators related to unemployment levels during the relevant period, there has been a gradual increase in the number of unemployed individuals, following the International Labor Organization (ILO) methodology. In2021, the number of unemployed people reached 1,711.6 thousand, which represents an increase of 222.9 thousand compared to 2019. This rise in unemployment can be primarily attributed to the unstable circumstances stemming from the implementation of quarantine measures during the Covid-19 pandemic. Furthermore, in relative terms, a corresponding analogy can be seen, with the unemployment rate rising from 8.6% in 2018 to 9.9% in 2021.

One of the most generalized characteristics of any country's economy is the population's employment level. This indicator reflects economic development, social and labor activity of citizens. The employment structure directly reflects the relationship between the production and consumption of goods. The need of any individual for social activity, social activity and satisfaction of material needs prompts the inclusion of a potential worker in the economic system. To date, the domestic labor market provides a significant range of vacancies for various types of economic activity (see Table 2 for more details).

Table 2. Number of vacancies by types of economic activity, 2020-2022. *Source: Calculated by the authors based on [1,7].*

Number of vacancies, units	2020	2021	2022	Growth rate, %	
				2021/2020	2022/2021
Total:	829653	705816	325145	-14.93	-53.93
Agriculture, forestry and fisheries	132416	113411	63403	-14.35	-44.09
Mining and quarrying	12181	11037	5781	-9.39	-47.62
Processing industry	142699	121496	61715	-14.86	-49.20
Construction	31586	26324	9290	-16.66	-64.71
Transport, warehousing, postal and courier activities	53649	44667	21931	-16.74	-50.90
Education	76675	65780	27971	-14.21	-57.48
Health care and provision of social assistance	50892	42029	21596	-17.42	-48.62
Arts, sports, entertainment and recreation	7568	7133	3007	-5.75	-57.84

Thus, the data of the State Employment Service of Ukraine (Table 2) [7,8] show a notable decline in job openings across various sectors of the Ukrainian economy between 2020 and 2022. During this time, the labor market of Ukraine experienced the most difficult situation caused by the pandemic and military actions on the territory of Ukraine. ILO forecasts show that the unemployment rate will reach 15.5% in 2023. Thus, the agriculture and industry sector suffered the most significant losses, as evidenced by reduced business entities in the Ukrainian market. Also, the sphere of education and health care underwent substantial transformations, primarily caused by the reduction in the number of educational and medical institutions during the destruction of the infrastructure. A significant part of the workforce left the country due to unsatisfactory working conditions and, as the main priority, concern for their safety. The imbalance of labor supply and demand accordingly affects the reduction of GDP due to decreased production, forging and technical potential, professional and qualification trends, etc. It is important to evaluate the factors that contribute to the growth of different components of the economy. These assessments are crucial for strategic analysis, devising new strategies, and establishing competitive advantages at both the industry and national levels. We will build a correlation-regression model of the assessment of the constituent elements (in terms of the presented indicators) of the GDP of Ukraine to identify the most critical factors and provide suggestions (Table 3). We will build a correlation matrix of indicators and determine the magnitude and nature of the impact on the studied indicator of all other hands. Let's choose the following analytical dependence between the indicators: Y - dependent variable, X_1, X_2, ..., X_{12} - independent variables. The model specification is presented in equation 1:

(1) $$Y = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4 x_4 + \ldots + a_n x_n$$

where:
$a_0, a_1, a_2, a_3, …, a_n$ - parameters of the model
n - the number of factors of the linear model.

Table 3. Indicators of GDP level assessment by components. *Source: Calculated by the authors based on [1,7].*

Value by indicators	Specific weight of the industry in GDP					
GDP of Ukraine (dependent variable)	Y	2018	2019	2020	2021	2022
Specific weight of the agricultural sector (independent variable)	X_1	10.1	9.0	9.3	9.5	9.8
Specific weight of construction (independent variable)	X_2	2.3	2.7	2.9	3.1	2.8
Share of finance and insurance (independent variable)	X_3	2.7	2.9	3.2	3.2	3.0
Specific weight of IT-spheres (independent variable)	X_4	3.9	4.6	5.4	5.9	6.1
Specific weight of education (independent variable)	X_5	4.5	4.3	4.3	4.5	4.4
Specific weight of the transport sector (independent variable)	X_6	6.4	6.7	6.3	6.9	6.5
Specific weight of the real estate transaction (independent variable)	X_7	5.8	6.1	6.4	6.8	6.2
Specific weight of public administration and defense (independent variable)	X_8	6.0	6.7	7.2	7.5	7.3
Specific weight of trade (independent variable)	X_9	13.3	13.2	14.0	14.5	15.3
Specific weight of taxes (independent variable)	X_{10}	14.7	14.8	15.0	15.2	14.8
specific weight of industry (independent variable)	X_{11}	21.3	20.7	19.0	20.2	19.7
Share of other industries (independent variable)	X_{12}	12.0	11.7	10.2	10.5	10.3

The initial data for building the model are presented in table 3.

In the first stage, we will check the model for multicollinearity. Let's combine the data into a correlation matrix, which measures the strength of the relationship between the selected factor values and the resulting indicator. The correlation matrix calculation makes it possible to draw a conclusion about the significant dependence between the performance indicator (Y) and the factor values.

In the second stage, it is advisable to point out the dependence of the factor values on each other. Checking for the presence of the multicollinearity phenomenon necessitates the exclusion of some factors from the economic - mathematical model. It is advisable to use such an exception to the factor values X_2, X_3, X_6, X_7, X_8, X_{10}, X_{11}, and X_{12}, the value of the absolute value of the correlation coefficients of which >0.7, which, according to the Chaddock scale [9], characterizes a strong and, accordingly, solid connection between the factorial data values. In this case, we will conduct a regression analysis between significant indicators and factor values X_1, X_4, X_5, X_9, X_{10}.

Furthermore, the model is built using the Eviews 4.0 software package. The constructed model has the following form:

$$(2) \quad Y = 2.620397021 * x_1 + 0.8543057437 * x_4 + 1.498573173 * x_5 + 0.6587120427 * x_9 + 1.218204845e - 05 * x_{10} - 3.362485605$$

In the third stage, we will check the indicators for importance. The initial data are presented in the table. 4.

Table 4. Output data for testing indicators for significance. *Source: Calculated by the authors used Eviews 4.0.*

Variable	Coefficient	t-Statistic	Prob.
$X_1 => X_1$	2.620397021	167.7110	0.0126
$X_4 => X_2$	0.8543057437	9.565177	0.0714
$X_5 => X_3$	-1.498573173	-20.2297	0.00210
$X_9 => X_4$	0.6587120427	217.7317	0.0019
$X_{10} => X_5$	1.218204845e-05	9.817612	0.0580
R-squared 1.000000 Adjusted R-squared 0.997978 S.E. of regression 0.006721 Durbin-Watson stat 2.121281 F-statistic 4121.0 Prob(F-statistic) 0.001312			

Let's check the significance of the regression. The obtained values of F-statistic = 4121.0 (> 100) and Prob (F-statistic) = 0.0013, which are less than 0.05 and 0.01 (significance level) confirm the statistical significance of the regression as a whole and the adequacy of the model according to the Fisher test. The coefficient of paired regression R2 = 1.000000, which highlights a strong interconnectedness between the components. Hence, the average error of approximation is calculated according to equation 3:

(3)
$$A = \frac{1}{n} \sum \left| \frac{(y - \widetilde{y_x})}{y} \right| * 100$$

Therefore, A = 1.52%. This model can be used because the average approximation error does not exceed 10%. Such a calculation can also be used considering other indicators, deepening the important indicators (employment, unemployment) of influence on the efficiency of the functioning of the labor market. Correlation-regression analysis has identified the key sectors of GDP that require special attention and support from the government. These include agriculture, education, IT sector, trade, and taxes. The given technique is convenient enough to use since only official statistical materials are used in the calculations.

Each country is distinguished from others by its socio-economic strategy, the inherent character of mentality, level of education, features of the cultural environment, etc. These primary factors form the basis of our own national model of the labor market. Social dialogue, which rages on the scale of a particular state, is an effective tool of state management, the main functions of which are to find acceptable ways of economic and social progress, increase the level of well-being and quality of life, social security, and a stable environment in society. Based on the given provisions, it acts as a catalyst for reforms and possible innovative solutions, primarily ensuring openness, transparency and cooperation between all possible sectors of the economy. The experience of foreign countries demonstrates a difficult path in forming a national model of the labor market. Today, the most influential factors exerting significant pressure on the European labor market are the globalization of the economy and, accordingly, regionalization. Each participant of the European market, against the background of strengthening the competitiveness of its participants, tries to adhere to the measures of the innovative economic development model. The global economic crisis remains the most influential factor in the labor market of European countries. Considering national specificities, resource, economic and other opportunities, each country forms its own model of the national labor market, which in turn is formed at the expense of the education system (training and retraining of personnel), the formation and filling of jobs, the system of material incentives, regulation of social and labor relations, etc. [1,4]. Each state adheres to its own anti-crisis policy regarding unemployment, employment, and the number of jobs, which is due to various models of regulating labor relations. In this course, each state has its inherent features of the labor market (see Table 5 for details).

The labor market, as the main core of resource markets, has an impact on political, economic and social life, the state and processes of which are transformed into the population's consciousness, ensuring social stability in society. Paying attention to the fact that Ukraine and many other countries are in complex, unstable social and political conditions, the need to study the experience of economically developed countries and analyze the information of the most critical stakeholders of the labor market increases. Among such essential

components, the level of unemployment, the definition of in-demand and in-demand professions, requirements for foreigners during employment, the social package and the average salary should be singled out (more details in Table 6).

Table 5. Comparison of positive and negative market features of individual European countries. *Source: Compiled by the authors according to the data [5,10–14].*

Country	Positive features of the market	Negative features of the market
Germany	− the level of unemployment is low, especially among young people, which is connected with the dual apprenticeship system − Germany's labor market was almost unaffected by the Great Recession, especially in terms of total employment − the labor market remains quite challenging in international comparison, but the country manages to avoid many adverse side effects.	− the tendency to prioritize academic education over professional training endangers the vital role of the dual apprenticeship system − given the relatively high cost of labor, it is important that Germany remains productive and innovative − the return of protectionism.
Switzerland	− unemployment remains stably low − wage inequality remains low by international standards − there is no evidence that the main events of the last 15 years (the crisis in the Eurozone, the mass flow of refugees or the appreciation of the Swiss franc) have had a negative impact on the labor market.	− unemployment among foreigners is more than twice as high as among Swiss citizens − the difference in wages between Swiss citizens and foreigners remains high, especially among men − the level of long-term unemployment increased and remained higher − notable regional disparities in both the proportion of the labor force and the levels of unemployment.
Poland	− the employment rate among persons aged 15-70 increased significantly between 2000 and 2016, while the unemployment rate decreased significantly over the same period − in 2016, the share of older adults in the labor force reached the highest level since 1990 − from 2000 to 2016, real wages increased by 54%.	− since 2000, the number of temporary employments has more than doubled, and now Poland has the highest share of temporary jobs in the EU − the labor force share of older workers remains low compared to most developed countries − the reduction of the retirement age in 2017 increases the decline in labor supply due to the ageing of the population − high gender pay gap.
Spain	− since 2014, there has been an increase in the level of employment − in 2018, gender gaps in workplace employment and temporary employment were smaller than before the recession − the overall level of temporary employment decreased after the Great Recession − slow growth of the share of employment of immigrants − reduction of overall monthly wage inequality and inequality in the lower half of the monthly wage distribution.	− during the Great Recession, youth unemployment and long-term unemployment rose sharply − the share of men in the labor force decreased due to a sharp reduction in the participation of young men in the post-crisis period − the level of temporary employment among young people has increased significantly − real wages fell during the recession and have not yet returned to pre-crisis levels.

Table 6. Comparative characteristics of labor market stakeholders. *Source: Compiled by the authors according to the data [1,2,6,10,15–20].*

Labor market stakeholders		Germany	Switzerland	Poland	Spain	Ukraine
In-demand professions	agriculture				+	+
	tourist business				+	
	industrial production			+		
	unqualified specialists	+			+	
	the field of it technology	+	+	+	+	+
	sphere of wholesale and retail trade			+		+
	media and telecommunications			+		
	medical staff	+	+			
	management positions		+			+
	financial sphere		+			
	the field of education		+			
Undemanding professions	specialists with higher education			+	+	+
	specialists without higher education	+	+			+
Requirements for foreigners during employment	registration at the labor exchange	+	+	+	+	+
	job search on special sites with job announcements	+	+	+	+	+
	contacting the company directly	+	+	+	+	+
	application to the employment service, which deals with employment	+	+	+	+	+
	residents	+	+	+	+	+
	application to a private employment agency	+	+	+	+	+
	job search in newspapers and on bulletin boards	+	+	+	+	
Social package	work permit	+	+	+	+	
	medical insurance, including against accidents	+	+			
	old age insurance	+	+			+
Salary*	rounded minimum/average, USD	2136/4100	4450/7430	830/1750	1300/ 2500	180/625

* wage data cannot be directly compared, as taxes on it are very different

By integrating the findings of economic and mathematical modeling with the analysis of European experience regarding labor market development, it becomes possible to identify priority areas and future prospects for economic and social growth in Ukraine (Figure 2).
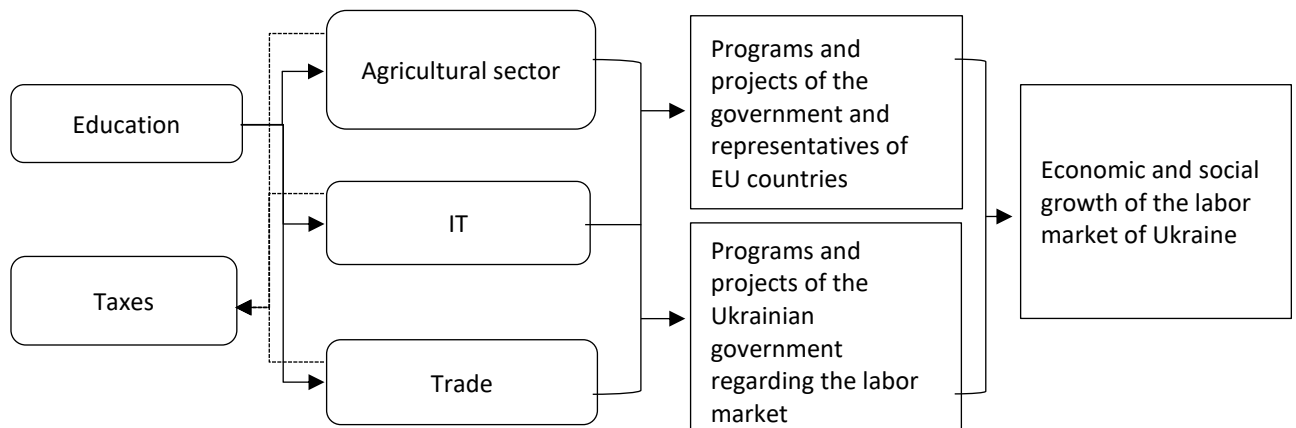

Figure 2 - Priority directions of economic and social growth of the labor market of Ukraine. *Source: Own development.*

The proposed model consists of two blocks of factors; The first block of factors, the basic one, is equally characteristic of any country and consists of Education and Taxes.

Education.
As the most complex sector, the sphere of education has been undergoing changes and reforms for a long time. The complexity and importance of this component lie in the fact that it covers all the features listed above (agricultural sector, trade, IT sphere and taxes).It would be helpful for Ukraine to choose the experience of Germany as a foundation. First, it concerns the implementation of the dual education system. Dual education is built on the coordination of the interests of the educational and production spheres, which makes it possible to overcome the inconsistency between these spheres in personnel training. Applicants of higher education, professional and pre-higher education first receive basic knowledge of theoretical material. Then he gets practice according to the chosen speciality at the enterprise with which the educational institution has signed a cooperation agreement. The work of young specialists is paid according to the contract. Moreover, such practice can be carried out during the entire training period (3 days of studying theoretical material and 2 days of gaining practical experience at the enterprise). This educational approach carries dual importance, both socially and economically, as it guarantees an equilibrium between labor market demand and the availability of skilled workforce. Namely: every willing citizen gets a profession; convergence of the employment system with the education system is carried out, which will ensure a balance between the needs and interests of employers and young professionals; stimulation of pedagogical skills of teachers by the conditions of the employer aimed at the quality of education; the participation of enterprise representatives in the development of educational plans, compilation of the opus of the profession; to permanently attract foreign teachers-practitioners to teaching in Ukrainian educational institutions, etc.

Taxes.
Today, a simplified and general taxation system operates in Ukraine. In the last years of the announcement of the European choice in Ukraine, many steps have been taken to integrate the economy into the European space. Considering world practices and Ukrainian experience in conducting economic activity, Poland is the most optimal country for business scaling in European countries. Poland has long proven itself on the positive side. The Polish government continues supporting business registration and economic activity in the country. Economic entities of which can choose the appropriate form of taxation: Single tax - 19% (9% - in case of compliance with the profit limit of 2,000,000 euros); Tax on withdrawn capital/dividends - 19%; Personal income tax (PIT): 17% - up to 18,000 euros; 32% - more than 18,000 euros; The tax rate for a self-employed person is 20% [21]. Although revising tax preferences, expanding the tax base, and increasing tax revenues may not have a substantial impact on GDP growth, it is important to note that GDP growth leads to enhanced financial well-being, higher wages, and increased tax revenues. To achieve this, addressing the shadow economy, establishing transparent control systems, simplifying tax payment procedures for small and medium-sized businesses (which are highly adaptable to innovation and technology in the real economy), implementing a progressive tax distribution among taxpayers, and reducing unwarranted benefits are crucial steps. In the previous phase, combating the surplus of labor present in nearly all sectors of Ukraine's economy requires implementing strategies to reorient enterprise activities. Additionally, the state should aid and support businesses by temporarily easing fiscal policies [5]. A priority vector of social policy will contribute to keeping the economy afloat by supporting the population's purchasing power. The second block, identified by us with the help of correlation analysis, is the most critical factors (agrarian, IT and trade sectors) that can most effectively and quickly help in the sustainable renewal of the country.

Agrarian sector.
The agricultural sector, which forms the socio-economic conditions of agricultural development, and creates economic, food and environmental security, has always been considered a city-forming branch of the economy of Ukraine. Agro-industrial regions include Odesa, Kherson, Mykolaiv, Dnipropetrovsk, Kharkiv, Cherkasy, Kirovohrad, Poltava, Sumy regions, and others [22]. The specified regions need a workforce of specialists in the agro-industrial complex. One of the key socio-economic objectives for the state in ago-complex development is to support farmers through various means.

This includes initiatives such as modernizing agricultural machinery by attracting investments from EU countries, implementing development programs with the involvement of the Ukrainian government and investor countries, enhancing living conditions through increased wages for rural populations, fostering interest among young people in pursuing agricultural professions (through educational system reforms), and consequently increasing

the workforce and elevating the significance of rural production. These efforts aim to raise the share of the agricultural sector within the overall GDP.

IT sphere.
Currently, information technology stands out as one of the most promising industries worldwide. As indicated in Table 5, the IT sector holds the highest relative importance in terms of the total GDP and national income of the state. It is characterized by lucrative compensation levels, fosters innovation, and generates employment opportunities. But in the conditions of the state of emergency, previous crisis phenomena in the country, reduction in demand for services and outsourcing of companies to European countries (high level of taxation of T companies and FOPs), there is an outflow of highly qualified personnel from abroad. The low level of education in the training of specialists is considered an equally important reason for the reduction of GDP in the IT sector. Hence, as part of education system reform, it is crucial for the state to focus on enhancing the quality of vocational training for specialists in the field of information technology. On the part of interested business entities, pay attention to the constant improvement of workplace qualifications, etc. Because if Ukraine focuses only on the agro-raw material economic development model, it will lead to the complete "organization" of the state. And Ukraine must develop in the direction of technological and digital transformation.

Trade.
The trade sector in the structure of Ukraine's GDP is approximately 13 - 15%. The predominant share of export goods is ferrous metals, about 20%; Ore - 11%, Other goods almost 30%; grain (corn, oil, wheat), oil, electric machines, etc. The state of war in Ukraine naturally changed the structure of exports of ferrous metals due to the destruction of industrial capacity in Mariupol. Therefore, the question of reproducing the export of ferrous metals is open until the war's end. In this case, targeted attention must be paid to the development and strengthening of the industrial sector and the agricultural sector. The aforementioned points outline the directions for the development of the agricultural sector. In summary, the conducted research underscores the importance of implementing a post-war recovery plan to sustain the economy. This plan should incorporate approaches, methods, and experiences from EU countries that promote efficient economic and labor market functioning, leading to social and economic benefits.

Discussion
A feature of the article is the use of the correlation-regression analysis method, which allows for considering the leading indicators of the impact on GDP, identifying the essential components of this structure and determining their effect on the performance indicator. Suppose correlation-regression analysis is quite a widespread technique in this kind of article [23–26]. The novelty of the study is the selection of the GDP indicator for the calculation of the model, due to the fact that it covers the final results of the production activity of economically active units of the labor market (labor force), which are reflected in the cost of manufactured goods and services provided, for final use. GDP as a summary indicator was used not long ago, but studies [27] show that the labor market choice is very justified. GDP is the main indicator that makes it possible to eliminate most of the shortcomings of existing studies, namely the limited scope of the analysis [28,29] and the lack of a comprehensive assessment of the labor market experience of European countries [27,30]. By utilizing GDP as a comprehensive measure of production activity across economically active entities, the article offers a more comprehensive and precise depiction of the labor market experiences of European countries.

Impact
Economic Impact.
The study provides a comprehensive analysis of the labor market experiences in European countries, thoroughly examining the impact of different factors on sustainable economic recovery. Using correlation-regression analysis and time-series analysis with Eviews 4.0 software package, the authors could identify the most essential components of the labor market's structure and determine their impact on the performance indicator (GDP). The article's findings can be valuable in developing sustainable policies and strategies for economic recovery, which can ultimately positively impact the European region.

Regional Impact.
The article focuses specifically on European countries' labor market experience, making it particularly relevant to the region. By comparing individual European countries' positive and negative market features and providing comparative characteristics of labor market stakeholders, the article offers insights into the regional impact of the labor market on economic recovery.

Social Impact.
The article's evaluation of the impact of unemployment rates, in-demand professions, and social packages on sustainable economic recovery has social implications. The article suggests that policies and strategies that prioritize employment opportunities and support social packages can lead to sustainable economic recovery, ultimately benefiting individuals and society.

Conclusions
Ukraine and the European world live in an era of crisis phenomena, unforeseen events, changes and modernizations. The labor market does not become an exception in terms of globalization processes. As Ukraine is still in the early stages of forming a market economy, it requires effective mechanisms for state regulation of the labor market to address pressing issues amidst an unstable socio-economic and political environment. Currently, Ukraine is undergoing decentralization of the state administration system, making the experience of European countries and the functioning of their labor markets highly relevant for domestic practices. By examining foreign labor market models and delving into European practices it becomes evident that the experiences of these countries can serve as a valuable reference in shaping policies for unemployment and employment regulation. Furthermore, studying European practices offers insights into potential prospects for labor management in Ukraine. Therefore, a systematic analysis of various aspects of the labor market will allow identifying significant indicators and relevant directions for restructuring economic processes and phenomena using correlation-regression analysis. The study of the practical experience of European countries will allow us to identify the positive and negative aspects of foreign experience, consider peculiarities and choose a scenario and integrate into the socio-economic environment of the state to ensure post-war economic and social development.

Limitations of the study
Some limitations of the study should be noted:
- the study focuses specifically on European countries' labor market experience and may not be directly applicable to other regions or countries outside of Europe. The findings should be interpreted within the context of the European labor market.
- the study's analysis is based on a specific timeframe, and the labor market experiences, and recovery strategies may vary over time. The findings may not capture the long-term dynamics or future trends in the labor market, potentially limiting the relevance of the conclusions for future policy-making.

Conflict of interest
There are no conflicts to declare.

Acknowledgments

References
[1]   G.A. Smokvina, A. V. Moisei, Experience of Developed Countries on Labor Market Development: Analysis of the Current State and Prospects of Development in Ukraine, Bus. Inf. 11 (2021) 248–254. https://doi.org/10.32983/2222-4459-2021-11-248-254.
[2]   L.H. Fedunchyk, The labor market in Ukraine: problems and ways to solve them: Labor economics and employment problems, (2016) 31.
[3]   D. Lewicka, The impact of HRM on creating proinnovative work environment, Int. J. Innov. Learn. 7 (2010) 430–449. https://doi.org/10.1504/IJIL.2010.032932.
[4]   Y. Malynovska, I. Bashynska, D. Cichoń, Y. Malynovskyy, D. Sala, Enhancing the Activity of Employees of the Communication Department of an Energy Sector Company, Energies. 15 (2022) 4701. https://doi.org/10.3390/en15134701.
[5]   KNEU, Convergence and divergence in Europe: Polish and Ukrainian cases - Monograph, (2013) 688.
[6]   M. Dudek, I. Bashynska, S. Filyppova, S. Yermak, D. Cichoń, Methodology for assessment of inclusive social responsibility of the energy industry enterprises, J. Clean. Prod. 394 (2023) 136317. https://doi.org/10.1016/j.jclepro.2023.136317.
[7]   State Employment Service of Ukraine, https://www.dcz.gov.ua/analytics/69. https://www.dcz.gov.ua/analytics/69.
[8]   State Statistics Service of Ukraine, http://www.ukrstat.gov.ua/, (2022).
[9]   R.E. Chaddock, Principles and methods of statistics, 1st Editio, Houghton Miffin Company, The Riverside

Press, Cambridge, Boston, MA, USA, 1925.

[10]   I. Bezzub, Foreign experience of labor market regulation and possibilities of its use in Ukraine: monograph, (2017).

[11]   N.V. Bakhchevanova, Ukraine on the global labor market: monograph.

[12]   Central Statistical Office of Poland, Obszary tematyczne - Rynek pracy. https://stat.gov.pl/obszary-tematyczne/rynek-pracy/.

[13]   National Institute of Statistics of Spain, Total Nacional. Tasa de paro de la población. Ambos sexos. 16 y más años. https://www.ine.es/consul/serie.do?d=true&s=EPA815.

[14]   D. Lewicka, Employee institutional trust as an antecedent of diverse dimensions of organisational commitment, Argumenta Oeconomica. 2020 (2020) 321–340. https://doi.org/10.15611/aoe.2020.1.13.

[15]   A. Nowaczek, E. Dziobek, J. Kulczycka, Benefits and Limitations of Indicators for Monitoring the Transformation towards a Circular Economy in Poland, Resources. 12 (2023) 24. https://doi.org/10.3390/resources12020024.

[16]   L. Burroni, A. Gherardini, G. Scalise, Policy Failure in the Triangle of Growth: Labour Market, Human Capital, and Innovation in Spain and Italy, South Eur. Soc. Polit. 24 (2019) 29–52. https://doi.org/10.1080/13608746.2019.1575571.

[17]   J. Kulczycka, L. Lelek, Tools for promoting environmental sustainability in Poland, in: Pathways to Environ. Sustain. Methodol. Exp., Springer International Publishing, Cham, 2014: pp. 193–203. https://doi.org/10.1007/978-3-319-03826-1_19.

[18]   Federal Statistical Office of Germany, Arbeitslosenquote Deutschland. https://www.destatis.de/DE/Themen/Wirtschaft/Konjunkturindikatoren/Arbeitsmarkt/arb210a.html.

[19]   Social security system in Germany. https://migrant.biz.ua/nimechina/zhittya-de/sotsialne-zabezpechennia.html.

[20]   Swiss Federal Statistical Office, Erwerbslose gemäss ILO. http://surl.li/dtobu.

[21]   D. Zakovorotnyj, Small business in Europe: what simplified taxation system are offered by EU countries, (2022).

[22]   T. Semigina, Frustrations or moving forward? Ukrainian social work within the 'hybrid war' context, Eur. J. Soc. Work. 22 (2019) 446–457. https://doi.org/10.1080/13691457.2017.1366432.

[23]   S. V. Belousova, Forecasting financial indicators of the company's activity using correlation-regression analysis, Bull. Odesa Natl. Univ. Ser. Econ. 21 (2016) 62–66.

[24]   P. Bite, M. Konczos Szombathelyi, L. Vasa, The concept of labour migration from the perspective of Central and Eastern Europe, Econ. Sociol. 13 (2020) 197–216. https://doi.org/10.14254/2071-789X.2020/13-1/13.

[25]   M. Garai-fodor, J. Varga, Á. Csiszárik-kocsir, Correlation between generation z in hungary and the motivating factors to do volunteer work in a value-based approach, Sustain. 13 (2021) 11519. https://doi.org/10.3390/su132011519.

[26]   A. Tibajev, The Economic Return to Labour Market Experience of Immigrants in Sweden, Soc. Indic. Res. (2023). https://doi.org/10.1007/s11205-023-03089-7.

[27]   A. Zhurauliou, J. Palomino, O. Gulevych, L. Vasa, Comparative analysis of labour markets in Ukraine, Armenia, Moldova, and Estonia: Institutional approach, 1995-2020, Reg. Stat. 13 (2023) 149–166. https://doi.org/10.15196/rs130107.

[28]   S. Mazhar, Tapping the latent resource (women) as a potential contributor towards increasing GDP, Mind Soc. 11 (2023) 27–31. https://doi.org/10.56011/mind-mri-114-20223.

[29]   Y. Arbel, Y. Arbel, A. Kerner, M. Kerner, What is the optimal country for minimum COVID-19 morbidity and mortality rates?, Environ. Sci. Pollut. Res. 30 (2023) 59212–59232. https://doi.org/10.1007/s11356-023-26632-y.

[30]   Ontario's panel on economic growth and prosperity, Strength in numbers: Targeting labour force participation to improve prosperity in Ontario, Ontario's Panel on Economic Growth and Prosperity, 2017. https://www.competeprosper.ca/uploads/Annual_Report_16_Strength_in_numbers_targeting_labour_force_participation_in_Ontario_Dec_2017.pdf.

THE IMPACT OF DIVERSITY ON JOB PERFORMANCE: EVIDENCE FROM PRIVATE UNIVERSITIES IN EGYPT

Dina Said
College of Business Administration, American University of the Middle East
dina.said@aum.edu.kw
https://orcid.org/0000-0002-2698-3100

Dina Youssef
Assistant Professor, Egyptian Chinese University - Faculty of Economics and International
Trade, International Business Department
dinayoussef@hotmail.com
https://orcid.org/0000-0001-7431-9389

Nourhan El-Bayaa
School of Business Administration, Holy Spirit University of Kaslik
N_Albayaa@hotmail.com

Yehia Ibrahim Alzoubi *
College of Business Administration, American University of the Middle East
yehia.alzoubi@aum.edu.kw
https://orcid.org/0000-0003-4329-4072

Halil Zaim
Visiting scholar at Alfred University
zaim@alfred.edu

Highlight
Diversity in the workplace can lead to higher employee performance.

Abstract
Employees from diverse backgrounds have been claimed to perform better; nevertheless, this link has been studied sparingly in the Egyptian setting. This paper addresses this gap by experimentally analyzing the link between employee performance and gender, educational background, and ethnic background. To investigate this link, a usable model was created, and data was collected from 269 academic staff members at private Egyptian institutions. PLS analysis was used, and the result revealed that educational and ethnic backgrounds have a positive effect on employees' job performance whereas, the impact of gender background on employee's job performance was found to be insignificant. Furthermore, the research findings disclose that the education and ethnic background of the employees mediates the relationship between employees' job performance and gender diversity. Future research is yet to validate these results.

Introduction
A major move is happening in the world economy because of advancements in transportation and telecommunications technology, cross-border trade and investment obstacles are being erased. In other words, the world is turning into a global village because of globalization [1]. Hence, the recent workforce is becoming more diverse in its composition than it was before. Thus, with the rising variety of the workforce, diversity management has become a topic of academic and practical concern [2]. Organizations need to pay greater attention to diversity management as it became a potentially valuable resource [3]. Diversity is gaining recognition and respect. It entails realizing that every one of us is unique and appreciating our particular peculiarities [4]. Mousa [5] denotes that diversity is the condition of being different. Furthermore, defines diversity in the workplace as any disparities between people in terms of sexual orientation, gender, age, cultural

background, education, job experience, and religion [6]. Workforce diversity from diverse backgrounds and ethnic backgrounds generates opportunities for greater creativity and more innovative solutions [7].Thus, workforce diversity can be considered a competitive advantage for organizations [8]. Although organizations participate in diversity management to ensure that there is no discrimination based on age, color, gender, handicap, ethnicity, or religion, and diversity management isn't merely another name for affirmative action or a problem of equal employment opportunity. Diversity management involves identifying, being open to, and exploiting individual differences to build a positive environment in the workplace [9]. The significance of diversity management is increasing as it has a major effect on organizational outcomes, including the individual and organizational level [10]. Managing diversity in an organization encompasses managing individual differences, facilitating the success of employees in performing the job, to build a work environment in which employees feel valued in their jobs [11]. Organizations that managed and encouraged diversity were reported to have a positive impact on employee performance, creativity, and satisfaction [12–14]. Furthermore, evidence indicates that diversity management practices may have a positive impact on employees' organizational citizenship behavior and that human resources management acts as a mediator in this relationship [15]. Nevertheless, Asia and Far East Area, the Middle East, GCC region have received less consideration in the literature on diversity management, in comparison to Western countries. The studies on how inclusion and diversity problems are overseen, in emerging economies, are scarce [16]. Egypt has proven to be an important place for many international businesses [17]. It is now very popular to find business specialists who are fluent in multiple languages, though coming from a highly diverse background in training and education [18]. However, diversity management has not been paid enough attention in Egypt. Diversity management may be new to the organization in Egypt and researches on diversity is still at an early stage [19]. As a result, managers must recognize the necessity of managing diversity in the workplace in order to achieve the desired results. Hence, this study fills this gap and investigated the effect of educator's workplace diversity on job performance in private educational institutions in Egypt.

The study aims to answer the following research questions:
- RQ1: what is the relationship between employee performance and gender?
- RQ2: what is the relationship between employee performance and ethnicity?
- RQ3: what is the relationship between employee performance and education?

To answer the above research questions and test the relationships between gender background, educational background, and ethnic background with the employee's performance, a quantitative data analysis approach was used. A field study was conducted based on data collected from private universities in Egypt. The data were analyzed using Partial Least Square (PLS) software package. The rest of this paper is organized as follows. Section 2 provides the research background. Section 3 discusses the research model and hypotheses development. Section 4 discusses the method. Section 5 discusses the study findings. Section 6 discusses the findings and limitations of this study. Section 7 discusses the impacts of this study. Section 8 concludes the paper.

Research Method
Research Background
Due to globalization and interaction between people with different ethnicities, origins, beliefs, and backgrounds, cultural diversity became an expanding trend [20]. The growing trend of workforce diversity among ethnic, racial, and gender emergence, as well as the increase in the percentage of workforce below the age of 30 years and above the age of 55, had many implications for companies and employees. This was triggered by the insensitivity in culture, differences in language, and the increasing percentage of women in the workforce. Diversity is not limited anymore to Western countries such as the USA and UK, however now it became familiar to all parts of the world, and its existence [21].

The focus on individual differences created the challenge of achieving workforce unity and nurturing this diversity to increase employees' performance [22]. Several studies focused on the performance aspects from a competency's deficiencies perspective due to the various models of performance that stress skills, knowledge, and attitudes for doing the job in the best and most efficient manner [23]. This is because managing diversity takes use of cultural variations in people's talents and inventiveness to gain a competitive advantage [24]. Job performance can be referred to as an individual's behavior of his productivity level and job-related outputs compared to others at work [25]. In other words, job performance is the input and participation of an employee or a group toward achieving the objective of the organization [26]. Factors that affect employees' performance can be grouped into many segregations, such as factors related to the work environment, administrative factors,

stress, and personal factors [27]. Diversity creates harmony in the work environment across the team members and cooperation to get the work done. When the members understand and accept each other regardless of the individual differences, they will be able to make good use of their accumulated knowledge and experience [12], which in turn will boost creativity and performance [28]. If diversity dimensions are considered individually, we can suggest that age diversity is positively associated with employees' job performance [29]. According to several research, there is a link between gender diversity and performance and some showed a negative effect [30,31]. On the other hand, other studies revealed a negative relationship between job performance and diversity [32].

Table 1. Summarizes the findings of similar previous studies. *Source: Authors.*

Study	Findings
[33]	There is a strong link between job performance and diversity (gender and ethnicity).
[34]	In universities and other businesses, excellent workplace performance has a favorable influence on criteria such as race and education. To be competitive, businesses should address these demographic groups.
[35]	Job performance is favorably and strongly connected to gender and ethnic diversity.
[36]	Age, educational background, yearly income, mother tongue, languages spoken and written, kind of schooling, and the sort of family structure in which the respondents reside all have an influence on work performance.
[37]	Job performance is unrelated to the variety of the workforce (i.e., age, gender, ethnicity, education, and experience). None of the dimensions of diversity investigated in this study have a substantial influence on employee performance.
[38]	Ethnicity, in the case of personnel in Pakistan's banking sector, has an extremely substantial beneficial influence on their performance and productivity. Employee performance is influenced by educational diversity in a favorable and meaningful way. In this study, all of the independent factors had a substantial influence on the dependent variables.
[39]	Individual performance was examined in relation to diversity management (individual attitudes and behaviors, organizational values and norms, administrative practices and policies), job satisfaction (general, intrinsic, and extrinsic job satisfaction), and job satisfaction (general, intrinsic, and extrinsic job satisfaction). The study discovered strong beneficial links between diversity management and work satisfaction, as well as individual performance.
[40]	The impact of diversity on job performance is negligible. Furthermore, ethnicity had no impact on performance. Furthermore, there was no gender discrimination in the recruiting and recruitment process. The findings revealed that educational background had little impact on job performance.
[29]	When classified by gender, age, and educational level, the various tests of hypotheses revealed a substantial level of relationship between performance and productivity levels.

Research Model and Hypotheses

This paper aims to study the impact of diversity background on job performance by investigating if gender background affects job performance (RQ1) if Ethnic background affects job performance (RQ2) and if educational background affects job performance (RQ3). Following the hypotheses, generation is discussed. Figure 1 illustrates the research model and hypotheses.
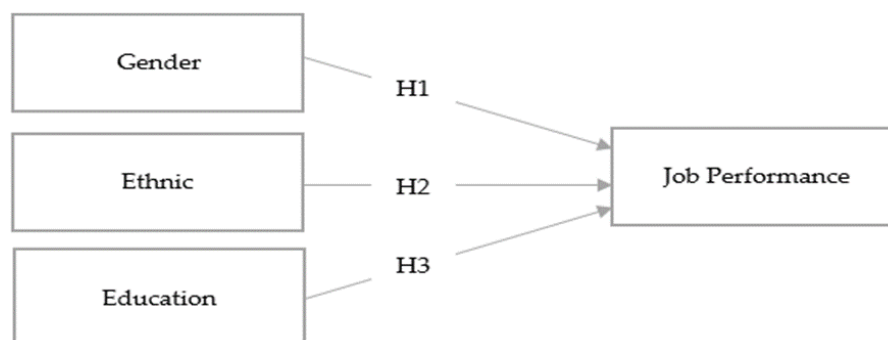

Figure 1. Research model. *Source: Authors.*

Relationship between Gender Background and Job Performance.

One of the facets of diversity in organizations is gender. Gender diversity has become a key challenge for organizations [19]. The rise in workforce gender diversity in the workplace has concerned both scholars and practitioners, which has raised the issue of whether workforce gender is associated with individual or group performance [41]. Gender diversity is concerned with the equal representation of males and females in the workplace [42]. Compared to 80 percent of males, only 54 percent of working-age females are in the workforce worldwide. In addition, females keep on dominating the 'invisible care economy' that involves caregiving and domestic work. While an increasing number of females are getting paid jobs, the majority of fresh employment in developed nations are in part-time jobs, whereas in developing nations, women are mostly working in the informal sector and home-based work. Moreover, females are paid 20–30% less than males and occupy only 1% of leading locations [43]. Many companies tend to employ men as they consider men perform better and have the ability to handle their jobs while women are stereotyped against them [18]. Gender, in management, has a U-shaped association with organizational effectiveness, according to certain research. For instance, showed in their study that gender diversity in management has a U-shaped relationship with company productivity [44]. On the other side, other evidence revealed that a high amount of diversity has a detrimental impact on group functioning and organizational success [45].

However, gender diversity is a major aspect that has an impact on the performance of employees [46]. For instance, In the Jordan context investigated the impact of worker diversity on job performance in hotels [41]. Diversity, which includes gender, age, nationality, and educational background, was found to have a beneficial impact on job performance [41]. Furthermore, emphasizes that gender diversity encourages economic returns through increasing productivity [47]. Moreover, according to Frink D. et. al [48] there is an association between gender diversity and organizational performance. They found that higher organizational performance is correlated with a more equal gender composition than proportional domination by either gender [48]. Also, as indicated by Brown S.L. [49] a substantial amount of diversity stays ineffectual if gender problems are not addressed. The challenge is first to effectively overcome the idea that women and men are not equal [49]. Consequently, we propose

- H1: There is a significant relationship between gender background and employee performance.

Relationship between Ethnic Background and Job Performance.

In an increasingly globalized world, ethnic diversity is highly significant. It is a part of life at present. Languages, faiths, ethnicities, and civilizations are all examples of ethnic variety [50]. One study found that ethnic diversity had no relation with client satisfaction, sales revenue, sales success, and client trustworthiness [12]. However, found that when compared to homogenous groups, racially diverse groups performed worse [51]. Also, revealed that group members who were different in ethnic background from other group members have less intent to remain, have a low psychological organizational commitment, and have the chance to be absent from the group [52]. On the contrary, because of a more diversified pool of skills and information that leads to complementary and shared learning, ethnic diversity was seen as having a beneficial influence on team performance [50]. There is also evidence that regards ethnic diversity has a positive impact on efficiency, creativity, market share, and sales [53]. Other evidence shows the positive effect of ethnic diversity on the performance of the oil and gas business interdisciplinary teams [45].
Consequently, we propose

- H2: There is a significant relationship between Ethnic background and employee performance.

Relationship between Educational Background and Job Performance

Studies indicate that employers typically do not recruit workers whose training, work experience, or level of education is deemed inadequate for a particular job role. This indicates that finding a job and performing well depends on having suitable educational background [54]. Furthermore, according to Hickman D.C. [55], the productivity of employees is associated with the level of education. In other words, employee productivity increases with the increase in the education level [55]. Another study found that different levels of schooling might lead to varied wage rates. For example, employment accessible to persons with practical experience but no formal education may differ from those open to those with a formal education [56]. Likewise, Choi et al. [12] found a significant relationship between the education level and financial growth. Significant evidence indicates a significant relationship between educational diversity and job performance. For instance, revealed that educational background diversity is positively associated with team performance since it encourages extensive scope of cognitive skills [57]. Moreover, demonstrates a positive effect of educational background

diversity on employee performance [18]. On the other hand, other evidence indicates a negative relationship between education diversity and employee performance. For instance, revealed that education diversity within a team is negatively associated with the performance level of the team [58].
Consequently, we propose
- ▪ H3: There is a significant relationship between educational background and employee performance.

Research Process
In this article, we investigated the links among the research model constructs using a quantitative technique. Figure 1 depicts the research model. To examine these connections, we created a survey questionnaire. According to Gable G.G. [59], the survey technique is recommended to investigate and validate relationships between several constructs or variables across a large population. Moreover, more information can be achieved using the survey technique than using other techniques such as observation, which may help researchers to generalize their findings to the whole study's population [60].

A close-ended questionnaire was employed for data collection from faculty members in private teaching institutions in Egypt. Two main sections were included in this questionnaire; demographic and job performance. In the demographic section, we asked the respondent to provide their age, job title, experience in the institution, and gender. In the job performance section, the respondent was asked to answer several questions that cover their ethnic background, gender background, educational background, and job performance. A five-point Likert scale was used (i.e., 1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, and 5 = strongly disagree). We included the "neutral" point since it does not have any drawbacks on the scale and it may decrease the bias in respondents' answers since it does not force them to either choose a positive or negative answer [61]. We conducted a face and content validity to the questionnaire to ensure that the survey meets accuracy and reliability requirements [62]. The questionnaire was forwarded to four academics to assess content validity (i.e., three assistants, one associate, and one full professor teaching management and human resource subjects. This was important to achieve the final agreement on the items that should be considered in this questionnaire as well as the accuracy of these items [59]. The questionnaire was submitted to three Ph.D. students to check face validity. This was done to test the required time to complete the questionnaire as well as provide us with any criticism. Moreover, this is necessary for the other aspects such as the understandability, readability, format, and terminology applied in the questionnaire [59]. Based on the evaluation feedback, the questionnaire was updated.

We used snowball sampling in a pilot study to evaluate and improve the survey questionnaire [63]. Based on the first author's contacts, the questionnaire was directed to seven participants. The selected respondents were based on the predefined unit of analysis (i.e., an academic teacher who works in a private university in Egypt). We asked respondents to answer the survey and offer feedback on how to improve it or if they had any issues completing it. Based on their feedback, we further revised the questionnaire and applied the required changes.

Participants
We targeted the teaching role in the institution that includes teaching assistant, assistant professor, associate professor, and full professor. The survey was conducted between July 2020 and August 2020. The survey questionnaire was sent to potential respondents in private institutions in Egypt. We targeted 200 or more complete surveys [64]. Accordingly, we sent the survey questionnaire to 450 potential respondents. The questionnaire was made available online using the Survey Monkey tool. The questionnaire link was sent to potential respondents through emails and messages on LinkedIn. The online-based survey was favored over other techniques such as in-house or telephone surveys since it gives the respondents enough time and completes it at their preferable times. No personal questions were included in the questionnaire such as the respondent or organization names. A total of 316 surveys were returned, achieving a 70 % survey response rate. We have prepared the data collected for analysis by conducting cleaning, missing data, and multi-screening processes [64].

The preparation process resulted in the exemption of 47 surveys due to the incompleteness of the answers of more than 10 percent, as recommended by Hair et al. 2010. Accordingly, the total usable responses were 269, which is well above the required sample size (i.e., 200 responses) that is recommended in PLS-SEM [64].

<u>Data Analytical Approach</u>
We used the Partial Least Square-Structural Equation Modeling (PLS-SEM) for data analysis. PLS-SEM provides a comprehensive multivariate analysis that includes a measurement model and structural model. The measurement model measures the association between data gathered from the survey and the latent variable. The structural model measures the strength of the relationship between the latent factors and the association between exogenous and endogenous variables at once rather than doing it separately [65].

<u>Measures</u>
Gender background (Gen) was measured by five items that were adapted from [66]. These items measure the extent to which different genders are treated differently in the job environment. Education background (Edu) was measured by three items that were adapted from [40]. These items measure the degree that different educational levels are treated differently in the job environment. Ethnic background (Eth) was measured by four items that were adopted from [18]. These items measure the extent to which how different Ethnic background groups may be treated differently in the job environment. Job performance (Perf) was evaluated through four items [67]. These items measure the degree that employees are convenient about the performance of their job.

Results and Discussion
Demographic Profile of Respondents
The respondents' demographic characteristics are listed in Table 2. These include age, job title experience in the same institute, and gender. Most of the respondents (70%) were aged between 18-38 years. The majority of respondents (54%) were associate professors, and the majority (55%) were female.

Table 2. Respondent demographics. *Source: Authors.*

Characteristic		Frequency	Percentage %
Age	18 - 30	189	70
	30 - 39	46	17
	40 - 49	29	11
	50 - 59	5	2
Job title	Teaching assistant	36	13
	Assistant professor	64	24
	Associate professor	145	54
	Full professor	24	9
Number of years in the institution	0 - 10	92	34
	11 - 15	92	34
	16 - 20	36	13
	Over 20yeras	51	19
Gender	Female	149	55
	Male	120	45

The non-response rate may represent an issue in data analysis. To ensure nonresponse was not an issue, we followed the recommendation by Sivo et al. [68], and split the sample into the initial group and secondary group. We used demographics to compare the replies of the two groups. The results of the test revealed no significant differences between the two groups, indicating that nonresponse bias is unlikely to be a major issue. Another issue related to data is the common method bias issue. Following recommendations by MacKenzie et al. [69], we conducted Harman's one-factor test statistically, which showed that the most covariance explained by one factor was only 33 percent (i.e., none of any solo aspect that could elucidate a large quantity of discrepancy). Hence, this issue does not represent a risk to the dimension validity. Moreover, the items that relate to one construct were dispersed among the questionnaire and not grouped to minimize the common method biases [63].

<u>Measurement Validation</u>
All indicators of Gender background, educational background, Ethnic background, and job performance were displayed as reflective indicators that are initiated by their latent concepts [65]. We used the SmartPLS 3.0 software [70] to validate the measurement model We conducted construct validity and reliability tests for all

items. The results revealed a satisfactory level and hence all items were valid and reliable. Following the recommendation of Hair et al. [65], four values were estimated to validate the measurement model. To begin, individual indicator dependability refers to the extent to which a measurement item is devoid of random mistakes and produces steady and consistent findings across time [71]. Second, the internal consistency of the measured reliability was measured using Composite Reliability (CR) and Cronbach Alpha (α). Third, the convergent validity (i.e., the degree to which one measure of a construct correlates favorably with other measures of that construct) [71]. Fourth, the discriminant validity of a notion relates to the extent to which it is distinct from others [71].

First, the outer loadings of each item on its corresponding latent construct were used to examine the indicator reliability of reflective items, which is recommended to be more than the 0.5 and 1.96 of t-statistical value [65]. Table 3 shows the loading of each item as well as the cross-loading with other items. Since all outer loading was above the recommended values, indicator reliability was supported.

Second, as indicated in Table 4, all components scored higher than the suggested value of 0.70 for CR. Third, we tested the Average Variance Extracted to see if it was convergent (AVE). All of the AVEs were higher than the acceptable value of 0.50 [65]. Finally, we assessed the discriminant validity by testing the indicators' cross-loadings and the Fornell and Larcker criterion [65]. First, the cross-loadings of the indicators demonstrate that no indicator has a stronger weight on the opposing endogenous constructs (see Table 3). Second, the square root of each construct's AVE value should be bigger than its greatest correlation with any other construct, according to the Fornell and Larcker criteria. The square root of the AVE score is represented by the numbers along the diagonal in bold type, while the off-diagonal elements indicate correlations among latent constructs. The square root of AVE is larger than the variance shared by each construct and its opposing constructions in all circumstances, as seen in Table 4. Accordingly, discriminant validity requirements of all constructs were achieved.

Table 3. Construct indicator; loading and cross loading; *P < .10, **P < .05, ***P < .01. Edu = educational background, Eth = Ethnic background, Gen = gender background, and Perf = job performance. *Source: Authors.*

	Education	Ethnic	Gender	Performance
Edu1	0.926***	0.274	0.306	0.341
Edu2	0.889***	0.240	0.294	0.310
Edu3	0.875***	0.243	0.201	0.311
Edu4	0.589***	0.308	0.230	0.436
Eth1	0.225	0.820***	0.367	0.328
Eth2	0.304	0.789***	0.347	0.317
Eth3	0.147	0.684***	0.222	0.309
Eth4	0.335	0.815***	0.359	0.336
Gen1	0.278	0.262	0.857***	0.247
Gen2	0.197	0.522	0.658***	0.269
Gen3	0.201	0.127	0.749***	0.167
Gen4	0.234	0.272	0.580***	0.188
Gen5	0.276	0.234	0.886***	0.251
Perf1	0.376	0.384	0.261	0.898***
Perf2	0.341	0.358	0.229	0.877***
Perf3	0.248	0.215	0.293	0.542***
Perf4	0.308	0.223	0.133	0.551***

Table 4. Composite reliability (CR), average variance extracted (AVE). *Source: Authors.*

Latent Construct	α	CR	AVE	Education	Ethnicity	Gender	Performance
Education	0.838***	0.897***	0.690***	0.831			
Ethnicity	0.782***	0.860***	0.606***	0.331	0.779		
Gender	0.807***	0.866***	0.570***	0.32	0.422	0.755	
Performance	0.693***	0.818***	0.543***	0.436	0.413	0.313	0.737

Test of the Structural Model

To test the significance of the relationships among all constructs, we run the PLS algorithm and the bootstrapping procedures using the following criteria [65] : path coefficient, coefficient of determination (R2), the mediation effect of gender background, and effect size for each track model (Cohen's f2).

First, the path coefficients that represent the strength of the relationships (B value) between variables should be significant and in line with the intended directions to ensure the relationship between two constructs exists [65]. Figure 2 shows the path coefficients and the significance for each path. One hypothesis was found not supported (B=-0.100, p=0.114, T=1.585) which is the effect of gender background on job performance (H1). The other two hypotheses were found supported; the effect of ethnic background on job performance (H2) was found significant (B=0.316, p<0.01, T=5.279), and the effect of educational background on job performance (H3) was found significant (B=0.267, p<0.01, T=3.906). Moreover, we tested if there are direct relationships between gender and ethnicity, and education. The findings show significant relationships such that the effect of gender background on the educational background (H1) was found significant (B=0.320, p<0.01, T=5.060), the effect of gender background on the ethnic background (H2) was found significant (B=0.422, p<0.01, T=8.227).

Second, the fundamental criterion for evaluating the inner model is R2, which relates to the model's prediction accuracy and indicates the combined effects of the independent (exogenous) latent variable on the dependent (endogenous) latent variable [65]. An acceptable R2 with 0.25, 0.5, and 0.75, describing small, considerable, modest, or strong levels of predictive accuracy, respectively [65]. Gender background explains 10.2 percent of the variance in educational background and 17.8 percent of the variance in ethnic background, which both can be described as weak predictive accuracy. Gender background, educational background, and ethnic background collectively explain 27.9 percent of the variance in job performance, which can be described as moderate predictive accuracy.

Third, we check the mediation role of gender background on the relationships between educational background and ethnic background with job performance. This was done by following the recommendation of Zhao et al. [72] where the indirect effects (i.e., gender background * educational background and gender background * ethnic background) should be significant if the gender mediates the effect of educational background and ethnic background on job performance [72]. We look for the direct effect if the indirect effect is significant. We have complementary (partial) mediation if the direct effect is considerable; however, we only have indirect (full) mediation if the direct effect is minor. Since the direct effect (i.e., the relationship between gender background and ethnicity background, and the relationship between gender background and educational background) were significant and the indirect effect was significant (B=0.312, T=5.643, p<0.01), then the relationship between both educational backgrounds and ethnic background on job performance is partially mediated by gender background.

Finally, to see if omitting a certain external component has a significant impact on endogenous constructs, we test the effect size – f2 values [65]. The value of 0.02 for ƒ2 represents a small effect, 0.15 – represents a medium effect, and 0.35 – represents a large effect [64]. A strong relationship was found between gender background and ethnic background (ƒ2= 0.216, T=3.248, P<0.01). Moreover, a medium relationship was found between gender background and educational background (ƒ2= 0.114, T=2.142, P<0.05). Furthermore, a medium relationship was found between educational background and Job performance (ƒ2= 0.118, T=2.329, P<0.05) as well as between Ethnic background and Job performance (ƒ2= 0.077, T=1.778, P<0.1). Finally, a small relationship was found between gender background and job performance (ƒ2= 0.011, T=0.698, P=0.485).
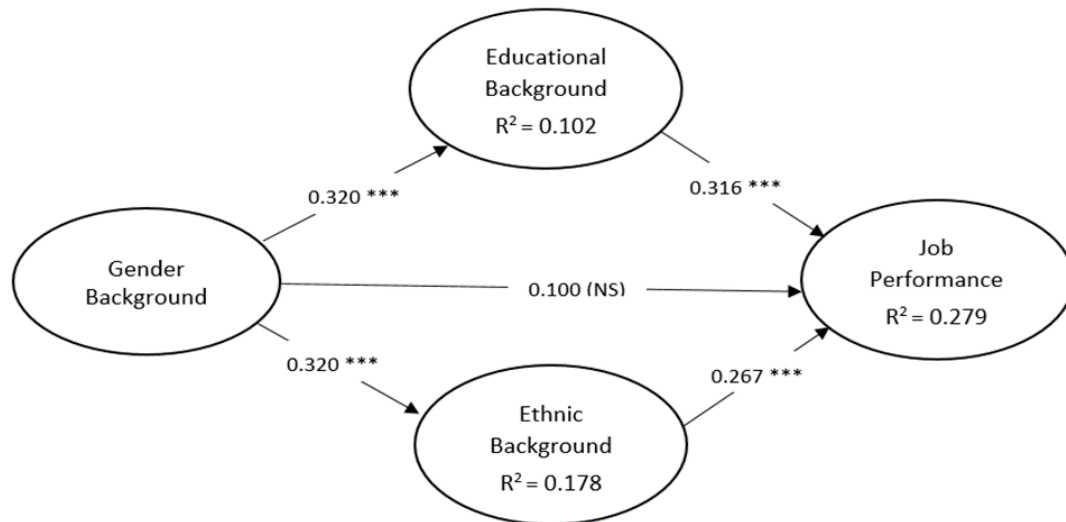
Figure 2. Partial least square SEM results. *Source: Authors.*

Discussion

This paper scrutinizes the direct and indirect effects of gender, ethnicity, and educational background on employees' job performance. All of the hypotheses of the study were supported except the direct effect of gender on job performance. Thus, the first contribution of this paper is to reveal empirical evidence regarding the positive association of employees' diverse backgrounds on job performance. This finding is consistent with the existing literature in general [33,35,73]. The major mainstream research focuses on investigating the impact of the management and inclusion of diversity on job performance rather than analyzing the effects of diverse backgrounds [16,39]. It is also suggested that the majority of the literature analyzing the relationship between diversity and job performance is concentrating on developed countries [16]. However, there is also a significant number of empirical findings revealing the impact of a diverse workforce on job performance in developing countries. For example [73], An Empirical Analysis of Key Antecedents of Workforce Diversity on Job Performance in Nigeria [41,46] also present actual data on the influence of workforce diversity on job performance in Afghanistan and Jordan respectively. Furthermore, there is an adequate number of research findings supporting the positive association of diversities with organizational performance in the Egyptian context [74]. There is a limited number of studies providing empirical results regarding the positive impact of diversity on employees' performance. For example, investigated the effects of gender, age, and education on employee performance in the Egyptian pharmaceutical business and found that gender and educational background is positively associated with employees' performance while age diversity has no significant impact [18]. Hence, our findings conclude a similar result based on data collected from private universities in Egypt. One common point of these industries is that both of them are renowned to employ a highly diversified and educated workforce.

On the other hand, our research findings indicate that the ethnic and educational backgrounds of employees have a positive effect on job performance and gender has no significant effect. The positive impact of ethnic and educational diversity on job performance is consistent with the prior research findings [34,46]. However, the insignificant relationship between gender diversity and job satisfaction is not consistent with the majority of the literature. Furthermore, a limited number of studies suggest that gender in particular, or diversity, in general, has no significant impact on job performance [75]. They claim that if workforce diversity is wisely accomplished, more positive outcomes may be resulted, nevertheless if it is not correctly managed it may lead to even negative outcomes. Therefore, the positive effect of gender difference on job performance can be achieved only if the diversity is well managed The effects of work Force diversity on employee performance in Singapore organizations [75].

Another significant finding of this paper is the indirect effect of gender on performance. Our analysis reveals that the ethnic and educational background of the employees partially mediates the relationship between gender diversity and job performance. The existing literature acknowledges that there is a partially significant link between performance and gender [76]. Accordingly, a sufficient number of studies suggest that several factors

mediate the relationship between gender diversity and job performance [77,78]. Among these factors, task type and task interdependence, transformational leadership, inclusion and person's job match are the most well-known ones [77–80]. Therefore, our finding, in general, is in line with the prior findings of the literature with the addition that we found ethnic and educational backgrounds of the workforce as the partially mediating factors.

This study, like any other empirical study, has inherent limitations. First, the number of participants in the survey was 269 individuals. This can be assumed as a limitation; however, according to many authors, e.g. [65], this number is an appropriate sample to be analyzed using PLS analysis. Moreover, this sample was based on the availability and willingness of the academic staff to participate in the survey. We sent the survey link to potential participants from all types of academic institutions and different backgrounds (i.e., Ethnic, educational, and gender). Future research may include a larger number of participants. Secondly, we did not cover all diversity variables like sexual orientation, marital status, physical ability, and geographic location. Future studies may investigate these variables.

Impact

This study, similar to any other empirical study, has several impacts for both academia and industry. Workforce diversity reflects changing work environments and marketplaces. A variety of studies has provided evidence that it is necessary to have effective management of the workforce to get a higher job performance and increased profitability. The current study reviews the literature on the relationship between employee performance and workforce diversity. The findings of this paper show that implementing diversity management is vital for any organization. It indicates that the level of employees' job performance is positively affected by ethnic background and educational background among academic staff in private universities in Egypt. From the managerial perspective, the study sheds light on three dimensions of diversity (gender, educational background, and ethnic background) and their impact on organizational performance. Thus, managers who are seeking to improve organizational performance need to focus on investing in managing workplace diversity.

There should be mechanisms to manage workforce diversity effectively. Organizations should create a suitable environment that positively supports workforce diversity. Improving the performance of academic staff requires a healthy and appropriate working environment and managing employees' issues and conflicts. Moreover, strategies should be formulated to reduce the negative ethnic discrimination climate within the organization. Furthermore, the diversity of employees based on educational backgrounds fosters greater innovation and creates opportunities for creative solutions. It also contributes to the development of a broader body of knowledge and understanding since it fosters shared learning and a more diverse set of intellectual capabilities. Hence, private universities need to better understand such demographic issues to remain competitive. They must adopt diversity management methods since varied viewpoints and expertise may help to enhance decision-making and problem-solving processes. It is also essential to foster the implementation of mentoring programs that encourage sharing and transfer of knowledge and experience among employees of diverse educational backgrounds and different work experiences. Moreover, employees must receive frequent training on diversity for the sake of improving the organization's performance and enhancing the organization's well-being. This contributes to building cohesive teams and enhancing concentration at work.

To promote gender diversity, it is essential for managers to ensure equal opportunities for both men and women to engage in the company's decision-making procedures. Moreover, management should develop a comprehensive plan aimed at fostering a diverse workforce, which involves regularly monitoring the representation of men and women within the company [81]. By scrutinizing promotion criteria and comparing average salaries across different organizational levels, managers can evaluate whether their policies effectively support diversity in the recruitment, advancement, and retention of both genders.

In order to achieve optimal performance, organizations should establish training and development programs that are tailored to the unique characteristics of their workforce. The overarching objective of the organizational strategy should be to foster a culture where management and the human resources department collaborate to effectively manage and enhance diversity. Consequently, businesses should design training and development initiatives that cater to the specific needs and requirements of diverse employee groups. To promote educational diversity, it is crucial for businesses to provide opportunities for career advancement and development to employees with lower educational levels. In addition, management should consider granting paid study leave to workers who opt to pursue further education. These management approaches serve as external motivation

for employees, while also offering financial assistance to alleviate the costs associated with education. Moreover, educational institutions should incorporate additional subjects related to diversity into their curricula to further enrich the learning experience.

Conclusions

The positive impact of workforce diversity on employees' job performance is well-acknowledged especially Western context. Some studies, although a few have claimed this positive impact were reported in some developed countries. To investigate this claim and provide more insights into the relationship between diversity and employee performance, this study empirically investigated the relationships between four constructs: gender background, educational background, ethnic background, and employee performance in the context of private academic institutions in Egypt.

The findings confirm two of the hypotheses (that ethnic background has a good influence on performance and that educational background has a favorable effect on performance); however, the hypothesis about the link between gender background and employee performance was not validated. The following are the paper's key contributions.

To begin, it is important to note that, to the best of the authors' knowledge, no previous attempts have been made to investigate the influence of cultural diversity on tutor performance in Egyptian educational institutions. Egypt's private educational institutions have a large and diversified workforce drawn from all over the world, allowing for unique research on worker diversity. Second, this research discovered that gender has a direct and favorable influence on educational and ethnic backgrounds. To our knowledge, this conclusion has not been documented in previous literature. Third, it was discovered that gender background somewhat moderated the correlations between ethnicity and educational background, and employee performance.

Conflicts of Interest
The authors declare no conflict of interest.

Acknowledgments

References
[1]   A. Saxena, Workforce Diversity: A Key to Improve Productivity, Procedia Econ. Financ. 11 (2014) 76–85. https://doi.org/10.1016/s2212-5671(14)00178-6.
[2]   J.N. Christian, L.W. Porter, G. Moffitt, Workplace diversity and group relations: An overview, Gr. Process. Intergr. Relations. 9 (2006) 459–466. https://doi.org/10.1177/1368430206068431.
[3]   E. Magoshi, E. Chang, Diversity management and the effects on employees' organizational commitment: Evidence from Japan and Korea, J. World Bus. 44 (2009) 31–40. https://doi.org/10.1016/j.jwb.2008.03.018.
[4]   H.A. Patrick, V.R. Kumar, Managing workplace diversity: Issues and challenges, SAGE Open. 2 (2012) 1–15. https://doi.org/10.1177/2158244012444615.
[5]   M. Mousa, Organizational inclusion, responsible leadership and physicians' psychological contract: a study from Egypt, Equal. Divers. Incl. 39 (2019) 126–144.
[6]   D. Mulkeen, How can the HR team improve internal communication?, Strateg. HR Rev. 7 (2008). https://doi.org/10.1108/shr.2008.37207baf.005.
[7]   D.W. Pitts, A.K. Hicklin, D.P. Hawes, E. Melton, What drives the implementation of diversity management programs? Evidence from public organizations, J. Public Adm. Res. Theory. 20 (2010) 867–886. https://doi.org/10.1093/jopart/mup044.
[8]   G.C. McMahan, M.P. Bell, M. Virick, Strategic human resource management: Employee involvement, diversity, and international issues, Hum. Resour. Manag. Rev. 8 (1998) 193–214. https://doi.org/10.1016/s1053-4822(98)90002-x.
[9]   C.W. Von Bergen, B. Soper, T. Foster, Unintended Negative Effects of Diversity Management, Public Pers. Manage. 31 (2002) 239–251. https://doi.org/10.1177/009102600203100209.
[10]   D. Pitts, E. Jarry, Ethnic diversity and organizational performance: Assessing diversity effects at the managerial and street levels, Int. Public Manag. J. 10 (2007) 233–254. https://doi.org/10.1080/10967490701323738.
[11]   R.R. Thomas, From affirmative action to affirming diversity., Harv. Bus. Rev. 68 (1990) 107–117.

[12] S. Choi, H.G. Rainey, Managing diversity in U.S. federal agencies: Effects of diversity and diversity management on employee perceptions of organizational performance, Public Adm. Rev. 70 (2010) 109–121. https://doi.org/10.1111/j.1540-6210.2009.02115.x.

[13] A.I.E. Ewoh, Managing and valuing diversity: Challenges to public managers in the 21st century, Public Pers. Manage. 42 (2013) 107–122. https://doi.org/10.1177/0091026013487048.

[14] C. Buckingham, A Case Study Exploring the Impact of Manageing Workplace Diversity on Diversity Awareness and Employee Job Satisfaction, Thesis. (2010).

[15] D. Youssef, O. Abidi, H. Zaim, Y. Keceli, V. Dzenopoljac, Impact of diversity management on citizenship behaviour: The mediating role of human resources management, Int. J. Learn. Intellect. Cap. 17 (2020) 384–409. https://doi.org/10.1504/IJLIC.2020.113154.

[16] O. ABIDI, H. ZAIM, D. YOUSSEF, A. BARAN, Diversity Management and Its Impact on HRM Practices: Evidence from Kuwaiti Companies, Eurasian J. Bus. Econ. 10 (2017) 71–88. https://doi.org/10.17015/ejbe.2017.020.05.

[17] A. Alshaabani, I. Rudnák, Impact of Diversity Management Practices on Organizational Climate – an Egyptian Study, J. Manage. 36 (2020). https://doi.org/10.38104/vadyba.2020.01.

[18] A.M. Elsaid, The Effects of Cross Cultural Work Force Diversity on Employee Performance in Egyptian Pharmaceutical Organizations, Bus. Manag. Res. 1 (2012). https://doi.org/10.5430/bmr.v1n4p162.

[19] M. Mousa, Does Gender Diversity Affect Workplace Happiness for Academics? The Role of Diversity Management and Organizational Inclusion, Public Organ. Rev. 21 (2021) 119–135. https://doi.org/10.1007/s11115-020-00479-0.

[20] B. Mazur, Cultural Diversity in Organisational Theory and Practice, J. Intercult. Manag. 2 (2010) 5–15.

[21] T. Ashikali, S. Groeneveld, Diversity management for all? An empirical analysis of diversity management outcomes across groups, Pers. Rev. 44 (2015) 757–780. https://doi.org/10.1108/PR-10-2014-0216.

[22] C. Tilly, Durable Inequality, Univ of California Press, 2020. https://doi.org/10.4324/9781315634050-15.

[23] K. Harrison, A. Goulding, Performance appraisal in public libraries, New Library World, 1997. https://doi.org/10.1108/03074809710188806.

[24] P.J. Fernandez, Managing a Diverse Workforce: Regaining the Competitive Edge, Jossey-Bass, 1991.

[25] B.J. Babin, J.S. Boles, Employee Behavior in a Service Environment: A Model and Test of Potential Differences between Men and Women, J. Mark. 62 (1998) 77–91. https://doi.org/10.1177/002224299806200206.

[26] M. Pasa, The Effects of Stress on Performance, Uludag University, Databases of National Thesis Center of the Council of Higher Education, 2007. papers3://publication/uuid/F3312BBD-91B5-47A4-B97D-7388B09A6726.

[27] Z. Odabas, The relation of personal performance and job satisfaction, 2004.

[28] K.Y. Williams, C. a O'Reilly III, Demography and Diversity in Organizations: A Review of 40 Years of Research, Res. Organ. Behav. 20 (1998) 77. https://doi.org/10.1177/104649640003100505.

[29] M.G. Munjuri, R.M. Maina, Workforce Diversity Management and Employee Performance in The Banking Sector in Kenya, DBA Africa Manag. Rev. 3 (2013) 1–21.

[30] C. Herring, Does diversity pay?: Race, gender, and the business case for diversity, Am. Sociol. Rev. 74 (2009) 208–224. https://doi.org/10.1177/000312240907400203.

[31] F.J. Milliken, L.L. Martins, Searching for Common Threads: Understanding the Multiple Effects of Diversity in Organizational Groups, Acad. Manag. Rev. 21 (1996) 402. https://doi.org/10.2307/258667.

[32] T.A. Timmerman, Racial diversity, age diversity, interdependence, and team performance, Small Gr. Res. 31 (2000) 592–606. https://doi.org/10.1177/104649640003100505.

[33] J. Kolade Obamiro, B. Oladipupo Kumolu-Johnson, J. Chidi Ngwamaj, Workforce Diversity and Employees' Performance: Evidence From A Nigerian Bank, J. Econ. Behav. 9 (2019) 13–26.

[34] R.M. Muange, N.W. Kiptoo, Effect of Workforce Ethnic Diversity and Education Backgrounddiversity on Employee Performancein Selected Universities in Kenya, Int. J. Innov. Sci. Res. Technol. 5 (2020) 1096–1103. https://doi.org/10.38124/ijisrt20jul728.

[35] S. Zhuwao, H. Ngirande, W. Ndlovu, S.T. Setati, Gender diversity, ethnic diversity and employee performance in a south african higher education institution, SA J. Hum. Resour. Manag. 17 (2019). https://doi.org/10.4102/sajhrm.v17i0.1061.

[36] R. Sundari, Workplace Diversity and Its Impact on Performance of Employees, BVIMSR's J. Manag. Res. 10 (2018) 145–156.

[37] Makhdoomi Ursil Majid, Nika Ahmad Fayaz, Workforce Diversity and Employee Performance An Empircal Study of Telecom Organisations, Amity Glob. Bus. Rev. 12 (2017) 107–116.

[38] M. Rizwan, M. Nazar Khan, B. Nadeem, Q. Abbas, The Impact of Workforce Diversity Towards Employee Performance: Evidence from Banking Sector of Pakistan, Am. J. Mark. Res. 2 (2016) 53–60.

[39] O. Aydan, The effects of diversity management on job satisfaction and individual performance of teachers, Educ. Res. Rev. 11 (2016) 105–112. https://doi.org/10.5897/err2015.2573.

[40] A.S. Mwatumwa, W. Kingi, H. Mohamed, M. Ibua, K. Omido, Effect of Workforce Diversity on Employee Work Performance: A Study of the County Government of Mombasa, Int. J. Manag. Commer. Innov. 3 (2015) 99–104. www.researchpublish.com.

[41] A.M.E.S. Mohammad, Effect of Workforce Diversity on Job Performance of Hotels Working in Jordan, Int. J. Bus. Manag. 14 (2019) 85. https://doi.org/10.5539/ijbm.v14n4p85.

[42] A. Wieczorek-Szymańska, Gender diversity in academic sector—Case study, Adm. Sci. 10 (2020) 41. https://doi.org/10.3390/admsci10030041.

[43] E.E. Kossek, S.A. Lobel, J. Brown, Human resource strategies to manage workforce diversity: Examining 'the business case,' in: J.K.P. A. M. Konard, P. Prasad (Ed.), Handb. Work. Divers., SAGE, London, 2006: pp. 53–74. https://doi.org/10.4135/9781848608092.n3.

[44] K. Bin Bae, S. Skaggs, The impact of gender diversity on performance: The moderating role of industry, alliance network, and family-friendly policies - Evidence from Korea, J. Manag. Organ. 25 (2019) 896–913. https://doi.org/10.1017/jmo.2017.45.

[45] B.L. Herring, R. Tsui, L. Peddada, M. Busch, E.L. Delwart, Wide Range of Quasispecies Diversity during Primary Hepatitis C Virus Infection, J. Virol. 79 (2005) 4340–4346. https://doi.org/10.1128/jvi.79.7.4340-4346.2005.

[46] M. Qasim, Effect of Workforce Diversity on Employee's Job Performance: The Empirical Assessment of Education Sector, Jalalabad, Afghanistan, Int. J. Econ. Manag. Sci. 06 (2017). https://doi.org/10.4172/2162-6359.1000452.

[47] A. Joshi, B. Neely, C. Emrich, D. Griffiths, G. George, Gender research in AMJ: An overview of five decades of empirical research and calls to action, Acad. Manag. J. 58 (2015) 1459–1475. https://doi.org/10.5465/amj.2015.4011.

[48] D.D. Frink, R.K. Robinson, B. Reithel, M.M. Arthur, A.P. Ammeter, G.R. Ferris, D.M. Kaplan, H.S. Morrisette, Gender demography and organization performance: A two-study investigation with convergence, Gr. Organ. Manag. 28 (2003) 127–147. https://doi.org/10.1177/1059601102250025.

[49] J.R. Votano, M. Parham, L.H. Hall, L.B. Kier, L.M. Hall, Diversity in the Workplace: a Study of Gender, Race, Age, and Salary Level, Chem. Biodivers. 1 (2004) 1829–1841. http://onlinelibrary.wiley.com/doi/10.1002/cbdv.200490137/abstract.

[50] G. Sandilya, Workforce Diversity and Organizational Culture, Int. J. Bus. Manag. Invent. 2 (2021) 36–41. https://blog.iilm.edu/workforce-diversity-and-organizational-culture/.

[51] S.E. Jackson, A. Joshi, N.L. Erhardt, Recent Research on Team and Organizational Diversity: SWOT Analysis and Implications, J. Manage. 29 (2003) 801–830. https://doi.org/10.1016/s0149-2063_03_00080-1.

[52] A.S. Tsui, T.D. Egan, C.A.O. III, Being Different: Relational Demography and Organizational Attachment, Adm. Sci. Q. 37 (1992) 549. https://doi.org/10.2307/2393472.

[53] C.T. Kulik, L. Roberson, Common goals and golden opportunities: Evaluations of diversity education in academic and organizational settings, Acad. Manag. Learn. Educ. 7 (2008) 309–331. https://doi.org/10.5465/AMLE.2008.34251670.

[54] W.E. Watson, L. Johnson, G.D. Zgourides, The influence of ethnic diversity on leadership, group process, and performance: An examination of learning teams, Int. J. Intercult. Relations. 26 (2002) 1–16. https://doi.org/10.1016/S0147-1767(01)00032-3.

[55] D.C. Hickman, The effects of higher education policy on the location decision of individuals: Evidence from Florida's Bright Futures Scholarship Program, Reg. Sci. Urban Econ. 39 (2009) 553–562. https://doi.org/10.1016/j.regsciurbeco.2009.04.002.

[56] K.R. Fleischmann, R.W. Robbins, W. a. Wallace, Designing educational cases for intercultural information ethics: The importance of diversity, perspectives, values, and pluralism, J. Educ. Libr. Inf. Sci. 50 (2009) 4–14. http://content.ebscohost.com/ContentServer.asp?T=P&P=AN&K=502993184&S=R&D=llf&EbscoContent=dGJyMNXb4kSeqK44y9fwOLCmr0uep7BSr6e4TbGWxWXS&ContentCustomer=dGJyMPGut0mwrbFPuePfgeyx44Dt6fIA%5Cnhttp://search.ebscohost.com.subzero.lib.uoguelph.ca/login.aspx?direct.

[57] S. Cohen, What makes teams work: Group effectiveness research from the shop floor to the executive suite, J. Manage. 23 (1997) 239–290. https://doi.org/10.1016/s0149-2063(97)90034-9.

[58] A. Joshi, H. Roh, The role of context in work team diversity research: A meta-analytic review, Acad. Manag. J. 52 (2009) 599–627. https://doi.org/10.5465/AMJ.2009.41331491.

[59]   G.G. Gable, Integrating case study and survey research methods: an example in information systems, Eur. J. Inf. Syst. 3 (1994) 112–126. https://doi.org/10.1057/ejis.1994.12.

[60]   D.S. Said, S. Agarwal, Y.I. Alzoubi, M.M. Momin, A. Naqvi, Occupational stress among Generation-Y employees in the era of COVID-19: cases from universities in India, Ind. Commer. Train. 55 (2023) 234–252. https://doi.org/10.1108/ICT-03-2022-0017.

[61]   M.S. Dinc, H. Zaim, M. Hassanin, Y.I. Alzoubi, The effects of transformational leadership on perceived organizational support and organizational identity, Hum. Syst. Manag. 41 (2022) 699–716. https://doi.org/10.3233/HSM-211563.

[62]   Y.I. Alzoubi, A.Q. Gill, B. Moulton, A measurement model to analyze the effect of agile enterprise architecture on geographically distributed agile development, J. Softw. Eng. Res. Dev. 6 (2018) 4. https://doi.org/10.1186/s40411-018-0048-2.

[63]   Y.I. Alzoubi, A.Q. Gill, An Empirical Investigation of Geographically Distributed Agile Development: The Agile Enterprise Architecture is a Communication Enabler, IEEE Access. 8 (2020) 80269–80289. https://doi.org/10.1109/ACCESS.2020.2990389.

[64]   B. Flury, F. Murtagh, A. Heck, Multivariate Data Analysis., Upper Saddle River: Prentice Hall, 1988. https://doi.org/10.2307/2007941.

[65]   A. Leguina, A primer on partial least squares structural equation modeling (PLS-SEM), Int. J. Res. Method Educ. 38 (2015) 220–221. https://doi.org/10.1080/1743727x.2015.1005806.

[66]   M.C. Schippers, D.N. Den Hartog, P.L. Koopman, J.A. Wienk, Diversity and team outcomes: The moderating effects of outcome interdependence and group longevity and the mediating effect of reflexivity, J. Organ. Behav. 24 (2003) 779–802. https://doi.org/10.1002/job.220.

[67]   Y. Benschop, Pride, prejudice and performance: Relations between HRM, diversity and performance, Int. J. Hum. Resour. Manag. 12 (2001) 1166–1181. https://doi.org/10.1080/09585190110068377.

[68]   S. Sivo, C. Saunders, Q. Chang, J. Jiang, How Low Should You Go? Low Response Rates and the Validity of Inference in IS Questionnaire Research, J. Assoc. Inf. Syst. 7 (2006) 351–414. https://doi.org/10.17705/1jais.00093. [69]   S.B. MacKenzie, P.M. Podsakoff, Common Method Bias in Marketing: Causes, Mechanisms, and Procedural Remedies, J. Retail. 88 (2012) 542–555. https://doi.org/10.1016/j.jretai.2012.08.001.

[70]   C.M. Ringle, S. Wende, J.M. Becker, SmartPLS 3 GmbH, Boenningstedt. 10 (2015).

[71]   D. Straub, D. Gefen, Validation Guidelines for IS Positivist Research, Commun. Assoc. Inf. Syst. 13 (2004). https://doi.org/10.17705/1cais.01324.

[72]   X. Zhao, J.G. Lynch, Q. Chen, Reconsidering Baron and Kenny: Myths and truths about mediation analysis, J. Consum. Res. 37 (2010) 197–206. https://doi.org/10.1086/651257.

[73]   H.E. Jekelle, An Empirical Analysis of Key Antecedents of Workforce Diversity on Job Performance in Nigeria, J. Econ. Bus. 4 (2021). https://doi.org/10.31014/aior.1992.04.01.331.

[74]   D. El-Bassiouny, N. El-Bassiouny, Diversity, corporate governance and CSR reporting: A comparative analysis between top-listed firms in Egypt, Germany and the USA, Manag. Environ. Qual. An Int. J. 30 (2019) 116–136. https://doi.org/10.1108/MEQ-12-2017-0150.

[75]   D. Joseph R., P.C. Selvaraj, The Effects of Work Force Diversity on Employee Performance in Singapore Organisations, Int. J. Bus. Adm. 6 (2015). https://doi.org/10.5430/ijba.v6n2p17.

[76]   R.R. Pidani, A. Mahmood, F.W. Agbola, Does the board gender diversity enhance firm performance?, Asian J. Bus. Res. 10 (2020) 29–46. https://doi.org/10.14707/ajbr.200074.

[77]   A. Jaiswal, L. Dyaram, Perceived diversity and employee well-being: mediating role of inclusion, Pers. Rev. 49 (2020) 1121–1139. https://doi.org/10.1108/PR-12-2018-0511.

[78]   W. Li, X. Wang, M.J. Haque, M.N. Shafique, M.Z. Nawaz, Impact of Workforce Diversity Management on Employees' Outcomes: Testing the Mediating Role of a person's Job Match, SAGE Open. 10 (2020) 215824402090340. https://doi.org/10.1177/2158244020903402.

[79]   K.A. Jehn, G.B. Northcraft, M.A. Neale, Why differences make a difference: A field study of diversity, conflict, and performance in workgroups, Adm. Sci. Q. 44 (1999) 741–763. https://doi.org/10.2307/2667054.

[80]   A.I. Kusumah, A.I. Haryadi, A. Indrayanto, I. Setiawan, A mediating and moderating role on employee performance appraisal, Manag. Res. Rev. 44 (2021) 1639–1659. https://doi.org/10.1108/MRR-11-2020-0701.

[81]   G. Raad, N.F. Easa, Workgroup Diversity and Employees Work Performance: Insights into Lebanon, BAU J. - Soc. Cult. Hum. Behav. 2 (2020). https://doi.org/10.54729/2789-8296.1020.

ROASTING CONDITIONS AND QUALITY COFFEE: THE EMPIRICALLY OPTIMISED PROCESS

Nadiia Vakaryk
Institute of Biology, Chemistry and Bioresources, Yuriy Fedkovych Chernivtsi National University
2 Kotsyubynskoho Str., 58002, Chernivtsi, Ukraine
https://orcid.org/0009-0009-8582-1409

Anastasiia Sachko[*]
Associate Professor, Department of Chemistry and Food Analysis, Yuriy Fedkovych Chernivtsi National
University, 2 Kotsyubynskoho Str., 58002, Chernivtsi, Ukraine, an.sachko@chnu.edu.ua
https://orcid.org/0000-0002-3364-4297

Oksana Sema
Associate Professor, Department of Chemistry and Food Analysis, Yuriy Fedkovych Chernivtsi National
University, 2 Kotsyubynskoho Str., 58002, Chernivtsi, Ukraine
https://orcid.org/0000-0003-0159-2151

Igor Kobasa
Professor, Department of Chemistry and Food Analysis, Yuriy Fedkovych Chernivtsi National University
2 Kotsyubynskoho St., 58002, Chernivtsi, Ukraine
https://orcid.org/0000-0002-5184-468X

Sergey Gubsky
Associate Professor, Department of Chemistry, Biochemistry, Microbiology and Nutrition Hygiene
State Biotechnological University, 333 Klochkiwska Str., 61051, Kharkiv, Ukraine
sergey.m.gubsky@btu.kharkov.ua
https://orcid.org/0000-0003-0358-8682

This work was published free of charge as a publisher's support for Ukrainian authors struggling with wartime difficulties caused by Russian aggression against their country.

Highlight
Coffee roasting: the delicate balance between a skilled roaster's expertise and the science of optimising roasting conditions for the highest quality brew.

Abstract
The degree of roast, temperature and duration of the roasting phases of the coffee bean directly affect the sensory characteristics of the coffee cup. Therefore, to achieve the best roasting result, it is important to combine the human factor with special software products. To automate the roasting process, the Artisan roasting recording software was used. Automation of roasting allows better reproduction of the process conditions for different coffee samples. However, roasting is a rather complex and multi-stage process, and its automation does not guarantee the full reproduction and disclosure of the taste and aroma properties of the "perfect cup". Therefore, the qualifications, skills and experience of the roaster play a significant role in achieving and further reproducing the desired flavour profile.

Introduction
Coffee is one of the most popular drinks among the population due to its taste and aroma. However, the reproducibility of the taste and aroma of coffee is a rather complex process, which depends not only on the variety and storage conditions of the beans, but also on the coffee roasting process. From a sensory point of view, roasting has a great influence on coffee quality and is thus an important aspect of product differentiation

has a great influence on coffee quality and is thus an important aspect of product differentiation in the market [1]. Although the roasting process has been studied in great detail [2,3], there are many factors that depend directly on the roaster and cannot always be clearly unified. For example, even when using special software, the roasting process often stops when the beans reach a certain colour. In addition, in some cases, it is the roaster who determines the first crack has happened. Experience, skills and the human factor can affect the result even when roasting according to a known temperature profile. Although there are attempts to fully automate the control of the end of the roasting process, they are either under development or too expensive for small roasting shops [4]. Technically, the complexity of roasting beans lies in the fact that each type of coffee has its own unique properties and requires a certain temperature regime.

Roasting process causes a change in the structural-mechanical, thermophysical and sensory properties of coffee beans, which together determine the consistency, colour, odour, taste, which characterise the degree of readiness of the product. During coffee beans roasting, a complex mixture of volatile aromatic compounds are formed [2,5–7]. The main processes that occur during roasting are the decomposition of sugars and chlorogenic acid [8]. Moreover, the destruction of chlorogenic acid is more complete, the longer the roasting process and the higher the temperature [9]. At destruction of chlorogenic acid caffeic and quinic acid are formed. All these acids give coffee bitterness and astringency. Under the influence of temperature in coffee beans, about 50% of trigonelline is decomposed with the formation of decomposition products containing pyridine, nicotinic acid derivatives and several other organic substances. Pyridine is one of the substances that give coffee a specific aroma. In the process of roasting coffee beans, in addition to chemical transformations, a significant loss of moisture occurs on average from 11% to 3% [10,11]. Colour is a suitable indicator of the degree of roast for a given raw material. Traditionally the colour of coffee has been used to determine the degree of roasts and to enhance consistency in the end product. Nowadays, roast temperatures are recorded to allow the reproduction of previous roasts. However, roast profiles vary widely across different conditions and roaster designs. The aim of the study was to compare the organoleptic characteristics of coffee brewed from two types of Arabica and Robusta coffee beans roasted under different conditions (temperature and time).

Methods

Sampling

Two species of green coffee beans Arabica (Brazil Santos) and Robusta (Vietnam) were purchased from a local shop (Chernivtsi, Ukraine). Therefore, in the manuscript, the acronyms A for Arabica and R for Robusta samples were used to designate samples. In accordance with Standards coffee from the Specialty Coffee Association [12], each batch of coffee must be tested in the laboratory for six indicators: sensory (bean colour, surface characteristics, aroma, flavour and absence of defective beans), caffeine content, amount of extracted substances, ash content and metal impurities. Before the roasting process gets started, all defective beans are taken out from the samples [13]. After that, 1 kg of beans was weighed for roasting. Analysis of sensory characteristics and the humidity and density data (Table 1) allows you to assert compliance with the standards.

Table 1. Some physico-chemical properties of green coffee beans. *Source: Authors.*

Parameter	Arabica	Robusta	Standard magnitude
Humidity, %	9.9 ± 0.2	8.6 ± 0.2	8.0-12.0 [14]
Density, g/mL	0.784 ± 0.025	0.692 ± 0.025	0.404-0.891 [13]

Roasting process conditions

Roasting of coffee samples was carried out using a coffee roasting machine shop type TKM-SX 1 (Toper, Izmir, Turkey). The mass of loaded samples was 1 kg. Roasting was carried out in a gas roaster at the following temperatures: 180°C, 200°C, and 220°C for 9 - 11.5 minutes. The choice of temperatures was not random. Several studies, for example [15], it is conducted at temperatures of 160-185°C for light roasting, however, other studies claim that the best conditions for flavour and aroma development of coffee are roasting temperatures of 220 - 230°C. This is because at lower temperatures, only a peanut-like note appears instead of the real coffee taste [16]. The samples roasted at the appropriate temperature were designated for the Robusta variety as R1, R2 and R3, and for Arabica varieties as A1, A2 and A3. The samples were roasted using a combination of visual and software control for light-medium roast. The process of samples roasting was stopped when the colour of the beans reached the desired level. For all samples, frying was stopped until the second crack. The coffee roasters record, analyse and control toast profiles was carried out using an open-source software Artisan

(Development team, Germany) [17]. The parameters of the process of roasting samples of coffee beans are presented in Table 2.

Table 2. Roasting conditions for all samples. *Source: Authors.*

Sample	Maximum roasting temperature, °C	Drying time, min	Time to first crack, min	Development time, min	Total roasting time, min	Roast colour, Tonino scale value
A1	180	5:08	8:21	3:38	11:59	108
A2	200	4:44	7:32	2:10	9:43	109
A3	220	4:05	6:03	2:36	8:49	112
R1	180	5:25	7:41	4:26	10:67	114
R2	200	4:10	7:10	4:24	11:34	116
R3	220	4:01	6:05	2:39	8:44	117

In general, the roasting process can be represented as three stages, each of which corresponds to the time presented in Table 2. At the first, preparatory stage, a heat exchange balance is achieved between the roaster and green coffee beans. The temperature set here is required for drying. The second stage is characterised by the occurrence of Maillard reactions at temperatures below the caramelization temperature of sugars [18]. At this stage, characteristics such as body and sweetness are formed. The less coffee present at this stage, the lower the complexity and the lighter the taste. The last stage, called caramelization, is very important and is characterised by many chemical reactions occurring in parallel. The influence of the transformations of these substances on the sensory characteristics of coffee will be significant. The beginning of this stage is accompanied by the appearance of the first crack. If you heat coffee to the second cod or longer, there is a risk of setting it on fire. Then carbon and ash tones will appear in the taste, which will significantly worsen the quality of the finished drink. To achieve a dark roast coffee with a pronounced bitterness, the roasting process can last up to the second "crack" at a temperature of 250 - 260 °C. However, the risk of coffee burning is high, making it unfit for consumption [19]. After firing, all test samples were kept for degassing for 15 days. This process is very important for coffee quality. Degassing was performed at room temperature in open plastic containers. After completion of the degassing process, the density and moisture content of the beans were re-determined.

Physicochemical properties
The colour of the coffee was evaluated by a Tonino Color Meter for Roasted Coffee (Development team, Germany) [20]. This spectrophotometric method makes it possible to measure the colour of the roast on a special Tonino numeric scale independent of the production process. This scale ranges from 50 to 130, with a smaller number indicating darker roasts. Beans moisturiser before and after roasting were measured on a grain moisture tester PM-450 (Kett, CA, USA). The density of coffee samples was measured with a laboratory measuring cylinder according to standard methods [13]. The efficiency and quality of the extraction brewing was evaluated using the VST LAB Coffee III refractometer as an instrument for measuring the total dissolved solids percentage (% TDS) of coffee.

Sensory analysis
Specialty Coffee Association (SCA) based on the following ten indicators: Fragrance, Aroma, Flavour, Aftertaste, Acidity, Body, Uniformity, Balance, Clean cup, Sweetness, Overall [12]. The intensity of each sensory characteristic was recorded on a 10-point hedonic scale after 1 h orientation sessions. In this session the panellists had specified the terminology and anchor points on the scale. The sensory analysis and the "blind" tasting were conducted by ten trained coffee experts. The panellists stayed in the room with temperature 25 ± 2 °C and the relative humidity 55 ± 3%. The samples were prepared 1 h before the evaluation. Samples were kept in coded plates covered with aluminium foil. The coded samples were shown simultaneously and evaluated in random order. The roasted coffee samples for cupping were ground using a coffee grinder (grind size #12 - "coarse"). After that, 12 grams of coffee were weighed and poured into special cups for brewing. The water temperature used was 93°C. The water was poured in a way that created a funnel in the cup, which should lift all the coffee particles upward for proper extraction. After pouring the water, the coffee was allowed to steep for 4 minutes. A special spoon was used to break the crust that formed during brewing, and the aroma

of the beverage was immediately evaluated. Then, using special spoon movements, the remaining crust and foam were removed from the surface of the drink. After 9 minutes from the start of brewing, the coffee was ready for taste evaluation. The beverage was "slurped" to distribute it across the entire oral cavity, reaching every taste receptor. After that, the drink was cooled to room temperature, and a re-evaluation of the taste was conducted. The coded samples were shown simultaneously and evaluated in random order.

Statistical and data analysis
For the statistical analysis a one-factor analysis (ANOVA) for a series of parallel measurements. Value of $p < 0.05$ was considered statistically significant. The Tukey-Kramer honestly significant test was used to determine significant differences between means. All data were expressed as average value ± standard deviation. Basic statistics and ANOVA were performed using the statistical software package Minitab ver. 18.1 (Minitab Inc., USA). Principal Components Analysis (PCA) was performed on the panel averaged data using the Minitab ver. 18.1 (Minitab Inc., USA). The data were scaled by centring and divided by their standard deviation.

Results and discussion
A general overview of the roasting process (Table 2) shows that the duration of the drying stage of the samples decreased with increasing of maximum roasting temperature. So, for all samples, the drying time, roasting time and total time decreased with roasting temperature increasing.

The moisture and density of the beans after roasting for all samples is very close ($p<0.05$) and amounted to 1.3 - 1.4 % and 0.362 - 0.369 g/cm^3 for R1 - R3 samples, and 1.0 - 1.2 % and 0.396 - 0.404 g/cm^3 for A1 - A3 samples, respectively. This indicates the uniformity of roasting and the correctness of the visual assessment of the time of completion of the roasting process. The specified values are within the limits defined by the standards for these values. The decrease in density is associated with an increase in the volume of coffee beans during roasting. However, their characteristics do not provide any information about coffee-drink sensory characteristics.

More informative are the colours of coffee and the content of extractives (Table 2). As follows from the data in Table 2, the samples are not too different in colour. For both varieties, an increase in roasting temperature caused an increase in colour intensity, which is consistent with the data of other authors [21,22]. It should be noted that the darker colour of Robusta samples compared to Arabica samples, indicates the difference in their chemical composition [23]. Based on research [3], our samples can be classified as light roasts. In general, the colour determines the degree of roasting. However, it is important to remember that loss of moisture, change in density and colour may not be sufficient criteria to determine the degree of roast. The frying temperature must also be considered (Franca et al., 2009). The time and temperature of the Maillard Phase and Final Phase will have a significant impact on the opening of the coffee body and its acidity. Artisan-software provides feedback on various phases of the roast, including the finishing phase, to help achieve desired flavour profiles. In our case, samples R1, R2 and A1 were marked as "Flat". The temperature gradient was insufficient, and this warning indicates a possible sensory problem. The roaster must consider these guidelines to achieve the "perfect cup". This demonstrates the need for a combination of visual and hardware monitoring by roasting final point. The amount of extractives directly affects the taste of the drink. The content of extractive substances in espresso coffee is presented in Figure 1.

According to Coffee Standards by SCA [12] the content of extractives in roasted coffee (light and medium) should be 18 - 22 %. In our case, for samples R1 and A2 a significant excess of their content was obtained, which should have a negative effect on the taste of coffee drink. For the remaining samples, the content of extractives is near the upper limit of normal. On the contrary, if the coffee has a low amount of extractive substances, the drink may be weak, without sweet or aromatic nuances. The taste may not be rich enough. Capping was the most important step in this study. It is the taste and aroma of the finished drink, and not the colour of the beans or its physical and chemical properties, that are important for the end consumer. The reproducibility of the taste and aroma of coffee is a big problem. The results of capping all coffee samples are presented in Figure 2.

It can be seen from the petal diagrams (Figure 2) that the best taste and aroma properties are inherent in samples A3 and R2, and the worst in samples A1 and R1. Thus, the samples fried at low temperatures were not sufficiently balanced in acidity, their taste properties were also uncertain. Sample S1 was markedly bitter, and sample S2, with higher extractives, had an unpleasant tarry taste. The calculation of the total number of points for all

samples testified to the best organoleptic indicators of samples R2 and A3, and the worst for samples R1 and A1. The last samples were roasted at a temperature of 180 ⁰C, which is clearly not enough to fully reveal the taste and aroma properties of coffee in a drink. On the other hand, the coloration of these samples was the weakest, and the first crack appeared earlier than the rest of the samples. The taste of the samples turned out to be slurred with bitterness as a defect. The likely reason for this lies in the fact that coffee beans are more dried than roasted. This conclusion is consistent with the analysis of the study [16]. R3 and A3 samples lacked cup clarity and aftertaste. Due to the maximum roasting temperature, their colour was darker, and the content of extractives was relatively high. The resulting unpleasant aftertaste is probably associated with the formation of compounds that mask the characteristic taste and aroma of coffee [2]. It is important to note that the assessments of the experts coincided with those of the Artisan-software. The relationships between serving temperature and the sensory attributes were evaluated in PCA with all sensory attributes included. A total of 95.5% of the variance was explained in the first two components (Figure 3). First principal component (87.2%) described the difference between the lower 180 °C versus the higher 220 °C maximum roasting temperatures. Second principal component (8.3%) mainly described the difference between two species of green coffee beans Arabica and Robusta. Correlation of samples with attribute loads showed a clear separation of samples, shifting from more "uniformity", "clean cup", "acidity", "aftertaste" characteristics (A1 - A3) to more distinct "aroma", "flavour" characteristics (R1 - R3).
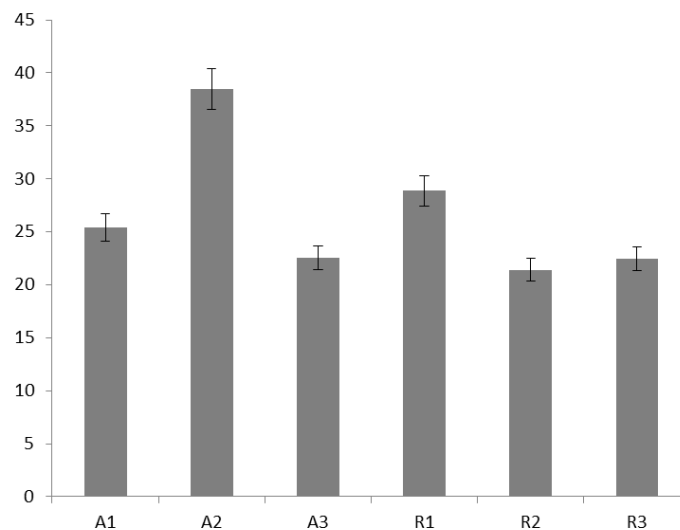

Figure 1. The content of extractives in espresso coffee made from samples. *Source: Authors.*
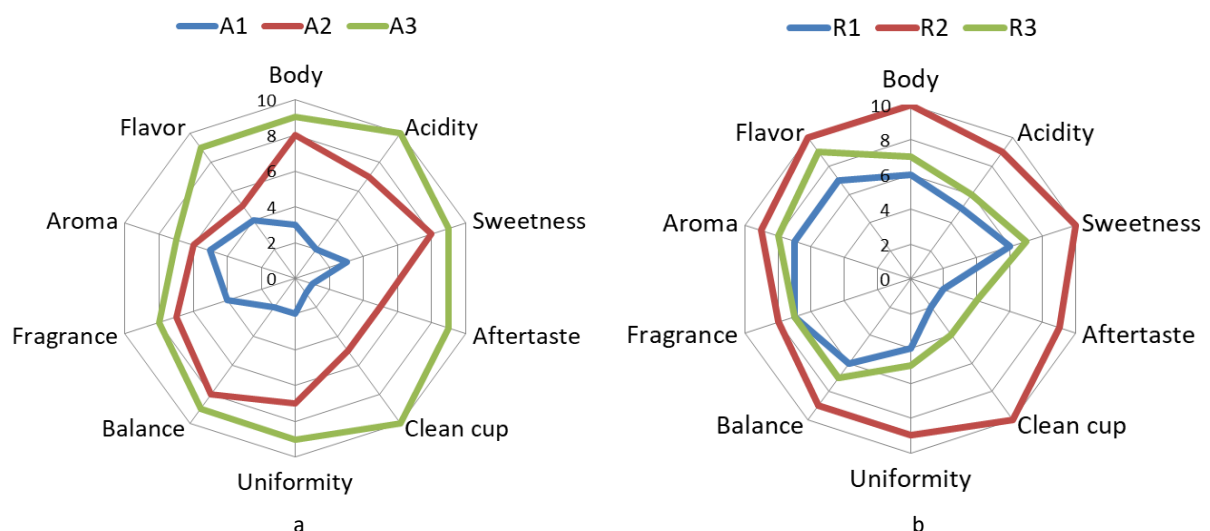

a

b

Figure 2. Spider plots showing consensus mean scores of espressos sensory evaluation (a) Arabica Santos and (b) Robusta Vietnam. *Source: Authors.*
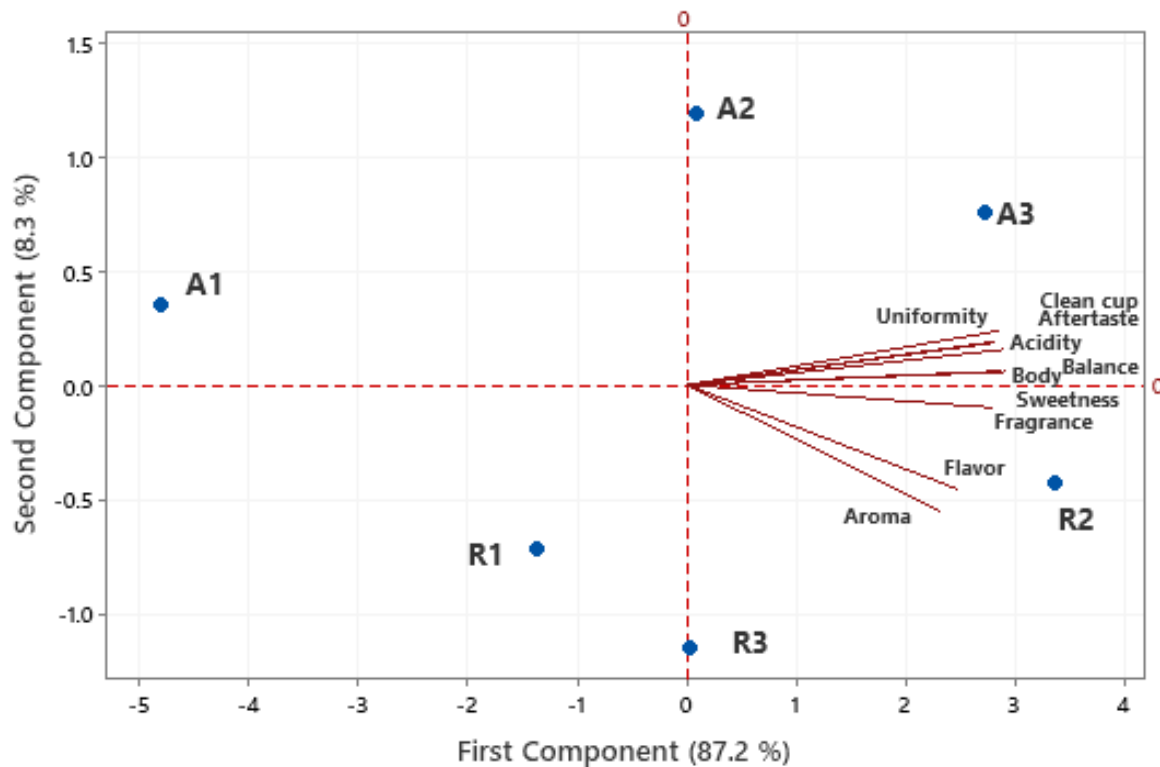
Figure 3. PCA bi-plot: loading of sensory characteristics of espresso coffee and scope of roasted coffee beans samples. *Source: Authors.*

None of the samples received the maximum score from the experts. For A3, the taste is shifted towards acidity, and the palatability is not sufficiently developed and pronounced (Figure 3). For R2, we didn't reveal enough flavours. Thus, the best roasting conditions for Vietnam Robusta were the maximum roasting temperature of 200 °C and the time of coffee in the roaster of 11:34 min for sample R2. Arabica Santos, known as a mild coffee with a comparatively low caffeine content [24], required a higher temperature of 220 °C with a faster roast time of 8:09 min for sample A3. For both samples, the duration of the drying step was almost the same, but sample R2 needed a longer firing than sample A3. These conditions make it possible to obtain coffee with a rich colour, with the content of extractive substances corresponding to the standard [13] and a good balance of taste and aroma properties.

It should be noted that the empirical study made it possible to obtain results that are fair for the tested conditions, which determine their limitation. Similar judgments are also given by the authors of a multi-study empirical investigation [1]. The main aspect limiting the wide application of the results is the use of unwashed coffee beans roasted using a coffee roasting machine shop type TKM-SX 1 with a flame drum. This should be considered when generalizing these results to both other types of processed coffee and other roasters, especially if the scale of the process extends beyond the coffee house. The process of roasting coffee in the production workshops of enterprises and small coffee houses is fundamentally different. Full automation and unification, combined with optimization of the duration of processes as a systematic approach, are important in the enterprise, which will certainly affect the quality of the product. Smaller coffee shops are more focused on a specific segment, using more expensive coffees and a much more flexible empirical process with a combination of visual and hardware control at the final stage of roasting. Visual control allows you to observe the change in colour and appearance of the beans during roasting, and hardware control can provide accurate numerical data. However, even with the correct use of the software, there are many factors that directly affect the "final cup". These factors contribute to achieving the desired result in achieving optimal coffee taste and quality.

Impact
The implementation of the research results will improve the technology of roasted coffee beans to obtain a quality beverage. This will contribute to the solution of an important social task of improving the health

of the population. On the one hand, coffee is one of the most popular beverages in the world, the consumption of which is growing significantly from year to year in many countries, including Ukraine. The main reason for this fact is the desire to satisfy the need, intensify activity or simply relax. These are important factors for creating an atmosphere of maximum effective work for members of a sustainable community. On the other hand, scientists argue that there are benefits from quality natural coffee. So, for women, caffeine as a component of coffee speeds up metabolism, stimulates digestion and promotes weight loss. For men, natural coffee's health benefits lie in its aphrodisiac action, an important aspect of population demographics.

The shift in the consumer's focus towards the consumption of natural coffee from roasted coffee beans compared to instant coffee allows reducing additional and rather significant energy costs that occur at the freeze-drying stage. It is an important economic factor for coffee industry enterprises.

Conclusions

The overall aim of this investigation was to assess the relative importance of roasting temperatures on the sensory properties of coffee. It has been shown that roasting conditions (maximum temperature, duration of drying and roasting processes) significantly affect both the physicochemical and sensory characteristics of he finished drink. The results obtained indicate that roasting coffee at temperatures below 200 $^{\circ}$C does not allow for sufficiently revealing the taste and aroma during brewing: the drink is unsaturated and inexpressive. The combination of high temperatures (200 - 220 $^{\circ}$C) with moderate ageing in the roaster allows you to achieve good results. Even with the use of special software, the roaster's qualifications have a strong impact on the result. For example, they must understand the raw materials they are working with; conduct an auditory (crackle) and visual (bean colour) assessment of the process; understand the impact of roasting parameters (temperature, duration of stages, profiles) on the physical and chemical processes that occur in the beans; and systematically document the roasting process and its parameters to achieve the desired flavour profile.

Conflict of interest

There are no conflicts to declare.

References

[1]   M. Münchow, J. Alstrup, I. Steen, D. Giacalone, Roasting conditions and coffee flavor: A multi-study empirical investigation, Beverages. 6 (2020) 1–14. https://doi.org/10.3390/beverages6020029.

[2]   S. Schenker, C. Heinemann, M. Huber, R. Pompizzi, R. Perren, F. Escher, Impact of roasting conditions on the formation of aroma compounds in coffee beans, J. Food Sci. 67 (2002) 60–66. https://doi.org/10.1111/j.1365-2621.2002.tb11359.x.

[3]   F. Wei, M. Tanokura, Chemical Changes in the Components of Coffee Beans during Roasting, in: Coffee Heal. Dis. Prev., Elsevier, 2015: pp. 83–91. https://doi.org/10.1016/B978-0-12-409517-5.00010-3.

[4]   D.S. Leme, S.A. da Silva, B.H.G. Barbosa, F.M. Borém, R.G.F.A. Pereira, Recognition of coffee roasting degree using a computer vision system, Comput. Electron. Agric. 156 (2019) 312–317. https://doi.org/10.1016/j.compag.2018.11.029.

[5]   D. Knysak, Volatile compounds profiles in unroasted Coffea arabica and Coffea canephora beans from different countries, Food Sci. Technol. 37 (2017) 444–448. https://doi.org/10.1590/1678-457x.19216.

[6]   F.M. Borém, G.F. de Abreu, A.P. de C. Alves, C.M. dos Santos, D.E. Teixeira, Volatile compounds indicating latent damage to sensory attributes in coffee stored in permeable and hermetic packaging, Food Packag. Shelf Life. 29 (2021) 100705. https://doi.org/10.1016/j.fpsl.2021.100705.

[7]   R.F. LeBouf, B.H. Blackley, A.R. Fortner, M. Stanton, S.B. Martin, C.P. Groth, T.L. McClelland, M.G. Duling, D.A. Burns, A. Ranpara, N. Edwards, K.B. Fedan, R.L. Bailey, K.J. Cummings, R.J. Nett, J.M. Cox-Ganser, M.A. Virji, Exposures and Emissions in Coffee Roasting Facilities and Cafés: Diacetyl, 2,3-Pentanedione, and Other Volatile Organic Compounds, Front. Public Heal. 8 (2020). https://doi.org/10.3389/fpubh.2020.561740.

[8]   J.R. Santos, O. Viegas, R.N.M.J. Páscoa, I.M.P.L.V.O. Ferreira, A.O.S.S. Rangel, J.A. Lopes, In-line monitoring of the coffee roasting process with near infrared spectroscopy: Measurement of sucrose and colour, Food Chem. 208 (2016) 103–110. https://doi.org/10.1016/j.foodchem.2016.03.114.

[9]   P. Diviš, J. Pořízka, J. Křikala, The effect of coffee beans roasting on its chemical composition, Potravin. Slovak J. Food Sci. 13 (2019) 344–350. https://doi.org/10.5219/1062.

[10]   R. Geiger, R. Perren, R. Kuenzli, F. Escher, Carbon dioxide evolution and moisture evaporation during roasting of coffee beans, J. Food Sci. 70 (2005) E124–E130. https://doi.org/10.1111/j.1365-2621.2005.tb07084.x.

[11]   J. Baggenstoss, L. Poisson, R. Kaegi, R. Perren, F. Escher, Roasting and aroma formation: Effect of initial moisture content and steam treatment, J. Agric. Food Chem. 56 (2008) 5847–5851. https://doi.org/10.1021/jf8003288.

[12]   Specialty Coffee Association, Coffee Standards, (2018) 4–14. https://static1.squarespace.com/static/584f6bbef5e23149e5522201/t/5bd985c1352f53cb4cc1be48/1540982325719/Coffee+Standards-Digital.pdf.

[13]   ISO (International Organization for Stardardization), Green and roasted coffee - Determination of free-flow bulk density of whole beans (Routine method), (1995) 1–3.

[14]   International Organization for Standardization, ISO 1446:1978 - Green coffee — Determination of moisture content (Basic reference method), (n.d.). https://www.iso.org/standard/6042.html.

[15]   I. Hečimović, A. Belščak-Cvitanović, D. Horžić, D. Komes, Comparative study of polyphenols and caffeine in different coffee varieties affected by the degree of roasting, Food Chem. 129 (2011) 991–1000. https://doi.org/10.1016/j.foodchem.2011.05.059.

[16]   R. SILWAR, C. LÜLLMANN, Investigation of aroma formation in robusta coffee during roasting, Café, Cacao, Thé. 37 (1993) 145–152.

[17]   Artisan, Coffee roasting software - artisan, (2023). https://artisan-scope.org/.

[18]   D.J.R. Manley, Technology of biscuits, crackers, and cookies. 2nd ed., Ellis Horwood Ser. Food Sci. Technol. (USA). (1991).

[19]   N.C. Bicho, A.E. Leitão, J.C. Ramalho, N.B. De Alvarenga, F.C. Lidon, Identification of nutritional descriptors of roasting intensity in beverages of Arabica and Robusta coffee beans, Int. J. Food Sci. Nutr. 62 (2011) 865–871. https://doi.org/10.3109/09637486.2011.588594.

[20]   Tonino, Color meter for coffee roasters, (2023). https://my-tonino.com/.

[21]   J.C.F. Mendonça, A.S. Franca, L.S. Oliveira, Physical characterization of non-defective and defective Arabica and Robusta coffees before and after roasting, J. Food Eng. 92 (2009) 474–479. https://doi.org/10.1016/j.jfoodeng.2008.12.023.

[22]   L.R. Cagliani, G. Pellegrino, G. Giugno, R. Consonni, Quantification of Coffea arabica and Coffea canephora var. robusta in roasted and ground coffee blends, Talanta. 106 (2013) 169–173. https://doi.org/10.1016/j.talanta.2012.12.003.

[23]   A.B. Rubayiza, M. Meurens, Chemical discrimination of arabica and robusta coffees by fourier transform raman spectroscopy, J. Agric. Food Chem. 53 (2005) 4654–4659. https://doi.org/10.1021/jf0478657.

[24]   H.D. Belitz, W. Grosch, P. Schieberle, Food chemistry, 2009. https://doi.org/10.1007/978-3-540-69934-7.

OPTICAL ROUGHNESS CALCULATION FOR MATERIAL STRUCTURAL ANALYSIS OF ENERGY STRUCTURE APPLICATIONS UNDER DC PLASMA PROCESSES

Alper Pahsa*

Graduate School of Natural and Applied Sciences, Ankara Yıldırım Beyazıt University
Ankara, Türkiye, apahsa@gmail.com
https://orcid.org/0000-0002-9576-5297

Highlight

Material structural reliability for low-dc plasma materials is determined by Weibull reliability predictions with surface roughness properties of materials in the determination of TOKAMAK fusion reactor structural design issues.

Abstract

Surface qualities make aluminium a low-DC plasma interaction candidate. Aluminum for energy system structure building is studied experimentally, with observations obtained. Aluminum is cheap and frequently utilized in aerospace applications. The selection of materials for new applications of thermonuclear fusion energy, such as Tokamak reactor walls and fusion-based spaceship thrust structures, is important to decide in the design phase. In this study, an experimental setup application is created with low DC-type He plasma ions processed on aluminium pellet surfaces. The physical changes of the aluminium pellet material as an example of an energy structure surface are analysed under a scanned array microscope and 3D surface plots to detect optical roughness attributes.

Keywords

Tokamak reactors; plasma material interaction; sputtering; 3DSurface Plot; optical roughness.

Introduction

Aluminum (Al) material is found in increasing usage in automotive, aerospace, defence, and energy industrial applications. The main reason to thrust Al is its strength-to-weight ratio, together with its good casting ability and machinability. Aluminum is a lightweight material with a density of 2.7 g/cm^3. Pure aluminium and its alloys have a face-centred cubic (fcc) structure. It is stable at a melting point of 657°C. Because the fcc structure includes multiple slip planes, this crystalline structure affects the excellent formability of Al alloys.

Figure 1. Pure Aluminum Metal Ore. *Source: [1].*

Though aluminium is a thermodynamically reactive material, it has good corrosion resistance. Because of the formation of a compact and adherent oxide film on the surface, it is used in many applications in structures in building construction, power lines, transportation fields, food, and the chemical industry. However, in aggressive environments, such as high-temperature plasma, space environments, and/or petroleum environments, aluminium surfaces can be subjected to many surface changes due to wear and erosion. One of

the most important considerations to minimize the cost in industry is to make it possible to decrease equipment downtime [2]. Energy systems and space applications Fusion reactors are ideal for energy production. It is an ideal application without radioactivity, and it has an endless fuel source. In fusion energy reactors, nuclear fusion reactions in the core plasma generate energetic particle sets, including He and neutrons for H-based fuels [3]. If two nuclei combine to form a single, larger nucleus, a process called nuclear fusion occurs. That process is blocked by Coulomb repulsion, which acts to prevent the two positively charged particles from coming close enough to be within range of their attractive nuclear forces and "fusing". The range of the nuclear force is short, hardly beyond the nuclear "surface", but the range of the repulsive Coulomb force is long, and that force thus forms an energy barrier. The height of this Coulomb barrier is related to the charges and the radii of the two interacting nuclei. For two protons, the barrier is 400 keV. With respect to highly charged particles, it is certain that the barrier is correspondingly higher. This formation is generally seen in plasma environments. Plasma is an electrically conducting fluid that is electrically neutral from the outside, in which ions and electrons move independently of each other. In fusion reactors submerged in a magnetic field, ions and electrons move on a helical trajectory winding around field lines and will be forced to move along the field. This is the magnetic confinement principle on which TOKAMAK fusion reactors are based [4]. Nuclear fusion also offers many opportunities for space applications. The future of nuclear technology for space exploration promises even more remarkable journeys and amazing discoveries. Future space missions will need increased power for propulsion and surface power applications to support both robotic and human space exploration missions. However, in normal fusion reaction operations, magnetic confined reactor structures or nuclear electric propulsion system structures are exposed to neutronic, thermal, radiative, and thermomechanical stress loading. Moreover, the management of the interface between the plasma and the wall structures is critical [5]. Furthermore, the main results obtained concerning confinement, like H mode, were based on efficient management of this interface. Several types of phenomena may enter play at the wall, for instance, the absorption of large quantities of gas issued by the plasma, erosion due to the action of fast particles, and heating (the heat flux can reach several megawatts per square meter). This process causes plasma radiation to lose a significant quantity of temperature and the type of impurities that plasma contains. This process causes the plasma wall to deteriorate over time and to release neutrons into the environment [3,6–16]. The interaction of plasma with the reactor walls has been one of the critical issues in the development of fusion energy reactors because plasma-induced erosion can seriously limit the lifetime of the wall components [17–19]. Therefore, in space applications, plasma-facing structures must be designed to minimize this type of effect and to withstand particles and radiation from the plasma.

In the literature, there are many studies related to plasma-tokamak reactor structural material interactions. In divertor sections, rising He ash measurements in ITER or DEMO-type reactors are stated. Studies reflect the effects of alpha particle concentration on plasma processes, and the calculations are given as zero-dimensional power and particle balance equations. As a result of this, fusion reactions and optimum conditions are investigated. The studies also show that hydrogen ash because of the deuterium-tritium reaction cannot be avoided in fusion. In respect to ITER and DEMO class reactors, experimental work underlines the importance of low-activation materials such as steel, SiC ceramic composites, and vanadium alloys in the material selection of the reactors resistant to fusion sputtering. As new materials are found in these investigations, new types of diagnostic tools and measurement techniques are also included [4,20,21]. In this study, Al material is selected as a candidate material for energy system structures in reactor wall structures, either in reactors or in space applications. In the experiment setup, a plasma of He ions is generated at a high DC voltage and low temperature. The generated plasma is directed at an aluminium target, and the deformation of the target is analysed as a function of interaction time. Then the aluminium target pellets surface roughness is physically observed under a scanning electron microscope, the images are analysed to derive the optical roughness of the surface of the metal image, and their surface plot mesh graph is drawn. So that created optical roughness information can be used in calculating the structural reliability calculations in future studies. This study brought a new perspective to the derived fault data by using the optical roughness parameters in future structural reliability calculations. So that the structural reliability calculations of the Tokamak fusion reactor will be made in a cost-effective manner.

Methods
In the experimental study, a setup was designed for the plasma-wall interaction. This setup helps to observe the plasma wall interaction and the plasma-surface interaction. Moreover, deformations on the surface are observed, and the material reliability of the target is calculated. The experimental setup schema considered in the work is shown in figure 2. In this setup, the air in the vacuum-able plasma boiler tube was initially evacuated

with the help of a vacuum pump. Then he flowed into the tube, and plasma was obtained by ionizing the gas inside with the high DC voltage applied between the cathode and the anode made up of Al. The effect of plasma and the surface of the Al anode and cathode plates are interacted. The physical effects of these plates were investigated. In the study, it was originally designed to make the plasma boiler tube from Al, but because of insulation problems and the possibility of arcing, the Al boiler was abandoned, and a quartz boiler (tube) was produced. Since the aim of the work is to concentrate on the physical surface effects on the Al anode and cathode surfaces, the Langmuir probe is not applied in the experiment. The same amount of vacuum and hydrogen gas is fed into the boiler as a control point in the experiment. So that the measurement of the plasma density in the tube was not observed.

The plasma beam is produced under high DC potential in the experimental setup given in figure 2. A 10 kV DC voltage source is applied between cathode and anode to ionize He in an evacuated glass hollow tube. The produced He ions and ejected electrons are then struck onto aluminium plates placed at the anode and cathode, respectively. The distance between the anode and cathode plates is placed at 5 cm to get plasma, as seen in figure 3. He plasma is generated by vacuuming the quartz tube many times until it reaches a 10 - 3 Torr vacuum and is filled fully with He gas. This process is repeated 5 - 6 times until the tube is free of air and the inside of the tube is filled with hydrogen gas from the input end. After the process to stabilize the hydrogen gas inside the quartz tube, a small pipe is connected to the exit end. This pipe of the quartz tube is put into the water-filled container. This is provided that stabilized He gas reside inside the quartz tube and that, at the same time, He gas flow is given at the input end of the quartz tube at 100 ml/min under atmospheric pressure. The used He gas was 99.9% pure, and the total gas flow rate was 100 ml/min.
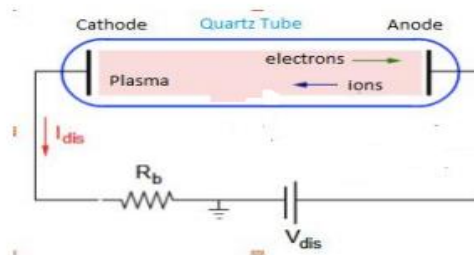

Figure 2. Experimental Setup Schema. *Source: [16].*

Figure 3. Generated He Plasma.

For the experiment, six aluminium pellet samples were made. Each time, two plates were placed at the cathode and anode, respectively, and subjected to the radiation for a time value of 60, 120, 180, 240, 300, and 360 minutes. The anode and cathode surfaces are affected by the He plasma. A Field Emission Scanned Electron Microscope (HITACHI SU5000 Scanned Field Emission Scanned Array Microscope) is used to display the detailed surfaces of the Al pellet surfaces at the final stage. SEM measurements are performed at room temperature (25°C). For anode and cathode, grey-scale value images are produced for different magnification scales under SEM. These images are used to calculate the following optical roughness parameters, respectively:

- Ra: Arithmetical mean deviation.
- Rq: Root means square deviation.

- Rku: Kurtosis of the assessed profile.
- Rsk: Skewness of the assessed profile.
- Rv: Lowest valley (given by the min measurements).
- Rp: Highest peak (given by the max measurements).
- Rt: The total height of the profile.

The above parameters are calculated for each SEM image for the anode and cathode of the pellet for different He plasma process times. The above optical roughness parameters were calculated using the open-source application Image [22]. It is a widely used research application in scientific image processing studies. Also, a surface mesh plot is performed for the surface images under SEM to see the peaks and valleys of the image. Table 1 shows the al anode and cathode samples that are irradiated with he plasma with different time processes and SEM image optical roughness parameters. In Table 1, optical roughness parameter values are going to be used in the three-parameter Weibull formula in the future for calculating the reliability of the Al under he plasma.

Table 1. He Plasma Al plate SEM Image Optical Roughness Failure Data Set.

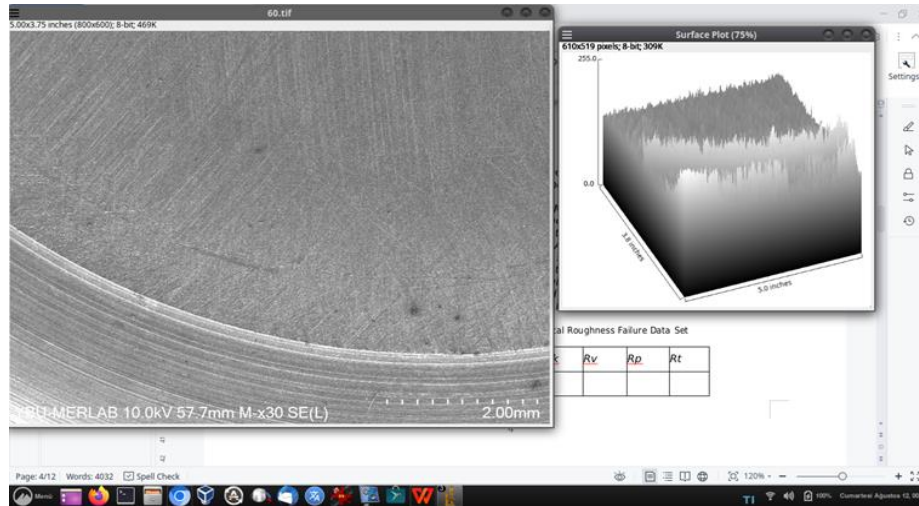| Sample Image Label	Ra	Rq	Rku	Rsk	Rv	Rp	Rt
60 min,2mm, Cathode	146.699	144.636	1.047	1.139	255	65	320
60 min, 500nm, Cathode	94.475	87.323	1.221	1.675	255	15	270
60 min,1μm, Cathode	91.764	84.420	1.313	2.114	255	3	258
60 min,3μm, Cathode	96.324	89.212	1.270	1.905	255	0	255
60 min,10μm, Cathode	95.300	88.055	1.298	2.035	255	0	255
60 min,50μm, Cathode	90.370	80.283	1.433	2.533	255	0	255
240 min,2mm, Cathode	126.826	125.879	1.025	1.080	255	74	329
240 min,50μm, Cathode	119.681	110.727	1.237	1.731	255	0	255
240 min,10μm, Cathode	104.405	96.393	1.266	1.866	255	0	255
240 min,3μm, Cathode	103.252	94.389	1.302	2.003	255	0	255
240min,500mm, Cathode	78.738	71.791	1.296	2.060	255	0	255
360 min,2mm, Cathode	128.992	127.426	1.039	1.119	255	76	331
360 min,50μm, Cathode	76.864	69.235	1.470	2.908	255	0	255
360 min,10μm, Cathode	97.095	89.890	1.307	2.094	255	0	255
360 min,3μm, Cathode	94.678	87.759	1.278	1.969	255	0	255
360 min,1μm, Cathode	93.285	86.242	1.284	1.977	255	0	255
360 min,500nm, Cathode	79.299	71.734	1.342	2.218	255	0	255
120 min,2mm,Anode	151.888	149.898	1.041	1.117	255	61	316
120 min,500mm,Anode	88.241	81.285	1.263	1.877	255	0	255
120 min,1μm,Anode	85.792	79.167	1.254	1.868	255	0	255
120 min,5μm,Anode	96.291	89.742	1.308	2.148	255	0	255
120 min,10μm,Anode	95.707	88.797	1.314	2.146	255	0	255
120 min,50μm,Anode	93.920	84.694	1.432	2.613	255	0	255
180 min,2mm,Anode	155.080	152.316	1.054	1.152	255	75	330
180 min,50μm,Anode	89.547	79.882	1.361	2.170	255	0	255
180 min,10μm,Anode	92.543	85.033	1.279	1.908	255	12	267
180 min,3μm,Anode	96.664	90.163	1.222	1.700	255	23	278
180 min,1μm,Anode	96.032	89.726	1.211	1.662	255	16	271
180 min,500nm,Anode	94.741	88.636	1.218	1.702	255	33	288
300 min,50μm,Anode	95.030	83.355	1.422	2.423	255	0	255
300 min,10μm,Anode	95.236	88.178	1.259	1.849	255	0	255
300 min,5μm,Anode	96.201	89.345	1.237	1.761	255	0	255
300 min,3μm,Anode	96.074	89.421	1.227	1.720	255	0	255
300 min,500nm,Anode	95.245	88.992	1.212	1.670	255	5	260
300 min,1μm,Anode	98.728	92.601	1.207	1.655	255	14	269
300 min,10μm,Anode	95.276	88.177	1.275	1.937	255	0	255

Results and discussion

Figure 4 displays physical surface plots and grey scale views of SEM on the surface of Al samples at the anode and cathode at 60, 180, 200, 240, 300, and 360 minutes under He plasma interaction. In these sample fields

of grains, black points and semi-grey spots are seen. SEM surface plots showed hills (high areas) and holes (low areas) on the Al pellet surfaces. The material reliability will be calculated with optical roughness parameters at Al anode pellets and cathode pellets to make comparisons as in reliability graphs. These results will show the status of the surface attributes of the optical roughness measures. So that material selection criteria will be determined for plasma-based energy structures such as fusion Tokamak reactors or space thrust systems based on fusion architecture.

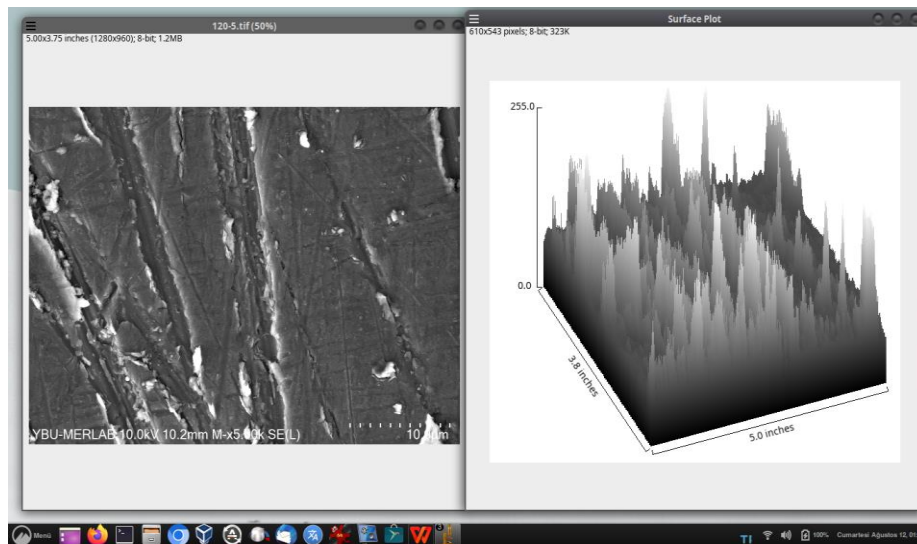| Sample Image Label	SEM Image Views and Surface Plots of the SEM Images
60 min, 2mm, Cathode	
240 min, 3µm, Cathode	
360 min, 1µm, Cathode	
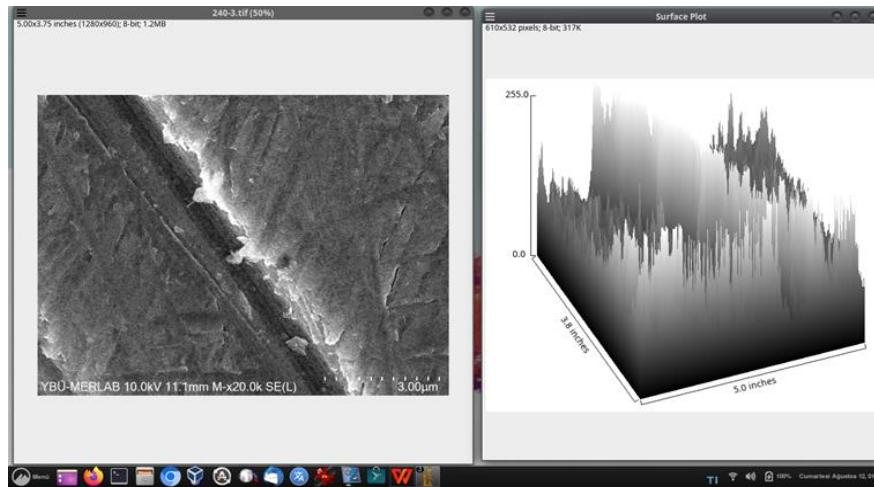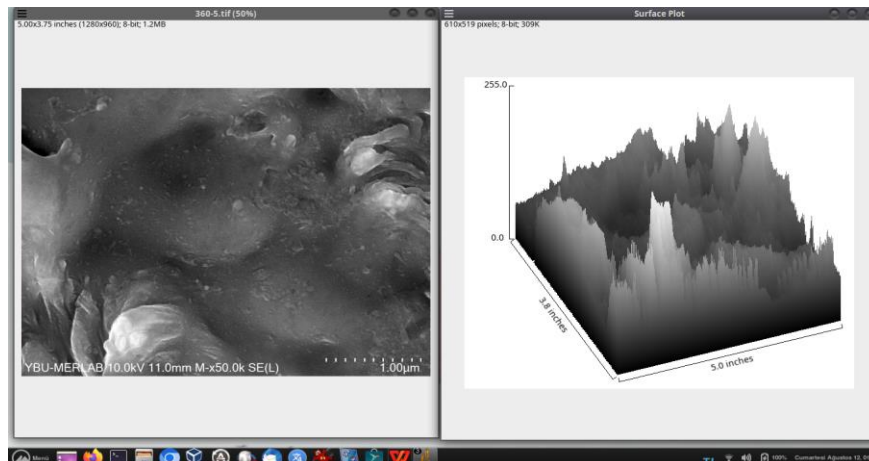
120 min,10μm,
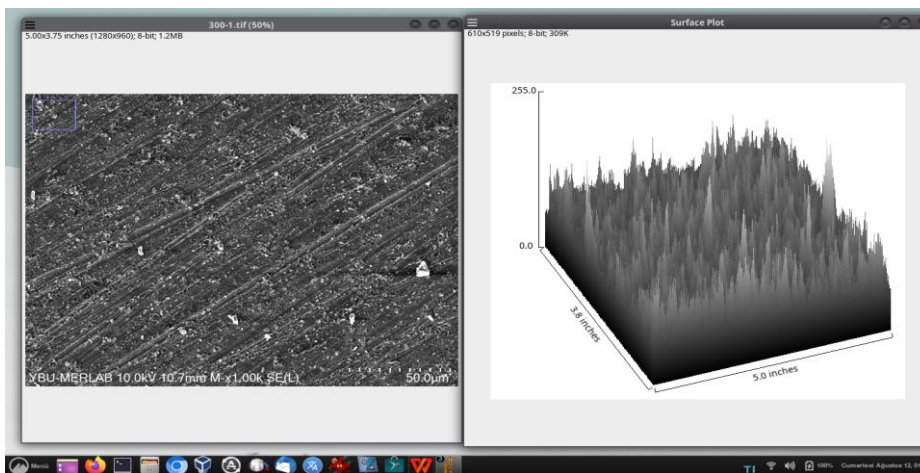Anode

300 min,50μm,
Anode

Figure 4. SEM Al surface observation images and their 3D surface of anode and cathode pellets with different process time under He plasma.

Based on the above findings, the observations given in Table 1 are compared with the findings given in [23]. According to [23], the study is performed under an atomic force microscope (AFM) and precisely measured, and the process is based on ASME B46.1 standard-defined terms Sa and RMS values. According to the ASME B46.1 standard, Sa (surface roughness) and RMS (root mean square) both represent surface roughness, but each is calculated differently. Sa is calculated as the roughness average of a surface's measured microscopic peaks and valleys. RMS is calculated as the root mean square of a surface measured by microscopic peaks and valleys. In the study above, ImageJ software is used on the SEM images for different plasma processing times to determine the optical roughness characteristics.

Using Table 1 and the study [23], the following graphs are generated for the common process times given in both methods:
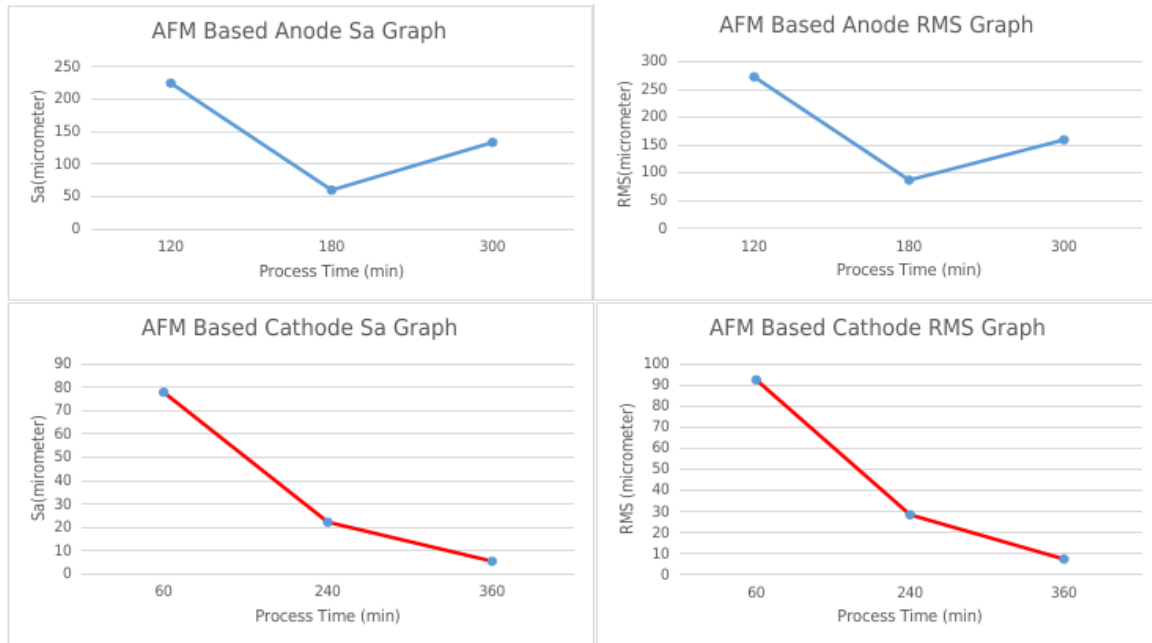
Figure 5. AFM Measured RMS and Sa Graphs of Anode and Cathode Surface Pellets Based on Different Process Times (min).
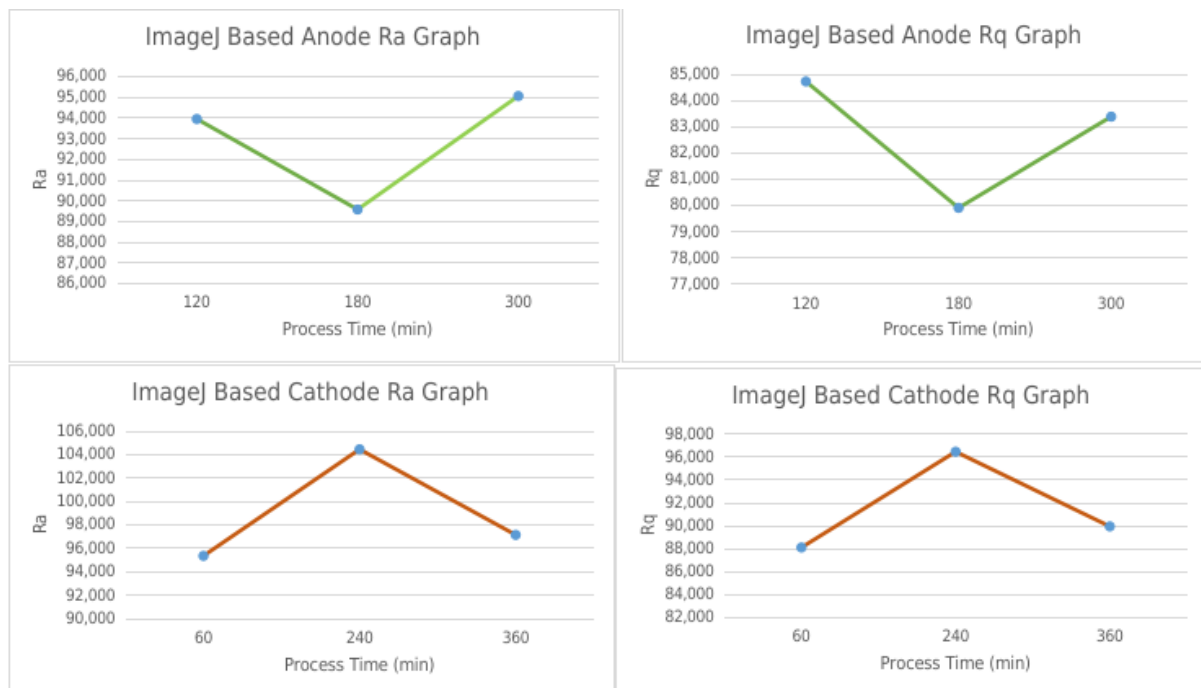

Figure 6. ImageJ Software Measured Rq and Rq Graphs of Anode and Cathode Surface Pellets Based on Different Process Times (min).

The same graphs are produced based on the Table-1 values for specified process times of the AFM measurements of anode and cathode pellets. In this case, the measured optical roughness values are Ra and Rq values measured under ImageJ software SEM images. The given figure 6 shows the anode and cathode surfaces of Ra and Rq at the specified process times as given in figure 5. The two measurements are compared by using the correlation function to determine if Ra values can be used for Sa and Rq values can be used for RMS. The correlation function is a statistical measure of strength used to determine the linear relationship between two variables. When the correlation of the two series is input, the correlation function then maps the output range between – 1 and 1. A correlation coefficient of -1 determines a perfect negative or inverse correlation, and a correlation coefficient

of 1 shows a perfect positive correlation. If the correlation coefficient shows 0, then there is no linear relationship between the values. To calculate the correlation, each series is determined by calculating the standard deviation and the covariance between them. The correlation coefficient is covariance divided by the product of the two variables' standard deviations [24].

Table 2. He Plasma Al Anode and Cathode Plates AFM Measurements (Sa and RMS) and ImageJ Calculations (Ra and Rq) Correlation Results.

Correlation Table	AFM Measurement of Anode for Sa	AFM Measurement of Anode RMS	AFM Measurement of Cathode for Sa	AFM Measurement of Cathode RMS
ImageJ Measurement of Anode Ra	0.711678358			
ImageJ Measurement of Anode Rq		0.92994807		
ImageJ Measurement of Cathode Ra			-0.468889172	
ImageJ Measurement of Cathode Rq				-0.474880479

According to Table 2, AFM measured anode Sa and RMS values, and InageJ calculated Ra and Rq values for the same processing times, showing a positive correlation above 0. AFM measured cathode Sa and RMS ImageJ calculated Ea and Rq values are negatively correlated.

Impact
This study provides a cost-efficient methodology for comparison method criteria to determine the material selection in designing Tokamak fusion reactors for future reactor wall structures. This method can be used to directly calculate different material optical characteristics for library generation so that the designers of future fusion reactors can use this bias to create the best match for their blueprints. This phenomenon will be used in designing economic budgets for the Tokamak fusion reactor's construction to underline productivity, efficiency, durability, and sustainability cost factors of the reactor's structural and operational lifetime.

Conclusions
From the results given above, optical roughness parameters are analysed by using image processing techniques on the surface structures of materials. According to the observations given in the results section, it is clearly determined that the ImageJ calculated optical roughness parameters can be used for anode pellets; however, in the cathode section, it is observed that there is a negative correlation that the calculated optical roughness parameters show unsatisfactory results. The reason for the negative correlation given in cathode pellet calculations for optical roughness parameters is that the original SEM images of the cathode pellets sampling size should be increased, and more images must be taken with the SEM. Another solution to increase the positive correlations between AFM measurements is to use metal microscope taken images to take more sample images from cathode pellets to increase the measurement samples and determine a satisfactory relationship for future uses. It is also expected to be a difference between the anode and cathode surfaces under the plasma process. This can be observed from the optical roughness parameters when compared with the AFM measurements for anode and cathode surfaces. Optical roughness measurement shows a promising method for future usage in material reliability calculations when precise sampling and calculations are performed during the experiments for future studies. This method is already used in different sectors of the manufacturing industry for quality control purposes. By spreading this technique to be used in the energy industry for material selection, it will achieve a cheap solution and cost-efficient method for the aviation and defence industries for calculating structural reliability predictions. In reliability literature, it is widely known that material structural reliability is investigated using five methods. These are material selection, reliability analysis, maintenance and inspection, heat and stress, and erosion and damage. In the literature, the structural reliability of Tokamak fusion reactors is not studied based on the values of the huge fusion reactor experiments. Construction and design of the Tokamak fusion reactors are focused on building costs. However, maintenance and material resilience are other questions that need to be asked during the operation. To calculate operational costs, an expert should consider material life cycle costs and maintenance costs for a fusion reactor's resilience. Material life cycle costs are directly tied to the material reliability data that must be known during construction and operation. In this respect, no special study is found in the literature with

respect to fusion reactors. Only commercial plasma reliability studies that are found in the literature are based on surface coating. This is not satisfactory in the determination of the structural reliability data for fusion reactors. In reliability data, faults need to be known as properties of the investigated subject. In this respect, fatigue, crack, and deformation information can be used to show the reliability of structural material studies of fusion reactors. This work's results will be used in calculating the optical roughness information for material directly from the fault data under a plasma processing activity, and this direct information can be used in predicting the characteristic curve of the material structure based on the Weibull Prediction method. As this statistical information is found, for candidate structural materials that are selected for fusion reactor construction, the life cycle time of the designed material will be known by using its measured surface roughness data over time specific to the selected material. Knowing the life cycle time of the material, the operational costs of the selected material will be determined. As a result, fusion reactor construction costs will be calculated directly during the planning phase of the construction work.

Conflict of interest
During the study of the work, no potential financial or non-financial conflict of interest existed. Also, with the study, no informed consent of human participants and/or animals was used, and the study complied with the widely accepted ethical codes of world-accepted research rules, guidelines, and literature standards.

References
[1]   Xometr Inc., Aluminum: History, characteristics, types, properties and applications, (2023). https://doi.org/https://www.xometry.com/resources/materials/what-is-aluminum/.
[2]   S. Pirizadhejrandoost, M. Bakhshzad Mahmoudi, E. Ahmadi, M. Moradshahi, The corrosion behavior of carburized aluminum using DC plasma, J. Metall. 2012 (2012) 1–4. https://doi.org/10.1155/2012/258021.
[3]   IAEA, Atomic and Plasma Material Interaction Data for Fusion, 13 (2007).
[4]   R. Alba, R. Iglesias, M.Á. Cerdeira, Materials to be used in future magnetic confinement fusion reactors: A review, Materials (Basel). 15 (2022) 6591. https://doi.org/10.3390/ma15196591.
[5]   A. Pahsa, Modelling plasma material interactions in spacecraft magnetic fusion devices, in: 2019 9th Int. Conf. Recent Adv. Sp. Technol., IEEE, 2019: pp. 655–662. https://doi.org/10.1109/RAST.2019.8767780.
[6]   IAEA, Lifetime predictions for the first wall and blanket structure of fusion reactors, (1985).
[7]   J. Rafelski, S.E. Jones, Cold nuclear fusion, Sci. Am. 257 (1987) 84–89. https://doi.org/10.1038/scientificamerican0787-84.
[8]   L. Rajablou, S.M. Motevalli, F. Fadaei, Study of alpha particle concentration effects as the ash of deuterium-tritium fusion reaction on ignition criteria, Phys. Scr. 97 (2022) 095601. https://doi.org/10.1088/1402-4896/ac831a.
[9]   L. Conde, An introduction to langmuir probe diagnostics of plasmas, (2011) Figure-2, p.3. http://plasmalab.aero.upm.es/~lcl/PlasmaProbes/Probes-2010-2.pdf.
[10]   ASME B46.1:2019, Surface Texture (Surface Roughness, Waviness, and Lay)", NS-996086, Technical Standards ASME, (2020).
[11]   K. Wojczykowski, New development in corrosion testing: Theory, methods and standards, AESF Found. Plat. Surf. Finish. (2011) 98.
[12]   IAEA, M. Kikuchi, K. Lackner, M.Q. Tran, Fusion physics, (2012) 20–21.
[13]   J.P. Freidberg, F.J. Mangiarotti, J. Minervini, Designing a tokamak fusion reactor—How does plasma physics fit in?, Phys. Plasmas. 22 (2015). https://doi.org/10.1063/1.4923266.
[14]   K. Miyamoto, Fundamentals of plasma physics and controlled fusion, (2011) 1–21. https://doi.org/10.1088/0029-5515/38/4/701.
[15]   C.M. Braams, P.E. Stott, Nuclear fusion: half a century of magnetic confinement research, Plasma Phys. Control. Fusion. 44 (2002) 1767–1767. https://doi.org/10.1088/0741-3335/44/8/701.
[16]   Y.A. Chang, G. Herdrich, C. Syring, Development of inertial electrostatic confinement in IRS, in: Sp. Propuls. Conf., Rome, Italy, 2016.
[17]   V. Kotov, Particle conservation in numerical models of the tokamak plasma edge, Phys. Plasmas. 24 (2017). https://doi.org/10.1063/1.4980858.

[18] J. Rapp, G. De Temmerman, G.J. Van Rooij, P.A. Zeijlmans Van Emmichoven, A.W. Kleyn, Plasma-facing materials research for fusion reactors at Fom Rijnhuizen, in: 15th Int. Conf. Plasma Phys. Appl. Rom. J. Phys., 2011: pp. 30–35.

[19] M. Malo, A. Moroño, E.R. Hodgson, Plasma etching to enhance the surface insulating stability of alumina for fusion applications, Nucl. Mater. Energy. 9 (2016) 247–250. https://doi.org/10.1016/j.nme.2016.05.008.

[20] S.M. Motevalli, N. Dashtban, M. Maleki, Determination of optimum conditions in ITER tokamak by using zero-dimensional model, Indian J. Phys. 95 (2021) 2211–2215. https://doi.org/10.1007/s12648-020-01857-6.

[21] M. Reinhart, S. Brezinsek, A. Kirschner, J.W. Coenen, T. Schwarz-Selinger, K. Schmid, A. Hakola, H. van der Meiden, R. Dejarnac, E. Tsitrone, R. Doerner, M. Baldwin, D. Nishijima, W.P. Team, Latest results of eurofusion plasma-facing components research in the areas of power loading, material erosion and fuel retention, Nucl. Fusion. 62 (2022) 042013. https://doi.org/10.1088/1741-4326/ac2a6a.

[22] C.A. Schneider, W. Rasband, K.W. Eliceiri, Image processing and analysis in Java, (2012).

[23] A. Pahsa, Y. Aydoğdu, F. Göktaş, Mathematical calculation of material reliability using surface roughness feature based on plasma material interaction experiment results, Eksploat. i Niezawodn. – Maint. Reliab. 25 (2023). https://doi.org/10.17531/ein/169815.

[24] Centre for Innovation in Mathematics Teaching, 12 correlation and regression, 215–242. https://www.cimt.org.uk/projects/mepres/alevel/stats_ch12.pdf.

TECHNICAL AND ECONOMIC STUDY OF THE ENERGY TRANSITION FROM NATURAL GAS TO GREEN HYDROGEN IN THERMAL POWER PLANTS

*Lance Pierre Moulebe**
Department of Electrical Engineering
Laboratory of Complex Cyber-Physical Systems (LCCPS) of ENSAM, Hassan II University
150 Bd du Nil, Casablanca 20670, Morocco, mpierrelaince12@gmail.com
https://orcid.org/0000-0001-7149-5694

Abdelwahed Touati
Department of Electrical Engineering
Laboratory of Complex Cyber-Physical Systems (LCCPS) of ENSAM, Hassan II University
150 Bd du Nil, Casablanca 20670, Morocco, touati2010@hotmail.com
https://orcid.org/0000-0001-9589-0090

Eric Obar Akpoviroro
Department of Electrical Engineering
Laboratory of Complex Cyber-Physical Systems (LCCPS) of ENSAM, Hassan II University
150 du Nil, Casablanca 20670, Morocco, akposobar@yahoo.com
https://orcid.org/0000-0002-4776-4708

Oumayma Belbsir
Department of Electrical Engineering
Laboratory of Complex Cyber-Physical Systems (LCCPS) of ENSAM, Hassan II University
150 Bd du Nil, Casablanca 20670, Morocco, belbsiroumaima123@gmail.com

Nabila Rabbah
Department of Electrical Engineering
Laboratory of Complex Cyber-Physical Systems (LCCPS) of ENSAM, Hassan II University
150 Bd du Nil, Casablanca 20670, Morocco, nabila_rabbah@yahoo.fr
https://orcid.org/0000-0002-2221-4830

Highlight
Decarbonization of gas-fired power plants by using green hydrogen as fuel.

Abstract
This research article contributes to the challenge of global warming by presenting the approach of the use of green hydrogen to reduce greenhouse gases. It shows that CO_2 emissions can be significantly reduced in thermal power plants by replacing natural gas with green hydrogen as a fuel. This work presents the techno-economic study of the energy transition of a 12 MW thermal power plant based on green hydrogen. The presented study is based on the energy consumption of Nigeria, 73% of which is covered by natural gas thermal power plants. The obtained results show that the cost of this transition is ca. 17 million dollars (USD) for a reduction of 114 tCO_2 per plant with a return on investment between 4-5 years. In addition, through modeling and numerical simulation, this article shows that estimated return on investment can be shortened by using the thermal power resulting from the turbine, through industrial use.

Keywords
Green hydrogen; thermal power plan; combustion.

Introduction
Our planet is facing numerous phenomena that threaten it today. One of the most devastating is a global warming [1]. Indeed, in the face of the effects of global warming, the actions taken on a daily basis do not have a considerable impact in the short term. Especially that such short-term damages are already visible,

i.e. the melting of glaciers, which causes rising waters and involves floods or fires that have repeated over the past two years due to high temperatures [2,3].

The fight against global warming involves the implementation of several technologies allowing the reduction of greenhouse gases (GHG) in the medium term. Faced with the effects observed in the world, the long-term solutions do not have considerable profitability these days, hence the solutions put in place must tackle the sectors having the greatest impact on GHG emissions. Among the most polluting sectors is energy supply, which relies still on power plants and particularly on thermal power plants, which occupy the second place after nuclear power [4] (Figure 1). The amount of GHG from thermal power plants is believed to be considerable over the next years [5] as shown in Figure 2.
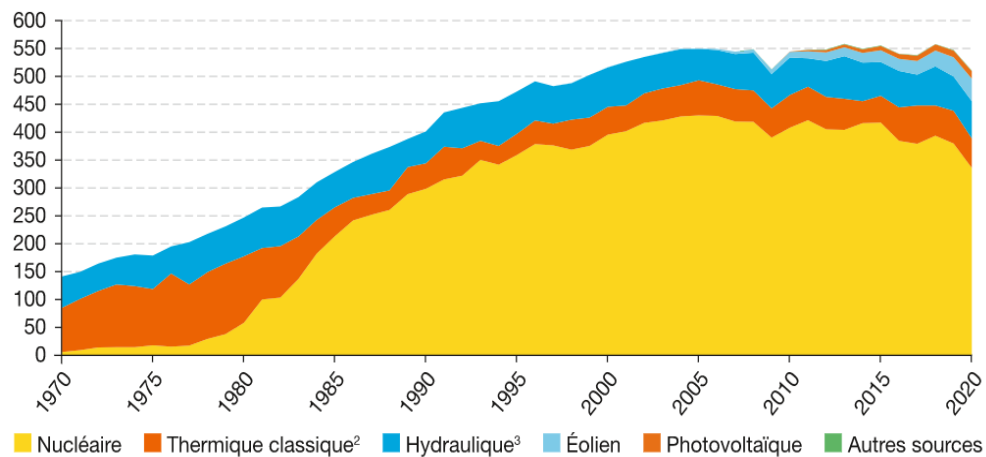

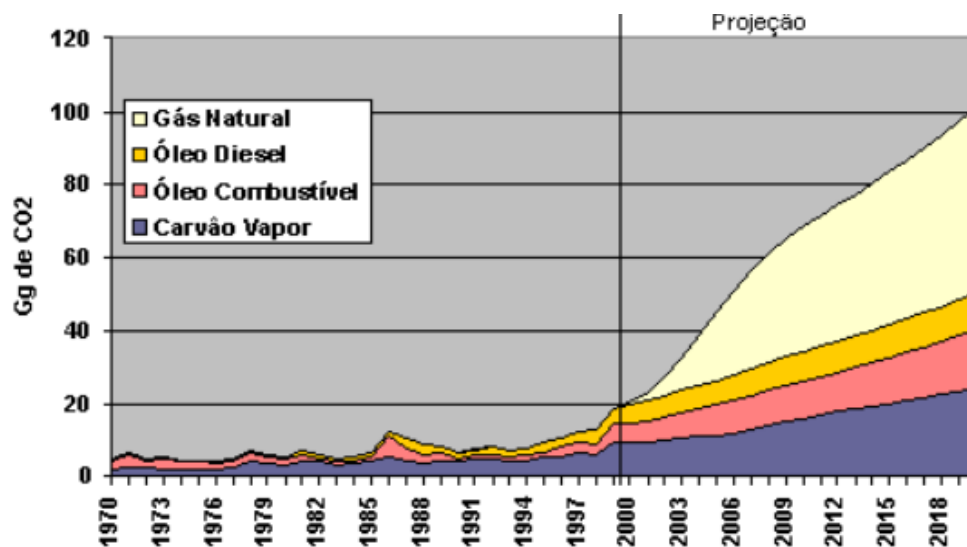Figure 1. Net-electricity generation. *Source: [4].*

Figure 2. Annual emissions of CO_2 from thermal generation of electricity in public power plants. *Source: [5].*

In 2019, global CO_2 emissions from fossil fuels accounted for 33 gigatons, of which 41% came from the electricity generation sector. The remaining 69% comes mainly from the transport sector and industry including the tertiary one. According to the IPCC 2018 special file "Global warming of 1.5°C", we have 580 gigatons of CO_2 in our carbon budget and with this value the terrestrial globe has a 50% chance of keeping global warming at 1.5°C compared to pre-industrial levels. However, if humanity continues on the current emissions trajectory, there are only 15 years left before the budget is exceeded.

Although actions to fight global warming undertaken today will have a positive impact in the years to come, it is important to invest in research and development (R&D) concerning these sectors, which on other hand can have more significant impact in the short-term perspective. Among the solutions in progress for several years are

those focused on the decarbonization of large and small-scale electricity production systems by replacing it be electricity from renewable energy such as photovoltaics or wind turbines. However, knowing that electricity production systems generate 41% of GHG [6], this article is particularly focused on the study of the reduction of CO_2 resulting from the production of electricity by thermal power plants using natural gas as fuel.

In this article, the technical and economic aspects concerning the integration of green hydrogen in the production of electricity of thermal power plants were analyzed. There are several articles that deal with the production of electricity from green hydrogen on a small, medium and large scale [7,8] . The integration of hydrogen in thermal power plants is a part of the fight against global warming especially the burning the hydrogen does not contribute to the CO_2 emission directly. In 2020, approximately 1.6TW of gas turbine was installed in the world, of which the production of electricity represented 22%. According to the literature, the most common and effective approach for the decarbonization of thermal power plants is to change the combustion gas, which is mostly natural gas or methane [6].

The article mainly deals with centralized production, which involves the production at medium and large scale [7,9], corresponding to the use of green hydrogen for mini generators [8]. In case of Nigeria, it represents the use of electricity by 40% of the population, i.e. 89,692,840 inhabitants who spend ca. 14 billion USD per year, i.e., equivalent to 40 million liters of fuel [10,11] or alternatively the use of hydrogen as fuel in thermal power stations [6,12]. The ability of a gas turbine to run on high hydrogen fuel requires a combustion system that can handle the specific nature of that fuel and General Electric (GE) has diffusion combustion systems in service for turbines Aeroderivative and Heavy-Duty gas engines capable of burning hydrogen. These include the Single Annular Combustor (SAC) for Aeroderivative gas turbines and the Quiet Single-Nozzle Combustor (MNQC) for heavy-duty gas turbines. Today, GE is able to quote hydrogen levels up to ~90 - 100% (by volume) for applications with the MNQC combustor or single nozzle combustor. The type of combustion system to be implemented in existing thermal power plants for 90-100% hydrogen combustion is not part of the study of this article. The work carried out in this article, with Nigeria as a case study, shows that thermal power plants and the use of generators have a considerable impact on GHG emissions and in particular on CO_2. Through research, it is shown that the carbon tax cost of operating thermal power plants covers the cost of transitioning from a CO_2 emitting turbine to a zero-carbon gas turbine with hydrogen as flue gas. This article also shows that Nigeria spends 14 billion dollars for generators using 43 million liters of fuel per year or 113 000t of CO_2

Methods

The scenario is based on Nigeria energy system. Through statistical calculations, the electricity production from thermal power plants is presented and the calculation of the cost linked to GHG emissions was performed. Subsequently, through bibliographic research the price of switching from a 12MW thermal power plant running on natural gas to operating with green hydrogen as fuel was found. All of these results made it possible to present the return on investment (ROI) linked to the decarbonization of thermal power plants of this power. The return on investment (ROI) is obtained by calculating the cost of the annual carbon tax, knowing that it is worth 11,493 USD/day, or 3.6 million USD/year for an emission of 114 931 200 g CO_2/ day, equivalent to 18 million USD over 5 years, which is compared to the cost of the transition of a thermal power plant from natural gas to hydrogen, which is 17 million USD. With the aim of reducing the number of years of the ROI, numerical modeling was carried out on MATLAB Simulink in order to observe the different powers which emerge from it, mainly thermal energy.

Results and discussion

Study sample

This part presents an assessment of the number of thermal power stations in Nigeria. All the data presented in this part were used to analyze and to present the economic and environmental aspects. This study showed the impact in terms of GHG emissions, the cost of these solutions as well as the cost of the carbon tax that can be applied.

According to Table 1, it can be seen that the production of electricity from natural gas in thermal power plants accounts for 73% of national production in Nigeria [13,14].

Table 1. Distribution of power generation plants. Source: *[12]*.

Type	Power (MW)	Percentage (%)
Gas-fired	11.972	73%
Hydro plants Providing	2.062	13%
Solar, wind, and other sources such as diesel and Heavy Fuel Oil (HFO)	2.35	14%
Total	16.384	100%

Table 2. GHG emissions per kWh electrical energy generated by actual best available technology for each energy vector. *Source: [15].*

Generation technology	Source	g CO2/ kWh$_e$	Ref.
Coal	Combustion	900	49
Gas	Combustion	400	49
Nuclear	Uranium enrichment	4	49
Wind	Construction	10-30	49
Photovoltaic	Construction	100-200	49
Hydro		18	6

According to this distribution (Table 1) and according to Table 2 presenting the amount of CO_2 emitted by the various electricity production technologies, estimation of all GHG from thermal power plants in Nigeria was made. The estimation of the amount of CO_2 from thermal power plants in Nigeria per day in these power plants can be obtained through the following equations.

(1)
$$GES_{co2} = E_{cth} \times GHG \times 24 = 114\,931\,200\ gCO_2$$

(2)
$$P_c = T_c \times GES$$

(3)
$$GES = C_a \times FE \times PRG$$

(4)
$$P_c = 114\,931\,200 \times 49 \times 10^{-6} \times 100 = 11\,493\ USD/day$$

where:
E_{cth} - 11972 kWh
GHG - 400 gCO_2/Wh$_c$
(PRG) = 1 - the global warming potential
(T_c) - carbon tax taken at 100 USD / tCO$_2$
(FE) - the emission factor
(GES) - GHG emission
(C_a) – consumption
(P_c) - carbon price
(E_{cth}) - power production by gas fire.

In this case study, the value of GES_{co2} is estimated at 114 931 200 gCO_2, which corresponds to 11,493 USD to be paid per day considering a carbon tax evaluated at 100 USD [16]. Through these data, it can be concluded that the interpolation concerning the carbon tax applied to these installations generates a significant cost of 3.6 million USD/year.

In order to perform a numerical simulation of the production of energy equivalent to 12 MW in a thermal power plant based on green hydrogen, several bibliographic searches were carried out. Thanks to this, it was found that the first electricity-hydrogen-electricity project on an industrial scale in the world was carried out in France [17]. It was based on the conversion of a thermal power plant producing heat and electricity of 12 MW with natural gas into a power plant using green hydrogen as combustion gas between 80 and 100%. The budget for this

implementation was 16.9 million USD. Therefore, by analogy it can be assumed that the conversion of a 12 MW thermal power plant from natural gas to hydrogen as the flue gas would require approximately 17 million USD. From where, through the estimate on the study sample, it can be deduced that after 5 years the country will spend on carbon tax the price necessary for the decarbonization of all of their natural gas thermal power stations.
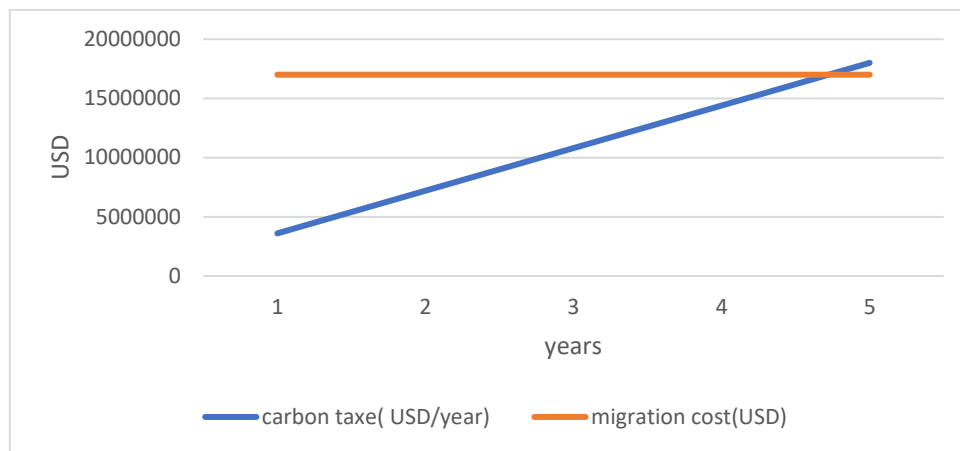

Figure 3. Evolution of the costs of the two technologies. *Source: Author.*

According to the interpolation presented on Figure 3, it can be deduced that in 5 years, Nigeria will spend 18 million USD for the carbon tax. This amount is higher than the cost necessary for the conversion of thermal power plants working on natural gas into the one using green hydrogen as a combustion gas.

Modeling, simulation and evaluation of the cost of a 12 MW thermal power plant running on green hydrogen.
During the process of generating electricity in a thermal power plant operating with green hydrogen as the fuel gas, a large amount of thermal energy is normally generated. In various research works, this phenomenon is represented by cogeneration techniques [18–20]. It is therefore important to analyze the productivity of a gas turbine with hydrogen fuel produced from wind or solar energy. For this purpose the SGT-400 [21] turbine was considered and various parameters resulting from several modeling oriented in the same framework were taken into account as well [22–24]. It is important to note that the ability of a gas turbine to operate with a fuel with a high hydrogen content requires a combustion system able to manage the specific nature of this fuel [25]. General Electric (GE) has diffusion combustion systems in service for Aeroderivative and Heavy-Duty gas turbines capable of burning hydrogen. This also leads to very high flame temperatures as well as high NOx emissions. The proposed system contains the Single Annular Combustor (SAC) for Aeroderivative gas turbines and the Quiet Single-Nozzle Combustor (MNQC) for heavy-duty gas turbines up to ~90 –100% (by volume) for applications with MNQC combustor or single nozzle combustor.

This modeling does not consider the characteristics of the combustion system and the modeling makes it possible to observe and to analyze the thermal parameters of the gas in order to have a possibility of implementing this thermal energy. As presented in [22,26], the gas turbine mainly consists of the compressor, the burner, and the turbine.

Modeling in the compressor

(5)
$$P_c = P_c^{in} \times PR$$

(6) $\qquad$ [24]
$$T_c = T_c^{in} \left[1 + \frac{\left(\frac{P_c}{P_c^{in}}\right)^{\frac{\gamma-1}{\gamma}} - 1}{\eta_c} \right]$$

(7)
$$W_c = \dot{m}_a \times C_p^a (T_c - T_a) \qquad [24]$$

(8)
$$\rho_a^C = \frac{P_c}{T_c \times C_p \times \dfrac{\gamma - 1}{\gamma}} \qquad [27]$$

where:
P_c^{in} - Compressor inlet pressure
P_a - Ambient air pressure
P_c - Compressor outlet pressure
P_c - Compressor outlet pressure (bars)
T_c^{in} - Compressor inlet temperature
T_a - Ambient temperature
T_c - Compressor outlet temperature
S_{out} – Entropy
hs - Specific enthalpy
W_c - Compressor thermal power
ρ_a^C - Compressor density
η_c - Compressor efficiency
C_p^a - Thermal capacity
$\dot{m}_c$ and $\dot{m}_a$ - respectively represent the flow of air leaving and entering in the compressor
τ_c - The time of the passage of the air in the compressor according to the speed and the length of the latter
W_c - Heat flux during compression (w)
$\dot{m}_a$ - Mass flow (kg/s) of incoming air
C_p^a - Heat capacity of ambient air entering the compressor($\frac{j}{kg \times K}$)
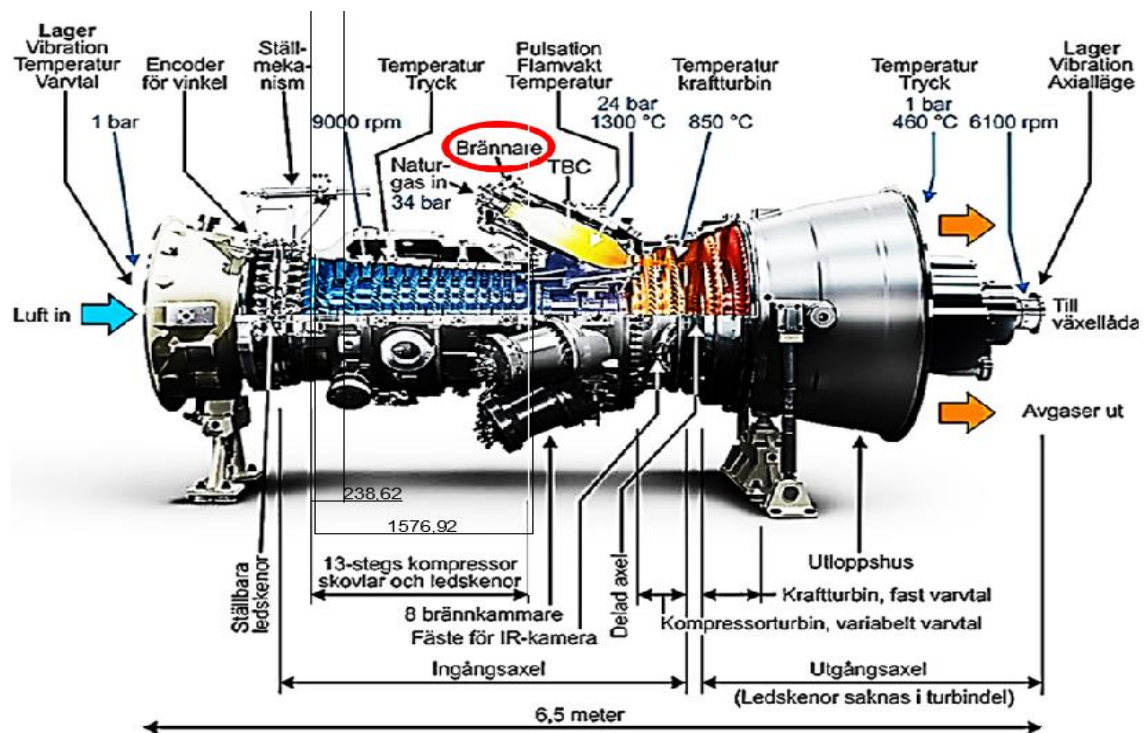ρ_a^C - Density of outgoing air of the compressor.

Figure 4. Industrial gas turbine SGT-750. *Source: [18].*

Using data given in Figure 4, the length of each main compartment intervening in the process including the approximate time of each phase can be estimated.

Modeling in the burner (combustion chamber)

(9) $$P_b = P_c \times (1 - dP)$$ [24]

(10) $$W_b = \dot{m}_{a/h} \times C_p^{hot}(T_b - T_c)$$ [24]

(11) $$\dot{m}_{a/h} = \dot{m}_a + ff$$ [24]

(12) $$ff = \frac{W_b}{FCV}$$ [24]

(13) $$T_b = \left[\frac{T_c + q_t \times \dfrac{Q_b \times \eta_f}{c_p}}{1 + q_t} \right]$$ [28]

where:
ff - Fuel flow (kg/s)
FCV - Value of the heat of combustion of hydrogen (141000 KJ/Kg)
W_b - thermal power in the burner (Kw)
$\dot{m}_{a/h}$ - flow rate of the air-hydrogen mixture entering the burner.

Turbine modeling

(14) $$\eta_t = \left[\frac{1 - \dfrac{T_t}{T_b}}{1 - \dfrac{P_t}{P_b}^{\frac{\gamma-1}{\gamma}}} \right]$$

According to the literature [27], P_T^m is the mechanical transmission power of the SGT-400 turbine estimated at 13.40MW.
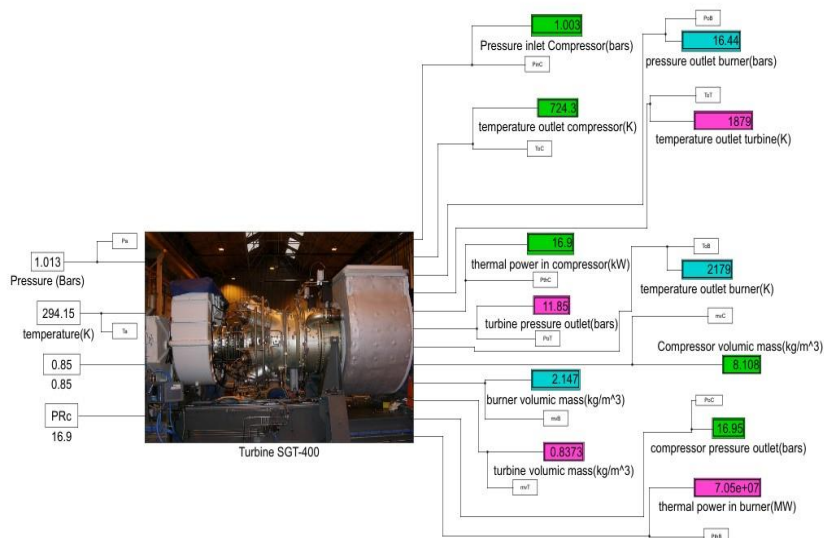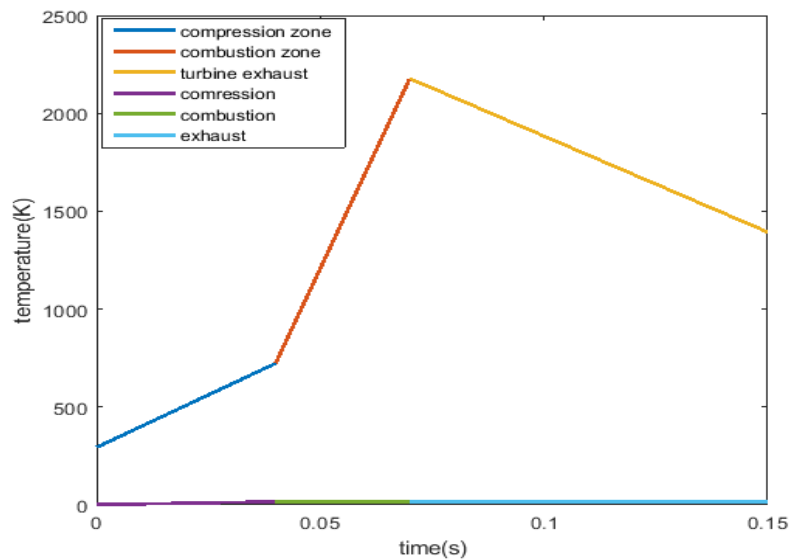

Figure 5: Extract of the modeled system. *Source: Author.*

Table 3. Specifications Adopted for The Simulation. *Source: Author.*

Components	Rating values
FE	49
T_c (USD)	100
PRG	1
η_c	0.86
Pa(Bars)	1.013
Ta(K)	294.15
FCV	141000
C_p^a (J/kg·K)	1010
C_p^{hot} (J/kg·K)	1230
GHG (gCO_2/Wh$_c$)	400
Pa (bars)	1.013
Ta (K)	294.15
Flux (kg/s)	38.9
dP	2%
V (m/s)	100
γ	1.4
PRc	16.8
PmecT (kW)	13.4
Lc (m)	1.6
η_b	36.8
$\dot{m}_b$ (kg/s)	39.4
$\dot{m}_c$ (kg/s)	38.9

Figure 6. Temperature variation. *Source: Author.*

Figures 6 and 7 show the evolution of temperature and pressure respectively in the modeled system according to the data in Table 3 below.
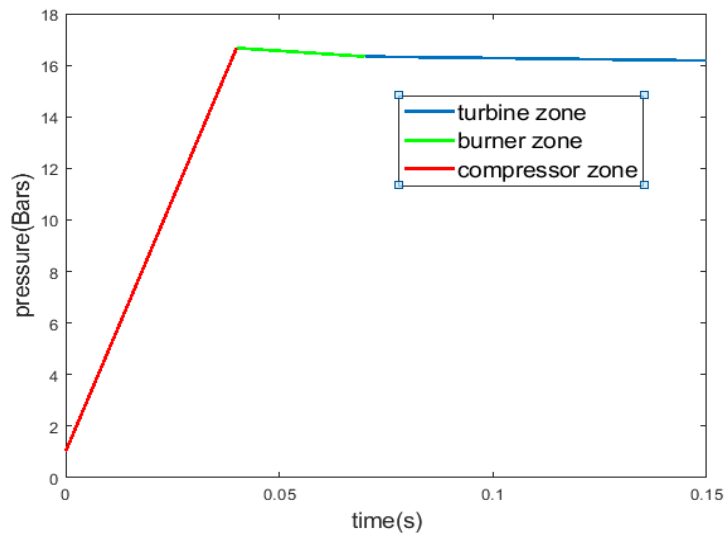
Figure 7. Pressure variation. *Source: Author.*

Impact

This article presents a techno-economic study on decarbonization through the use of the green hydrogen energy vector. Faced with the global challenge of reducing the rate of GHG emissions, several R&D projects are emerging. With this in mind, R&D presents several points of considerable progress in clean electricity production and clean storage systems like the construction of solar and wind power plants. Concerning this, R&D has been making other efforts for several years for the integration into the industrial world of green hydrogen, which is considered to be the energy vector capable of changing and revolutionizing the energy trend. Indeed, green hydrogen is currently being used in many sectors such as transport, refinery industries, power plants and energy storage, the configuration and traditional implementation of which causes an emission of considerable quantities of GHG. Knowing that the primary objective of R&D today is the reduction of GHG emissions, mainly CO_2, and that achieving of this objective requires acting on the systems and sectors most polluting on a global scale, this study focuses on the electricity production sector, which represents 41% of the CO_2 emission rate in the world. The study is particularly oriented towards thermal power plants running on natural gas. This article shows that the energy transition of thermal power plants from natural gas to green hydrogen as fuel is an effective way to fight against CO_2 emissions. Through a techno-economic study based on the case of Nigeria, it was shown that the transition from a 12MW natural gas plant to green hydrogen requires approximately 17 million USD investment. In comparison to a carbon tax estimated at 100 USD/tCO_2, it can be noted that the return on investment is possible after 4 years because the quantity of carbon emitted is estimated at 114 931 200 gCO_2, which corresponds to a tax of 11.493 USD/day, or 3.6 million USD/year and over 5 years the carbon tax expenditure will account for 18 million USD. In addition, the study shows that the country spends 40 million liters of fuel per day for the use of generators knowing that one liter of fuel emits 2.67 kg of CO_2. On the other hand, in order to analyze certain data of a gas turbine at the time of combustion, a numerical modeling accompanied by a production simulation was made. The results show that the amount of thermal energy coming out of the turbine part can be enhanced for industrial use. Applied internationally, the result on the environmental plan will be considerable but also on the financial plan because after valorization of the thermal energy coming out of the turbine the return of investment could be close to 3 years.

Conclusion

With the aim of expanding and promoting solutions to fight and reduce CO_2 emissions into the atmosphere, this article presents a techno-economic study of the migration of natural gas thermal power plants to green hydrogen as fuel. Indeed, this work has shown that power plants contribute significantly to CO_2 emissions reduction, particularly in the case of thermal power plants. The economic study shows that it cost about 17 million dollars for the transition from Natural Gas to Green Hydrogen of a 12 MW thermal power plant for a return on investment over 4.5 years without considering the tri-generation that can be applied to the view of the thermal power released by the turbine. According to the simulation, the inlet of a temperature of 294.15K after passing through the burner is achieved, whereas temperature goes to 2100K, at the outlet after driving the turbine and the outgoing gas has a temperature of 1879K for a thermal power of around 16 MW. This result

shows that the thermal power obtained can be used in the wood industry for drying, or in the industry of the circular economy by recycling plastic so as to act doubly on the protection of the environment and improve the overall efficiency of the combined system.

Conflict of interest
There are no conflicts to declare.

References
[1] S. Sharma, C. -, Global warming and Climate change, Int. J. Glob. Sci. Res. 6 (2019). https://doi.org/10.26540/ijgsr.v6.i2.2019.140.
[2] J.A. Church, N.J. White, Sea-Level Rise from the Late 19th to the Early 21st Century, Surv. Geophys. 32 (2011) 585–602. https://doi.org/10.1007/s10712-011-9119-1.
[3] R. Lindsey, Climate Change: Global Sea Level | NOAA Climate.gov, Climate.Gov. (2021) 1–8. https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level.
[4] Ministere de La Transition Ecologioque, Electricite. Chiffres cles de l'energie, (2022).
[5] Emissions of gases causing the greenhouse effect by thermoelectric power plant in the 2000 -2020 period, Econ. Energy. 23 (2000).
[6] J. Goldmeer, J. Catillaz, Hydrogen for power generation, 2022. www.ge.com/power/future-of-energy.
[7] B. Deboyser, La toute première batterie domestique à hydrogène : quel est son intérêt ?, (2021). https://www.revolution-energetique.com/la-toute-premiere-batterie-domestique-a-hydrogene-quel-est-son-interet/.
[8] L.P. Moulebe, A. Touati, E.A. Obar, N. Rabbah, SIMULATION AND DESIGN OF AN ENERGY ACCUMULATOR AROUND THE HYDROGEN ENERGY VECTOR, Acta Innov. 2023 (2023) 65–78. https://doi.org/10.32933/ActaInnovations.46.5.
[9] D. Parra, M. Gillott, G.S. Walker, Design, testing and evaluation of a community hydrogen storage system for end user applications, Int. J. Hydrogen Energy. 41 (2016) 5215–5229. https://doi.org/10.1016/j.ijhydene.2016.01.098.
[10] UN, Nigeria Population, World Popul. Rev. (2020) 1. https://worldpopulationreview.com/countries/nigeria-population.
[11] O. Nnodim, 40 % Nigerian households use generators, spend on fuel, Niger. Households Use Gener. (2022) 1–7. https://punchng.com/40-nigerian-households-use-generators-spend-14bn-on-fuel-report/.
[12] G. Glenk, S. Reichelstein, Reversible Power-to-Gas systems for energy conversion and storage, Nat. Commun. 13 (2022) 1–10. https://doi.org/10.1038/s41467-022-29520-0.
[13] Energypedia, Nigeria Electricity Sector - energypedia, (2022). https://energypedia.info/wiki/Nigeria_Electricity_Sector.
[14] N. Edomah, C. Foulds, A. Jones, Energy transitions in Nigeria: The evolution of energy infrastructure provision (1800-2015), Energies. 9 (2016) 484. https://doi.org/10.3390/en9070484.
[15] M. Steen, Greenhouse Gas Emissions from Fossil Fuel Fired Power Generation Systems. EUR 19754 EN, Joint research centre., 2000.
[16] A. Poupard, M. Fetet, S. Postic, Les comptes mondiaux du carbone en 2022, I4CE. (2022).
[17] S. Patel, World's First Integrated Hydrogen Power-to-Power Demonstration Launched, POWER. (2020). https://www.powermag.com/worlds-first-integrated-hydrogen-power-to-power-demonstration-launched/.
[18] A. Kundu, Experiments and Simulations Combustion Characteristics of a Swirl Dry Low Emission Burner Concept for Gas Turbine Application, 2016.
[19] L. Luo, P.P. Stouffs, École doctorale Sciences Technologie et Santé Modélisation , simulation et optimisation d ' un système de stockage à air comprimé couplé à un bâtiment et à une production photovoltaïque, (2018).
[20] M.J. IVANOV, Mathematical Models of Gas Turbine Engines And Their Components, 1994.
[21] C. Starmer, INDUSTRIAL GAS TURBINES., Chart. Mech. Eng. 27 (1980).
[22] H. Asgari, X.Q. Chen, R. Sainudiin, Modelling and simulation of gas turbines, Int. J. Model. Identif. Control. 20 (2013) 253–270. https://doi.org/10.1504/IJMIC.2013.057137.

[23]	J.W. Chapman, T.M. Lavelle, J.S. Litt, Practical techniques for modeling gas turbine engine performance, in: 52nd AIAA/SAE/ASEE Jt. Propuls. Conf. 2016, American Institute of Aeronautics and Astronautics, Reston, Virginia, 2016. https://doi.org/10.2514/6.2016-4527.

[24]	T.J. Ajoko, E.M. Adigio, Mathematical modelling of gas turbine diagnosis, 2012. http://www.interesjournals.org/JPGER.

[25]	GE Power, Power to Gas: Hydrogen for power generation, Gen. Electr. Co. (2019) 2. https://www.ge.com/content/dam/gepower/global/en_US/documents/fuel-flexibility/GEA33861 Power to Gas - Hydrogen for Power Generation.pdf.

[26]	R. Algerienne, D. Et, F.D.E. Technologie, D.D.E.G. Electrique, D.E.M. En, G. Electrique, THEME Etude et modélisation d'un turbo-alternateur, (2014).

[27]	S.D.E. La, T. Et, B. Mohammed, Etude thermodynamique et maintenance de remerciement, (2016).

[28]	P. Ailer, Mathematical Modeling of a Low-Power Gas Turbine Engine and Its Control System, in: Icas 2000 Congr., 2000.

ANALYSIS OF THE ROLE OF SERVANT LEADERSHIP ON EMPLOYEE'S JOB SATISFACTION MEDIATED BY LEADER-MEMBER EXCHANGE STYLE AMONG EMPLOYEES IN THE PRIVATE HIGHER EDUCATION SECTOR IN KUWAIT

Nourhan El-Bayaa
School of Business Administration, Holy Spirit University of Kaslik
Noorhan.elbayaa@usek.edu.lb
https://orcid.org/0000-0002-2751-3696

Dina Said
College of Business Administration, American University of the Middle East
dina.said@aum.edu.kw
https://orcid.org/0000-0002-2698-3100

Yehia Ibrahim Alzoubi*
College of Business Administration, American University of the Middle East
yehia.alzoubi@aum.edu.kw
https://orcid.org/0000-0003-4329-4072

Highlight
The servant leadership can lead to higher employee job satisfaction and leader-member exchange may mediate the relationship between servant leadership style and employee job satisfaction.

Abstract
A growing body of literature explores the underlying mechanisms and processes that enable servant leadership to impact organizational performance, engagement, and outcomes positively. This research assesses the mediation role of leader-member exchange between servant leadership and job satisfaction among employees in Kuwait's universities. The study utilized a closed-ended survey that was distributed to 240 workers, with 205 valid responses received from employees working in two private higher education sectors in Kuwait. using Partial Least Squares-Structural Equation Modelling (PLS-SEM) was used for data analysis. The outcomes of the study demonstrated strong backing for the beneficial influence of servant leadership on leader-member exchange and job satisfaction. Furthermore, a positive correlation was established between leader-member exchange and job satisfaction among employees employed in Kuwait's private higher education sector. Moreover, the results partially validated the mediating effect of leader-member exchange in the relationship between servant leadership and employee job satisfaction. These results underscore the significance of integrating servant leadership principles into leadership approaches within this sector to improve employee satisfaction and overall organizational achievement.

Introduction

Robert K. Greenleaf [1] coined the term "Servant Leadership" (SL) in 1970, defining it as putting serving before leading. According to Greenleaf, servant leaders aim to help followers grow healthier, wiser, more autonomous, and more likely to become servants themselves. Over the last few decades, there has been a growing interest in the topic of leadership. Scholars have noted that servant leaders operate at a higher level, with their focus being on serving others [2–4]. Due to changes in globalization, demographics, work practices, and technology, the concept of leadership has evolved. Studies have explored how leadership can impact organizational culture, employee performance, effectiveness, motivation, retention, and Job Satisfaction (JS) within organizations [4]. The most significant aspect of SL is its focus on serving first, and then aspiring to lead. The two dimensions of serving and leading in SL are crucial to the success and growth of an organization [2].

The achievement of an organization's objectives is intricately tied to the effectiveness of every facet of the company, particularly the performance of each hierarchical level, spanning from upper management to lower-tier employees. It is imperative to underscore that reaching high-performance levels necessitates the

cultivation of a strong sense of JS among employees [5]. Performance is fundamentally connected to the extent of dedication everyone dedicates to their respective tasks. Evaluating performance is vital as it provides a clear gauge of the extent to which personnel can successfully fulfil their assigned responsibilities [2]. As SL is connected to JS, it is possible to examine JS at the levels of the team, individual, and organization. Task performance is a common measure of individual performance (in-role behaviour) that can be used [6]. The authors in [7] found that SL indirectly affects task performance, with servant leaders promoting self-sufficiency and autonomy, resulting in higher levels of subordinates' performance. The pursuit of a "greater form and practice of leading" has been ongoing over the years. In recent studies, two non-leader-cantered styles have emerged: transformational leadership and SL. SL, in essence, is "leading by serving." This style of leadership focuses on the emotional needs, growth, and physical well-being of team members and the organization.

By embodying attributes such as stewardship, healing, conceptualization, foresight, commitment to others' growth, empathy, persuasion, listening, building a community, and awareness, this style of leadership becomes a tool for establishing sustained relationships, emotional healing and support, and organizational constitution [8]. Employee JS can be influenced by a multitude of factors. According to the definition of JS mentioned earlier, it becomes apparent that satisfaction is inherently linked to the individual characteristics and subjectivity of each employee. However, there are identifiable commonalities that impact JS across board [9]. Conversely, some factors exert a significant influence on overall JS. For instance, opportunities for career advancement hold a substantial sway over JS. In this context, the chance to acquire experience and hone one's skills while on the job plays a pivotal role [10]. This study's importance is underscored by the scarcity of research focused on SL in the Middle East, particularly in Kuwait. No previous studies have explored the mediation impact of Leader-Member Exchange (LMX) on JS and SL in private higher education institutions in Kuwait, making this study an important contribution to the field. This study contributes to the body of academia as follows.

- It explores how adopting the SL style and its attributes can improve work engagement, create a strong academic community, and empower private higher education institutions in Kuwait. It investigates the relationship between SL and employee JS in the private sector of Kuwait and examines the mediating effect of LMX on this relationship.
- It provides practical insights for leaders and managers in the private higher education sector, offering guidance on how adopting an SL approach can potentially enhance LMX and subsequently lead to increased employee JS.
- This study affirms the mediating role of LMX in the connection between SL and JS. This underscores the significance of giving attention to LMX to enhance outcomes in the workplace.
- By focusing on the private higher education sector, the study addresses a specific context that may have unique dynamics and challenges. This sector-specific insight is valuable for practitioners and policymakers in the field.
- The findings and methodology of this study can serve as a basis for further research in leadership, LMX, and employee satisfaction in diverse sectors and industries.

To tackle the shortage mentioned above, a survey was conducted among 240 employees in the private higher education sector in Kuwait. Out of the total surveys distributed, 205 were received and analysed from personnel who regularly report to their managers/leaders. The survey results unveiled noteworthy correlations between SL and JS, SL and LMX, as well as LMX and JS. Additionally, the findings offered partial validation for the notion that LMX acts as a mediator in the relationship between SL and JS. The paper's structure for the subsequent sections is as follows. The following subsections provide context, a review of related literature, and delve into the research model and the formulation of hypotheses. The research method is discussed in Section 2. The study findings and discussion are presented in Section 3. The impact of the study findings is discussed in Section 4 and Section 5 offers concluding remarks for the study.

Servant leadership

Greenleaf [1] introduced the concept of SL which prioritizes human capital and focuses on the leader as a servant. His own experiences working for giant organizations and his study of Journey to the East by Herman Hesse served as the foundation for Greenleaf's concept of SL. Initially, Greenleaf's work was based on his observations rather than research. While other leadership styles emphasize achieving organizational goals and standards, SL prioritizes the needs of followers, with the organization's goals being met as a result. Moreover, SL is considered a philosophy of leadership that addresses ethical concerns and emphasizes morality, ethics, and virtues [6]. SL has gained research interest in the field of organizational studies, with a focus on leaders serving others first to achieve positive organizational outcomes. This shift towards serving others has changed the focus of leadership

research from solely leading to balancing the paradox of leading and serving simultaneously [11]. While transformational and charismatic leaders can achieve remarkable outcomes, without ethical and moral considerations, their results could lead to disastrous consequences.

Several studies have been conducted to investigate the impacts of SL within the higher education sector across different geographical regions. For example, Abbas et al. [12] explored SL effects in the higher education sector in Pakistan, while Al-Asfour et al. [13] examined the SL style's consequences in the context of higher education in the USA. Regarding the Middle East, Dahleez et al. [10] examined the effects of SL in the setting of Palestine's higher education industry and recommended that Palestinian colleges and universities embrace the SL style and provide management training to help them hone their SL abilities. Regarding SL in Gulf countries, a study conducted by Shafai et al. [14] investigated the correlation between SL and the role of administrators in higher education in the Kingdom of Saudi Arabia. The study aimed to produce successful leaders who prioritize meeting people's basic needs without abusing their power. However, there is currently a lack of research that adequately captures the practical application of SL approaches in higher education by Saudi leaders. As power and leadership are closely linked, it is essential to investigate how leaders use their authority in daily operations to gain a better understanding of their leadership styles [14].

Leader-member exchange

According to Graen's LMX theory [15], leaders should forge various kinds of relationships or exchanges with each member rather than employing a single leadership style with all members [16]. The fundamental premise of LMX theory revolves around the idea that leadership is inherently varied within each leader-follower relationship. Consequently, employing a blanket or average leadership style to encapsulate the conduct of any leader does not hold much theoretical or practical validity. This is primarily because a leader's behaviour is inclined to vary based on the specific follower, they are interacting with [15]. Consequently, LMX theory transcends the mere characterization of leader-member relationships and instead provides recommendations for achieving an optimal state of affairs within a group [17].

SL, LMX, and JS are all essential components when setting an organization's goals and objectives and achieving success. High levels of collaboration, transparency, trust, and both informal and formal rewards indicate a positive relationship within a group. Leaders who prioritize the interests of their subordinates have an advantage in building such relationships. In contrast, strong task focus, and distrust are characteristics of a negative or inadequate relationship [17]. Instead of focusing on the more complex interaction between the leader and the followers, the LMX Theory studies the relationship between two variables (e.g., SL and JS). This study aims to investigate the effectiveness of SL in promoting employee JS and the mediating role of LMX in the relationship between JS and SL. SL, LMX, and JS are all crucial factors in establishing an organization's goals, objectives, and achievements.

Job satisfaction

JS is a complex and multifaceted term that can have different meanings for different individuals. While JS is often associated with motivation, the underlying reasons for this link are not well understood. Put differently, JS essentially measures the contentment of team members with their jobs and their employers. Both corporate leaders and personnel in staff development teams commonly employ this term to gain insights into how satisfied and content employees are in their roles. For an organization to continue evolving and adjusting effectively, it is imperative to recognize the factors that influence employee JS and take the necessary steps to achieve it [18].

Several studies have explored the factors that influence an individual's perception of JS. For example, Hasanuddin et al. [19] concluded that motivating elements had an impact on an employee's JS level. Conversely, Conant [20] found that JS and a desire to leave a job are associated with a lack of work responsibilities. Additionally, Kalifa et al. [18] found that employees who have been with a company for an extended period are less likely to quit. Employees who are content in their current roles are more likely to stay with the organization and not actively seek alternative employment. Therefore, managers in the casualty insurance industry should understand the impact of JS on employee retention to prevent employees from seeking alternative job opportunities. Lawler's theory [21] is prominent in studying the relationship between employee JS and leadership style. Lawler categorizes JS into four main theories: fulfilment, discrepancy, equity, and two-factor [21]. The discrepancy theory, one of the four theories, is focused on the gap between what employees expect and what they receive. The theory emphasizes that employees' expectations, evaluations, and hopes for their work are more important than what they have. To understand the gap between expectations and reality, Lawler suggests three questions

and reality, Lawler suggests three questions that should be considered: What are the employees' wishes? What do they have in mind? What are the possibilities for them?

Discrepancy Theory suggests that JS is the result of a discrepancy between two judgments regarding valued characteristics of work [22]. This assessment is affected by a person's needs, desires, goals, beliefs, values, and aspirations, which are related to different JS theories. Here, the level of congruence between an individual's expectations of each component of their work and the experience of those components determines their level of satisfaction. Locke [22] defines JS as "a positive or pleasant emotional state resulting from the appraisal of one's job or job experiences."

Related literature

The involvement of LMX in the connection between SL and JS has received little attention in the literature. However, some earlier investigations looked at the link between JS and SL. For instance, in the study conducted by Sahin [23], an examination was made into the relationship between McGregor's Theory X and Y management styles and their impact on LMX. The results showed a positive correlation between Theory Y and LMX. Additionally, the study revealed that LMX acted as a mediator in the connection between affective commitment and Theory Y management [23]. In addition, Akdol et al. [17] conducted a study using quantitative data to investigate the influence of SL on JS and to explore the mediating effects of LMX on this relationship. According to the results, LMX somewhat mediated the association between JS and SL. In a study conducted by Aggarwal et al. [9], the authors reported that SL has a significant positive impact on LMX, and it also enhances employees' organizational commitment, except for continuous commitment. Additionally, they reported that LMX positively affects employees' commitment levels and SL mediates the relationship between employees' commitment and LMX [9]. Previous studies have indicated that factors beyond LMX may impact the relationship between JS and SL. For instance, van Dierendonc et al. [24] proposed trust and justice in the psychological climate as important elements in this relationship. Additionally, Mayer et al. (2008) demonstrated that organizational justice partially mediates the link between SL and JS. Furthermore, Aboramadan et al. [25] reported that JS serves as a complete mediator in the relationship between educational performance and SL.

Relationship between SL and JS

Several studies have identified a noteworthy relationship between SL and JS [26–28]. Researchers have also compared SL practices with other organizational dynamics in various industries, such as academic institutions, daycares, community foundations, media, public works, health care, government, and high-tech. The results of these studies revealed that SL techniques and JS have a statistically significant positive association. Employee JS can be influenced by employee participation and trust, as well as the opportunity to participate in decision-making and charting the organization's direction. These factors align with Patterson's SL model's components of trust and empowerment, making SL an ideal choice for enhancing employee JS [29]. Previous studies have found measurable effects of SL in different areas, including its influence on JS. Hebert et al. [27] reported a significant correlation between JS and SL. In their study, they assessed both intrinsic and extrinsic JS scale scores. Hebert et al. [27] found a strong positive correlation between JS and Laub's SL dimensions of developing people, valuing people, promoting community, offering leadership, demonstrating authenticity, and sharing leadership, as measured by the OLA and the MCMJSS. Herbert et al. [27] focused on the followers' perspective and found a strong association between their perception of SL and subjective and extrinsic JS, as evaluated by the MCMJSS.

Previous research, such as the study conducted by Aboramadan et al. [25], found a significant relationship between SL and JS in educational institutions, indicating that SL positively impacts JS and ultimately leads to improved educational performance. Similarly, some researchers [30–33] have also found a strong association between SL and JS in several types of businesses and organizations. Accordingly, we propose.

- ▪ H1: SL positively affects the JS in private institutions in Kuwait.

Relationship between servant leadership and leader member exchange

SL is known to develop a high level of LMX by empathizing with followers, focusing on their personal development needs, and building interpersonal trust with them [4]. This approach helps establish durable connections between servant leaders and their followers based on mutual trust and benefit. Earlier studies have demonstrated that SL is positively correlated with LMX for several causes, including the servant leaders' empathy, morality, and acceptance, which foster followers' trust [34]. By empowering their subordinates and offering them a respectable degree of responsibility based on their requirements and capabilities, servant

leaders can build strong relationships with their followers. This may lead followers to adopt the servant leader's principles and strive to earn their approval [17]. According to Zeng et al. [35], a harmonious relationship between followers and leaders is essential for the success of SL. SL's underlying belief in the intrinsic value of every individual is reflected in the genuine, humble, and accepting nature of servant leaders, who foster a safe work environment. The success of LMX may thus impact how followers perceive themselves because of SL. Based on these findings, we propose.

- ▪ H2: SL positively affects the LMX in private institutions in Kuwait.

Relationship between leader-member exchange and job satisfaction
SL, LMX, and JS are important aspects of achieving an organization's goals and objectives. Various tools are available to measure LMX, with different dimensions and elements. Liden and Maslyn [16] proposed a conceptualized model consisting of four dimensions, which include affection, loyalty, contribution, and respect. The study by Janssen et al. [36] revealed that relationships between mastery orientation and leader-rated in-role work performance, and between JS and leader-rated inventive job performance are mediated by the LMX. Volmer et al. [37] that a strong LMX not only enhances JS but also promotes positive supervisor-employee relationships. Their research highlights the importance of considering the reciprocal relationships between LMX and JS when analysing workplace outcomes. In addition, Heriyadi et al. [38] conducted a study with 169 nursing staff in an Indonesian hospital to investigate the effect of LMX, JS, and work-life balance on organizational citizenship behaviour. The study found that LMX and work-life balance have a significant positive impact on JS and organizational citizenship behaviour, leading to improved performance in health services. Therefore, it is suggested that organizations should focus on developing strong LMX and promoting work-life balance to enhance JS and organizational citizenship behaviour, ultimately resulting in better performance. Based on these findings, we propose

- ▪ H3: LMX positively affects the JS in private institutions in Kuwait.

Mediating effect of leader-member exchange between servant leadership and job satisfaction
Although the relationship between SL and JS has been extensively studied by researchers such as [24,25,27] studies exploring LMX's mediation role in the SL-JS interaction are few. According to Graen's LMX theory [15], leaders should cultivate distinct and individualized relationships with each follower, rather than employing a one-size-fits-all approach with their team members. By demonstrating empathy, emphasizing staff growth, and facilitating social trust, SL produces high-quality LMX. This leads to strong supportive relationships with each follower and reciprocally favourable relationships with subordinates and high levels of employee JS. LMX is often used as a mediator between SL and JS, and statistical research shows that being a part of the in-group with a high-quality LMX connection led to greater rewards and JS, as leaders tend to entrust more choices to them. This information is derived from several studies, including those by [16,24,39,40]. Wu et al. (2013) anticipated a positive correlation between SL and LMX, attributing it to the ethical and accepting nature of servant leaders who empathize with their followers, thereby creating a sense of trust and empowerment. This, in turn, allows followers to exercise more autonomy and control over their work, leading to increased JS and a greater likelihood of meeting job requirements. Akdol et al. [17] conducted a study using quantitative data to examine the impact of SL on JS and they found that LMX mediation was significant yet partial, between JS and SL. Based on these findings, we propose.

- ▪ H4: LMX mediates the relationship between SL and JS in private institutions in Kuwait.

Methods
Research process
The article utilized a quantitative approach to test the relationships among SL, JS, and LMX. A survey questionnaire was designed to assess these connections, following the recommendation of Tsang et al. [41] to use the survey methodology for analysing and validating interactions among various structures or variables within a large population. The survey approach was chosen as it offers more detailed data than other methods, such as observation, and can help generalize the findings to the entire sample community [41]. The study utilized a structured questionnaire with two main sections, demographic information, and JS, to survey faculty representatives in private teaching institutions in Kuwait. The questionnaire utilized a Likert scale of five points (i.e., ranging from strongly disagree as 5 to strongly agree as 1). The inclusion of the neutral option on the scale helped minimize bias by not forcing participants to select a positive or negative response [42].

To ensure that the questionnaire used in the study was accurate and dependable, we tested its face and content validity. Four management professors were surveyed to determine the questionnaire's content validity, and

three Ph.D. candidates were surveyed to determine the questionnaire's face validity. The purpose of the tests was to ensure that the questionnaire was understandable, readable, and in the right format and that its items were accurate. Based on the feedback received, we adjusted the questionnaire [43]. Additionally, we used snowball sampling to validate and refine the questionnaire, which involved sending it to seven people working as academic teachers in private universities in Kuwait and making changes to the questionnaire based on their feedback [42].

Participants

In this research, a convenience sampling method was employed to choose participants from two private universities in Kuwait. These universities were the exclusive ones that consented to take part in the survey. Convenience sampling was deemed appropriate in this context, as it was the most feasible sampling method available for this study [44]. The survey was sent to a total of 240 educators. This study included full-time employees who work for 32 hours per week and focused on the Human Resources, Marketing, Finance, Operations, Sales, and Information Technology departments.

Out of the 240 surveys that were distributed, a high survey response rate of 87.5% was achieved with the return of 210 questionnaires. To prepare the data for analysis, a cleaning process was undertaken to eliminate incomplete data using a multi-screening method, in line with the recommendations of Hair et al [44]. As a result of this preparation process, five surveys were excluded due to incomplete responses in over 10% of the cases. Ultimately, there were 205 usable responses for analysis.

Partial Least Square-Structural Equation Modelling (PLS-SEM)

PLS-SEM was employed in this study to analyse the data. A form of statistical multivariate analysis known as PLS-SEM combines a structural model with a measurement model [45]. In contrast to the structural model, which concurrently evaluates the level of correlation among dependent and independent variables, the measurement model is utilized to investigate the connection between survey outcomes and the fundamental latent variables. The authors opted to use PLS-SEM because of the small sample size, the exploratory nature of the work, and the absence of constraints on the normality of the data [44].

Measures

The study utilized three survey instruments to gather data on JS, SL, and LMX. The SL instrument was adopted from Liden et al. [46], the JS instrument (MCMJSS) was adopted from Mohrman et al. [47], and the LMX instrument was adopted from [15]. The complete list of indicators is provided in Table 1. According to the most recent PLS-SEM recommendations [44], all items with outer loadings below 0.7 were eliminated throughout the route analysis such that their removal did not affect the content validity. For SL, after running the initial loading test, SL2, SL6, SL8, SL17, SL18, SL19, and SL20 all scored above 0.7.

However, due to collinearity between SL18 and SL19, we removed 18, which scored less than SL19. Similarly, for JS, all JS1, JS2, JS3, JS4, JS6, and JS8 all scored above 0.7. However, due to the collinearity between JS2 and JS3, we removed JS2, which scored less than JS3. For LMX, all items scored more than 0.7, except for LMX5, which was removed from further analysis.

Table 1. Questionnaire (1-totally disagree, 2-disagree, 3-neutral, 4-agree, 5-total agree). *Source: [15,46,47].*

I	Servant leadership					
1	I would seek help from my immediate supervisor if I had a personal problem	1	2	3	4	5
2	My immediate supervisor cares about my personal well-being	1	2	3	4	5
3	My manager takes time to talk to me on a personal level	1	2	3	4	5
4	My immediate supervisor can recognize when I'm down without asking me	1	2	3	4	5
5	My immediate supervisor emphasizes the importance of giving back to the community	1	2	3	4	5
6	My immediate supervisor is always interested in helping people in our community	1	2	3	4	5
7	My immediate supervisor is involved in community activities	1	2	3	4	5
8	I am encouraged by my immediate supervisor to volunteer in the community	1	2	3	4	5
9	My immediate supervisor can tell if something is going wrong	1	2	3	4	5
10	My immediate supervisor is able to effectively think through hard problems	1	2	3	4	5
11	My immediate supervisor has a very good understanding of our organization and its goals	1	2	3	4	5
12	My immediate supervisor can solve work problems with new or creative ideas	1	2	3	4	5
13	My immediate supervisor gives me the responsibility to make important decisions about my job	1	2	3	4	5
14	My immediate supervisor encourages me to handle important work decisions on my own	1	2	3	4	5
15	My immediate supervisor gives me the freedom to handle hard situations in the way that I feel is best	1	2	3	4	5
16	When I have to make an important decision at work, I do not have to consult my immediate supervisor first	1	2	3	4	5
17	My career development (my improving and progressing in my career) is very important to my immediate supervisor	1	2	3	4	5
18	My immediate supervisor is interested in making sure that I achieve (reach) my career goals	1	2	3	4	5
19	My immediate supervisor provides me with work experiences that enable me to develop new skills	1	2	3	4	5
20	My immediate supervisor wants to know about my career goals	1	2	3	4	5
21	My immediate supervisor seems to care more about my success than his/her own	1	2	3	4	5
22	My immediate supervisor puts my best interests ahead of his/her own	1	2	3	4	5
23	My immediate supervisor sacrifices his/her own interests to meet my needs	1	2	3	4	5
24	My immediate supervisor does what she/he can do to make my job easier.	1	2	3	4	5
25	My immediate supervisor holds high ethical (moral) standards	1	2	3	4	5
26	My immediate supervisor is always honest	1	2	3	4	5
27	My immediate supervisor would not compromise ethical (moral) principles (standards/values) (give in to wrong values or behaviour) in order to achieve (reach) success	1	2	3	4	5
28	My immediate supervisor values honesty (telling the truth) more than profits (money)	1	2	3	4	5
II	Leader member exchange					
1.	I know where I stand with my leader (follower) . . . [and] I usually know how satisfied my leader (follower) is with what I do?	1	2	3	4	5
2	My leader (follower) understands well my job problems and needs	1	2	3	4	5
3	My leader (follower) recognizes well my potential	1	2	3	4	5
4	Regardless of how much formal authority my leader (follower) has built into his or her position, I have high chances that my leader (follower) would use his or her power to help me solve problems in my work	1	2	3	4	5
5	Regardless of the amount of formal authority my leader (follower) has, I have high chances that my leader would "bail me out" at his or her expense	1	2	3	4	5
6	I have enough confidence in my leader (follower) that I would defend and justify his or her decision if he or she were not present to do so.	1	2	3	4	5
7	I would characterize my working relationship with my leader (follower) as extremely effective	1	2	3	4	5
III	Job satisfaction					
1	The feeling of self-esteem or self-respect you get from being in your job.	1	2	3	4	5
2	The opportunity for personal growth development in your job	1	2	3	4	5
3	The feeling of worthwhile accomplishment in your job	1	2	3	4	5
4	Your present job when you consider the expectations you had when you took the job	1	2	3	4	5
5	The amount of respect and fair treatment you receive from your supervisors	1	2	3	4	5
6	The feeling of being informed in your job	1	2	3	4	5
7	The amount of supervision you receive	1	2	3	4	5
8	The opportunity for participation in the determination of methods, procedures, and goals	1	2	3	4	5

Results and discussion

Demographic profile of respondents

The respondents' demographic profile is shown in Table 2. Considerations include gender, age, employment history, and qualifications. 51.2% of respondents were female, compared to 48.8% of respondents who were males. 64% of the participants were aged between 29 and 35, making 70% of respondents. More than 74 had experience between one to five years. The majority of the respondents (80%) held a bachelor's degree.

Table 2. Respondent demographics. *Source: Authors.*

Characteristic		Frequency	Percentage
Gender	Female	105	51.2%
	Male	100	48.8%
Age	Equal to or below 28	45	21.9%
	29-35	131	63.9%
	36-45	20	9.8%
	Equal to or above 46	9	4.4%
Work experience	1-5 years	152	74.1%
	6-10	28	13.7%
	11- 20	22	10.7%
	More than 20	3	1.5%
Qualification	Bachelor	164	80%
	12th class	9	4.4%
	10th class	1	0.5%
	post-graduation	31	15.1%

To ensure that nonresponse bias does not affect the data analysis, the sample was split into two groups; an early group and a late group and compared their responses using demographic variables [42]. The lack of substantial variations among the two groups in the data suggests that nonresponse bias is not considered a serious issue. Additionally, the researchers used Harman's one-factor test to check for process bias, and the results showed that no one factor could account for a sizable portion of the variation, as recommended by MacKenzie et al. [48]. Thus, this problem did not affect the validity of the calculations. Finally, to reduce common method biases, the researchers scattered items that refer to the same construct throughout the questionnaire, rather than clustering them together [49].

Measurement validation

The measures of SL, LMX, and JS were considered reflective indicators that are influenced by their respective latent constructs, according to the modelling approach used in this study [45]. To confirm the validity of the model, we employed the SmartPLS 4.0 software [50] and conducted tests for construct validity and reliability for all indicators. Our findings showed that all items had satisfactory levels of validity and reliability. A number of parameters, such as reliability and outer loadings of indicators, discriminant validity, construct reliability, and convergent validity, were explored to evaluate the measurement model. The ideal threshold for outer loadings is 0.7, and in Table 3, all the items included had outer loadings larger than 0.7 [45]. However, some items with lower loadings were excluded from further analysis to ensure that the indicator's reliability was supported. In total, the final analysis used six items for SL, six items for LMX, and five items for JS, having minimal impact on the model's overall fit. In this study, the researchers assessed the construct reliability using two measures, namely Cronbach Alpha (α) and Composite Reliability (CR). An ideal threshold value of 0.7 was used for both measures to evaluate the construct reliability [45]. According to Table 4, the CR and α values for the constructs were above 0.7, indicating satisfactory construct reliability. The convergent validity was tested using the Average Variance Extracted (AVE). Each construct has a larger AVE value than 0.7, as shown in Table 4, suggesting sufficient convergent validity.

To ensure discriminant validity, the study conducted two tests: cross-loadings, the Fornell and Larcker criterion, and Heterotrait-Monotrait (HTMT) ratio [45]. No indicator had a stronger load on competing constructs than any other, according to the cross-loading test. The Fornell and Larcker criterion showed that each construct has a square root of AVE that exceeds the maximum degree of similarity to other constructs. The bold diagonal cells, shown in Table 4, correspond to the AVE values. As depicted in Table 5, the findings demonstrated that each group of constructs' HTMT ratio fell well short of the conservative threshold of 80. All these tests indicated that

the discriminant validity criteria for all constructs were met.

Table 3. Construct indicator; VIF and loading; *P < .10 (T >1.65), **P < .05 (T > 1.96), ***P < .01 (T >2.58). *Source: Authors.*

	SL	LMX	JS
SL 2	0.719 ***	0.542	0.594
SL 6	0.748 ***	0.561	0.597
SL 8	0.721 ***	0.543	0.478
SL 17	0.740 ***	0.544	0.572
SL 19	0.776 ***	0.503	0.460
SL 20	0.772 ***	0.532	0.513
LMX 1	0.557	0.781 ***	0.549
LMX 2	0.594	0.848 ***	0.542
LMX 3	0.587	0.831 ***	0.595
LMX 4	0.585	0.789 ***	0.550
LMX 6	0.574	0.817 ***	0.577
LMX 7	0.638	0.841 ***	0.610
JS 1	0.556	0.561	0.742 ***
JS 3	0.616	0.573	0.859 ***
JS 4	0.517	0.463	0.779 ***
JS 6	0.524	0.570	0.752 ***
JS 8	0.608	0.563	0.787 ***

Table 4. AVE, α, and CR results. *Source: Authors.*

Latent construct	A	CR	AVE	JS	LMX	SL
JS	0.843 ***	0.846 ***	0.616 ***	**0.785**		
LMX	0.901 ***	0.902 ***	0.669 ***	0.698	**0.818**	
SL	0.841 ***	0.843 ***	0.557 ***	0.722	0.721	**0.746**

Table 5. Direct and indirect effects, HTMT, and effect size (f^2). *Source: Authors.*

Relationship	HTMT ratio	VIF	f^2 value	Direct effect	Lower Interval (2.5%)	Upper Interval (97.5%)	Indirect effect	Lower Interval (2.5%)	Upper Interval (97.5%)
SL → JS	0.849	2.082	0.240	0.455 ***	0.320	0.592	0.267 ***	0.149	0.390
SL → LMX	0.826	1.000	0.450	0.721 ***	0.646	0.790			
LMX → JS	0.798	2.082	0.160	0.371 ***	0.211	0.522			

<u>Test of the Structural Model</u>
To evaluate the structural model the PLS algorithm and bootstrapping (The bootstrapping was run with the following settings: Subsamples: 5000, Complete Bootstrapping, Confidence: Two tailed, Sig. Level: 0.05, and 206 cases) procedures were utilized and several steps were conducted, including assessing the model fit, the structural relationships for multicollinearity, regression, testing hypotheses, the R^2, and the f^2 statistic [45]. The Standardized Root Mean Square Residual (SRMR) test was utilized to evaluate the model fit (i.e., the degree to which the empirical data matches the conceptual model under examination and quantifies the disparity between observed and predicted correlations). A smaller SRMR indicates a better fit between the model's structures and the real-world phenomenon, and an SRMR value less than 0.10 (or 0.08 for a more conservative view) is generally considered indicative of a good fit [50]. Our PLS analysis revealed an SRMR value of 0.069, which is less than 0.08, indicating a good fit for the test model.

To assess multicollinearity, we used the Variance Inflation Factor (VIF), which should be below 3 [45], as depicted in Table 5. Another important structural model test is the consistency and significance of the path coefficients to evaluate the strength of the relationships between variables. As noted by Hair et al. [45], significant path coefficients are important to confirm that a relationship between two constructs exists. The path coefficients and significance for each path are displayed in Figure 1 and summarized as direct effects in Table 5. Our findings

indicated that all hypotheses were supported. Specifically, SL had a significant impact on JS (H1) (B=0.445, p<0.01), SL had a significant impact on LMX (H2) (B=0.721, p<0.01), and LMX had a significant impact on JS (H3) (B=0.371, p<0.01).

R^2 is a metric used to evaluate how well the model can predict the dependent variable based on the independent variables. An R^2 value of 0.25, 0.50, or 0.75 indicates weak, moderate, or substantial accuracy prediction, respectively [45]. In this study, the R^2 values for SL predicting LMX and JS are 52% and 58.7%, respectively, indicating moderate predictive accuracy. Another test that evaluates the strength between two variables is the f^2 effect size, with values of 0.02, 0.15, and 0.35 indicating small, medium, and large effect sizes, respectively [45]. The study found that SL and LMX have a moderate or medium effect size on JS (f^2 = 0.24 and 0.16, respectively), while SL has a large effect size on LMX (f^2 = 0.45).
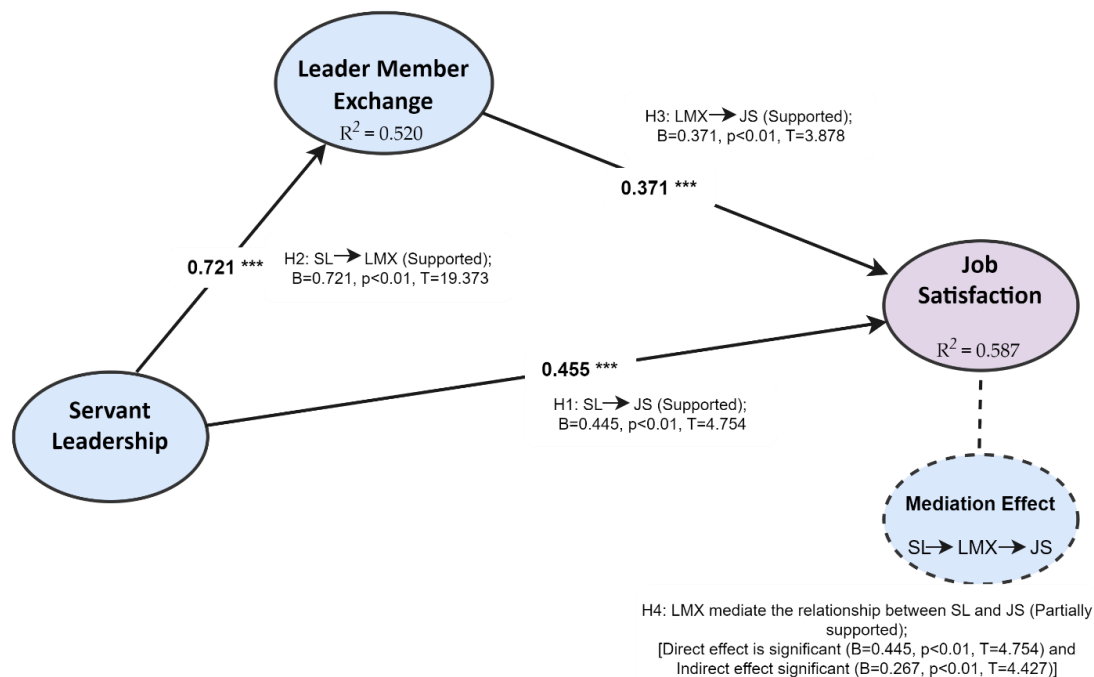

Figure 1. Partial least square SEM results. *Source: Authors.*

Test of the Mediation of LMX on the Relationship between LS and JS
To evaluate the mediating effect of LMX, we followed the approach recommended by Zhao et al. (2010), in which the indirect effects (i.e., SL * LMX) indicate whether LMX mediates the impact of SL on JS. If the indirect effect is significant, we then proceed to examine the direct effect [51]. If the direct effect is significant, it suggests complementary (partial) mediation, while an insignificant direct effect suggests indirect (full) mediation. Our findings reveal a significant indirect effect (B=0.267, p<0.01, T=4.427) and a significant direct effect of SL on JS (B=0.445, p<0.01, T=4.754). These findings imply that the association between JS and SL is either complementary or partially mediated by LMX.

Gender-based Analysis
To determine whether there were any gender differences in the hypotheses, we compared the male and female groups. Given that there were 100 male cases and 105 female cases, we analysed the first 100 cases of the female group and performed PLS analysis on both groups. The results are displayed in Table 6 and reveal a minor distinction between the two groups. Specifically, the male group exhibited greater significance for H1 and H2, while the female group exhibited more significance for H3 and H4. Notably, our findings suggest that the mediation role of LMX is more apparent for females, in the relationship between JS and SL, as indicated by H4.

Table 6. Group analysis results. *Source: Authors.*

Gender	H1	H2	H3	H4	R²
Male	0.537***	0.744***	0.294***	0.222**	JS=0.611, LMX=0.553
Female	0.395***	0.702***	0.472***	0.331***	JS=0.640, LMX=0.492

Discussion

This study investigated the mediation effect of LMX in the relationship between JS and SL in private universities in Kuwait. The study investigated several hypotheses, namely SL and JS (H1), SL and LMX (H2), LMX and JS (H3), and the mediation effect of LMX (H4). We analysed the data collected (205 surveys) from two universities using PLS-SEM. The results showed that in the SL style, there is a strong emphasis on supporting followers rather than trying to align their interests with those of the organization. SL plays a vital role in influencing LMX and LMX partially mediates the relationship between JS and SL. Additionally, LMX may play a crucial role in influencing follower happiness and contentment. In the following sections, the implications and research limitations are discussed. JS and SL are connected because when leaders put their followers' needs first, it can increase their sense of fulfilment at work. When leaders demonstrate SL traits like empathy, listening, and autonomy, they foster a productive workplace that can raise employee JS. Also, servant leaders may provide their followers the chance to explore their passions and grow their talents, which may enhance their overall JS. However, the robustness of the connection between commitment and SL might fluctuate contingent upon numerous factors, such as organizational culture, individual disparities among employees, and the distinct conduct of the servant leader. As no study is completely inclusive of all possible aspects, some limitations throughout the study were to be noted. As such, the study included two private higher education institutions situated in a specific geographical area with a sample size of 205, and thus the findings and results obtained from this research may not apply to other regions. Data and results from different geographical sites could vary and differ from those of this study. In addition, the sample size of the studied population, which is 205 may not be large, however, PLS-SEM has the capability and robustness to analyse as small as 30 samples [52]. Another limitation of this study lies within the chosen sample as not all academic institutions and their faculties/departments were surveyed, as well as the cohort of the higher education institutions' members and employees as this study focused mainly on the non-faculty (i.e., administration individuals such as employees from executive roles, manager group, and personnel group (team leaders, supervisors, employees)). This may decrease efficiency and representativeness.

Impact

Advocates of SL argue that there are numerous benefits to this leadership style. Empowered staff tend to work more creatively and innovatively, resulting in greater engagement, purpose-driven attitudes, and lower turnover costs for the organization. The findings confirmed that implementing the SL style in private higher education institutions in Kuwait has a positive impact on employees' level of JS, leading to better employee outcomes and productivity, which supports the first hypothesis (H1). These findings provide insights into the potential benefits of applying SL and the importance of balancing learning, service, and leadership [25]. This result is consistent with other research that showed the positive effects of SL on JS [53,54]. Nevertheless, research by Liu et al. [55] on Chinese public sector employees showed that they were unable to properly recognize all the aspects of SL, highlighting the need to consider its dimensionality in many situations. The findings also suggest that the SL approach can be a useful tool for team leaders, supervisors, and managers in the higher education sector to improve employee outcomes, such as JS, productivity, and retention, and enhance the long-term vitality of their organizations [11]. The results also offer proof that embracing the SL approach results in an elevated standard of LMX and a more robust bond between the leader and their followers, as indicated by Hypothesis 2 (H2). This finding is consistent with other earlier research that looked at the connection between SL and LMX and demonstrated a positive effect of SL on LMX (e.g., [33,56]). Leaders who defer credit to others, maintain a low profile, and refrain from seeking praise or rewards for their achievements on behalf of others can decrease employee satisfaction levels [12]. As servant leaders place a great value on their followers' individual consideration and relationship-building, SL may help create LMX partnerships of the highest calibre. Servant leaders may foster good interactions that strengthen trust and loyalty with their followers by actively listening to their followers' needs and responding with encouragement and empowerment [57]. Strong LMX connections can support the JS level (H3). This finding aligns with prior research endeavours that have explored the connection between JS and LMX (e.g., 36-37). Strong ties between leaders and followers may make them feel more at ease talking openly and working together to achieve common objectives, which can promote an SL

Employees' goal orientations, the quality of leader-member exchange, and the outcomes of job performance and job satisfaction culture inside the company and result in more JS. Building trust, affection, and mutual respect at the LMX stage of personalized relationships leads to the formation of stronger links between leaders and followers. Well-trained and trusted employees can continue to grow as future leaders, ensuring the organization's long-term vitality.

The findings, however, partially supported (H4). This result is in line with Akdol et al. [17] findings. This partial mediation may mean that the mediation role of LMX might be effective and positive under certain circumstances on the relationship between JS and SL. This may also suggest that other factors may also play a role in determining employee satisfaction. The findings of this research may help leaders in the importance of prioritizing employee needs, providing them with encouragement and praise, and establishing personalized relationships based on trust, respect, and mutual affection. Moreover, team leaders, supervisors, and managers can foster a culture of empowerment by delegating responsibilities, providing opportunities for skill development and growth, and recognizing employees' contributions and achievements. To sum up, leaders have the authority, influence, and ability to grow and expand employees' JS levels when they demonstrate leadership behaviours, acquire definite leadership styles, and define their position as leaders. This means that these team leaders and managers must expand and enhance their leadership services and talents, as well as adapt their leadership style to the circumstances, settings, and goals they intend to attain. Furthermore, administrative leadership recruiting, for example, which is based on a psychometric exam on SL leader style and readiness, may need to provide leadership style training and growth to all managers and leaders in the institution.

Conclusions

This research endeavours to investigate the influence of SL on JS and to scrutinize the connections between LMX and JS, and LMX and SL, specifically within the private universities in Kuwait. Furthermore, the study aims to assess the mediating role played by LMX in the connection between JS and SL in this sector. Furthermore, the study sought to examine gender differences in the data analysis. The research employed PLS-SEM to test several hypotheses on the connections between SL, JS, and LMX. According to the findings, there were positive and significant relationships observed between SL and JS (H1), SL and LMX (H2), and LMX and JS (H3). However, the mediation impact of LMX (H4) was only partially supported. It was also found that there were no significant differences between males and females in all hypotheses. In conclusion, SL, LMX, and JS are connected conceptions that may have an impact on one another. Positive LMX connections may be facilitated and increased levels of JS among followers through SL activities like empathy and empowerment. Like this, strong LMX connections might encourage an SL culture where leaders put their followers' development and well-being first. High levels of JS among workers may increase their propensity to form wholesome LMX connections and regard their managers as servant leaders. Generally, these ideas are linked and may cooperate to produce productive workplaces and outcomes for people and organizations. To further validate the findings, future research could be conducted in other countries within the Middle East region and with a larger sample size that includes more institutions.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

References

[1]   R.K. Greenleaf, Servant leadership: A journey into the nature of legitimate power and greatness., (2002).

[2]   A. Amussah, Leadership styles and its impact on employee performance, School of Social Sciences, Near East University, Nicosia, 2020.

[3]   F. Saleem, Y.Z. Zhang, C. Gopinath, A. Adeel, Impact of servant leadership on performance: The mediating role of affective and cognitive trust, SAGE Open. 10 (2020) 215824401990056. https://doi.org/10.1177/2158244019900562.

[4]   D. van Dierendonck, Servant leadership: A review and synthesis, J. Manage. 37 (2011) 1228–1261. https://doi.org/10.1177/0149206310380462.

[5]   D. Said, D. Youssef, N. El-Bayaa, Y.I. Alzoubi, H. Zaim, The impact of diversity on job performance: evidence from private universities in Egypt, Acta Innov. (2023) 17–30. https://doi.org/10.32933/ActaInnovations.49.2.

[6]   A. Abbas, M. Saud, I. Usman, D. Ekowati, Servant leadership and religiosity: An indicator of employee performance in the education sector, Int. J. Innov. Creat. Chang. 13 (2020) 391–409.

[7]   M. Chiniara, K. Bentein, Linking servant leadership to individual performance: Differentiating the mediating role of autonomy, competence and relatedness need satisfaction, Leadersh. Q. 27 (2016) 124–141. https://doi.org/10.1016/j.leaqua.2015.08.004.

[8]   A.M. Kumar, Servant leadership in Indian NGOs, 2020.

[9]   A. Aggarwal, K. Nobi, D. Jaisinghani, G. Sharma, Analysing the mediating effect of leader-member exchange on the relationship between servant leadership and organisational commitment, Int. J. Econ. Bus. Res. 21 (2021) 287. https://doi.org/10.1504/IJEBR.2021.113144.

[10]   K. Dahleez, M. Aboramadan, Servant leadership and job satisfaction in higher education: the mediating roles of organizational justice and organizational trust, Int. J. Leadersh. Educ. (2022) 1–22. https://doi.org/10.1080/13603124.2022.2052753.

[11]   N. El-Bayaa, H.A. Elsaman, The efficacy of adopting servant leadership to improve employee engagement and job satisfaction. Empirical Study of Higher Education Sector in Kuwait, J. Posit. Sch. Psychol. 6 (2022) 10261–10265.

[12]   A. Abbas, M. Saud, F. Suhariadi, I. Usman, D. Ekowati, Positive leadership psychology: Authentic and servant leadership in higher education in Pakistan, Curr. Psychol. 41 (2022) 5859–5871. https://doi.org/10.1007/s12144-020-01051-1.

[13]   A. Al-Asfour, A. Charkasova, J. Rajasekar, E. Kentiba, Servant leadership behaviors and the level of readiness to covid-19 pandemic: evidence from USA higher education institutions, Int. J. Leadersh. Educ. (2022) 1–18. https://doi.org/10.1080/13603124.2022.2108505.

[14]   A.A. Shafai, Servant-leadership in Higher Education in Saudi Arabia, Int. J. Servant-Leadersh. 12 (2018) 297–335. https://doi.org/10.33972/ijsl.79.

[15]   G.B. Graen, M. Uhl-Bien, Relationship-based approach to leadership: Development of leader-member exchange (LMX) theory of leadership over 25 years: Applying a multi-level multi-domain perspective, Leadersh. Q. 6 (1995) 219–247. https://doi.org/10.1016/1048-9843(95)90036-5.

[16]   R. Liden, Multidimensionality of leader-member exchange: An empirical assessment through scale development, J. Manage. 24 (1998) 43–72. https://doi.org/10.1016/S0149-2063(99)80053-1.

[17]   B. Akdol, F.S. Arikboga, Leader member exchange as a mediator of the relationship between servant leadership and job satisfaction: A research on Turkish ICT companies, Int. J. Organ. Leadersh. 6 (2017) 525–535.

[18]   T. Kalifa, S. Ololo, F. Tafese, Intention to leave and associated factors among health professionals in Jimma Zone Public Health Centers, Southwest Ethiopia, Open J. Prev. Med. 06 (2016) 31–41. https://doi.org/10.4236/ojpm.2016.61003.

[19]   B. Hasanuddin, M. Mustainah, C.P. Dewi Buntuang, The influence of servant leadership on job satisfaction with individual character as a moderating variable, Probl. Perspect. Manag. 19 (2021) 445–455. https://doi.org/10.21511/ppm.19(1).2021.37.

[20]   E.B. Conant, The impact of role conflict on job satisfaction of independent school athletic directors, J. Amat. Sport. 3 (2017). https://doi.org/10.17161/jas.v0i0.5730.

[21]   E.E. Lawler III, Motivation in work organizations, Brookes-Cole Publishing, Monterey, California: ERIC, 1973.

[22]   E.A. Locke, The nature and causes of job satisfaction, Handb. Ind. Organ. Psychol. 1 (1976) 1297–1343.

[23]   F. Şahin, The mediating effect of leader–member exchange on the relationship between Theory X and Y management styles and affective commitment: A multilevel analysis, J. Manag. Organ. 18 (2012) 159–174. https://doi.org/10.5172/jmo.2012.18.2.159.

[24]   D. van Dierendonck, I. Nuijten, The servant leadership survey: Development and validation of a multidimensional measure, J. Bus. Psychol. 26 (2011) 249–267. https://doi.org/10.1007/s10869-010-9194-1. [25] M. Aboramadan, B. Albashiti, H. Alharazin, K.A. Dahleez, Human resources management practices and organizational commitment in higher education, Int. J. Educ. Manag. 34 (2020) 154–174. https://doi.org/10.1108/IJEM-04-2019-0160.

[26]   S. Drury, Employee perceptions of servant leadership: Comparisons by level and with job satisfaction and organizational commitment, Regent University, 2004.

[27]   S.C. Hebert, The relationship of perceived servant leadership and job satisfaction from the follower's perspective, Capella University, 2003.

[28]   R.R. Washington, Empirical relationships among servant, transformational, and transactional leadership: Similarities, differences, and correlations with job satisfaction and organizational commitment, Auburn University, 2007.

[29]   M. Lavoie-Tremblay, C. Gélinas, T. Aubé, E. Tchouaket, D. Tremblay, M.P. Gagnon, J. Côté, Influence of caring for COVID-19 patients on nurse's turnover, work satisfaction and quality of care, J. Nurs. Manag. 30 (2022) 33–43. https://doi.org/10.1111/jonm.13462.

[30]   C.A. Amadeo, A correlational study of servant leadership and registered nurse job satisfaction in acute health-care settings, University of Phoenix, 2008.

[31]   K.P. Anderson, A correlational analysis of servant leadership and job satisfaction in a religious educational organization, University of Phoenix, 2005.

[32]   C.I. Chu, H.M. Hsu, J.L. Price, J.Y. Lee, Job satisfaction of hospital nurses: an empirical test of a causal model in Taiwan, Int. Nurs. Rev. 50 (2003) 176–182. https://doi.org/10.1046/j.1466-7657.2003.00165.x.

[33]   A. Salie, Servant-minded leadership and work satisfaction in Islamic organizations: A correlational mixed study, University of Phoenix, 2008.

[34]   L.Z. Wu, E.C.Y. Tse, P. Fu, H.K. Kwan, J. Liu, The impact of servant leadership on hotel Employees' "Servant behavior," Cornell Hosp. Q. 54 (2013) 383–395. https://doi.org/10.1177/1938965513482519.

[35]   J. Zeng, G. Xu, Linking ethical leadership to employee voice: The role of trust, Soc. Behav. Personal. an Int. J. 48 (2020) 1–12. https://doi.org/10.2224/sbp.9200.

[36]   O. Janssen, N.W. Van Yperen, Employees' goal orientations, the quality of leader - member exchange, and the outcomes of job performance and job satisfaction., Acad. Manag. J. 47 (2004) 368–384. https://doi.org/10.2307/20159587.

[37]   J. Volmer, C. Niessen, D. Spurk, A. Linz, A.E. Abele, Reciprocal relationship between leader-member exchange (LMX) and job satisfaction: A cross-lagged analysis, Appl. Psychol. 60 (2011) 522–545. https://doi.org/10.1111/j.1464-0597.2011.00446.x.

[38]   H. Heriyadi, H.K. Tjahjono, M.K.P. Rahayu, Improving organizational citizenship behavior through job satisfaction, leader-member exchange, and work-life balance, Binus Bus. Rev. 11 (2020) 97–104. https://doi.org/10.21512/bbr.v11i2.6193.

[39]   B.J. Avolio, W. Zhu, W. Koh, P. Bhatia, Transformational leadership and organizational commitment: mediating role of psychological empowerment and moderating role of structural distance, J. Organ. Behav. 25 (2004) 951–968. https://doi.org/10.1002/job.283.

[40]   O. Epitropaki, R. Martin, From ideal to real: A longitudinal study of the role of implicit leadership theories on leader-member exchanges and employee outcomes., J. Appl. Psychol. 90 (2005) 659–676. https://doi.org/10.1037/0021-9010.90.4.659.

[41]   S. Tsang, C. Royse, A.S. Terkawi, Guidelines for developing, translating, and validating a questionnaire in perioperative and pain medicine, Saudi J. Anaesth. 11 (2017) 80. https://doi.org/10.4103/sja.SJA_203_17.

[42]   Y.I. Alzoubi, A.Q. Gill, An Empirical Investigation of Geographically Distributed Agile Development: The Agile Enterprise Architecture is a Communication Enabler, IEEE Access. 8 (2020) 80269–80289. https://doi.org/10.1109/ACCESS.2020.2990389.

[43]   D.S. Said, S. Agarwal, Y.I. Alzoubi, M.M. Momin, A. Naqvi, Occupational stress among Generation-Y employees in the era of COVID-19: cases from universities in India, Ind. Commer. Train. 55 (2023) 234–252. https://doi.org/10.1108/ICT-03-2022-0017.

[44]   J.F. Hair, W.C. Black, B.J. Babin, R.E. Anderson, Multivariate data analysis, 7 ed., Pearson Prentice Hall, New York, 2010.

[45]   J.F. Hair, G.T. Hult, C.M. Ringle, M. Sarstedt, N.P. Danks, S. Ray, Partial least squares structural equation modeling (PLS-SEM) using R. A workbook., Springer Nature, 2021.

[46]   R.C. Liden, S.J. Wayne, H. Zhao, D. Henderson, Servant leadership: Development of a multidimensional measure and multi-level assessment, Leadersh. Q. 19 (2008) 161–177. https://doi.org/10.1016/j.leaqua.2008.01.006.

[47]   A.M. Mohrman, R.A. Cooke, S.A. Mohrman, Participation in decision making: A multidimensional perspective, Educ. Adm. Q. 14 (1978) 13–29. https://doi.org/10.1177/0013161X7801400105.

[48]   S.B. MacKenzie, P.M. Podsakoff, Common Method Bias in Marketing: Causes, Mechanisms, and Procedural Remedies, J. Retail. 88 (2012) 542–555. https://doi.org/10.1016/j.jretai.2012.08.001.

[49]   M.S. Dinc, H. Zaim, M. Hassanin, Y.I. Alzoubi, The effects of transformational leadership on perceived organizational support and organizational identity, Hum. Syst. Manag. 41 (2022) 699–716. https://doi.org/10.3233/HSM-211563.

[50]   J. Henseler, C.M. Ringle, M. Sarstedt, A new criterion for assessing discriminant validity in variance-based structural equation modeling, J. Acad. Mark. Sci. 43 (2015) 115–135. https://doi.org/10.1007/s11747-014-0403-8.

[51]   X. Zhao, J.G. Lynch, Q. Chen, Reconsidering Baron and Kenny: Myths and truths about mediation analysis,

J. Consum. Res. 37 (2010) 197–206. https://doi.org/10.1086/651257.

[52]   Y.I. Alzoubi, A.Q. Gill, B. Moulton, A measurement model to analyze the effect of agile enterprise architecture on geographically distributed agile development, J. Softw. Eng. Res. Dev. 6 (2018) 4. https://doi.org/10.1186/s40411-018-0048-2.

[53]   Y. Ramma, S.P.S. Patiro, A. Daud, The influence of servant leadership on motivation and job satisfaction employees at the ministry of religious affairs of merauke regency: The mediation role of trust in leaders, Budapest Int. Res. Critics Institute-Journal. 5 (2022).

[54]   N. Vrcelj, V. Bevanda, N. Bevanda, Servant leadership: influence of job satisfaction and organizational commitment, Manag. Sustain. Bus. Manag. Solut. Emerg. Econ. (2022). https://doi.org/10.7595/management.fon.2022.0009.

[55]   B. Liu, W. Hu, Y.C. Cheng, From the west to the east, Public Pers. Manage. 44 (2015) 25–45. https://doi.org/10.1177/0091026014555995.

[56]   A.M.S. Mostafa, E.A.A. El-Motalib, Servant leadership, leader–member exchange and proactive behavior in the public health sector, Public Pers. Manage. 48 (2019) 309–324. https://doi.org/10.1177/0091026018816340.

[57]   T.M. Huning, K.J. Hurt, R.E. Frieder, The effect of servant leadership, perceived organizational support, job satisfaction and job embeddedness on turnover intentions, Evidence-Based HRM a Glob. Forum Empir. Scholarsh. 8 (2020) 177–194. https://doi.org/10.1108/EBHRM-06-2019-0049.

SECOND-HAND CLOTHING TRADE: ACHIEVING CIRCULAR ECONOMY IN THE FASHION SECTOR THROUGH INTERNATIONAL COOPERATION

Ana Gabriela Encino-Munoz*
UnitelmaSapienza – University of Rome
Piazza Sassari 4, 00161 Roma, Italy, gabriela.encino@unitelmasapienza.it
https://orcid.org/0000-0003-0008-6986

Piergiuseppe Morone
UnitelmaSapienza – University of Rome
Piazza Sassari 4, 00161 Roma, Italy, piergiuseppe.morone@unitelmasapienza.it
https://orcid.org/0000-0002-3240-7089

Highlight
The import and export of second-hand clothing require international cooperation to overcome circularity gaps and reduce the associated environmental and social issues.

Abstract
This paper explores the global dynamics of second-hand clothing (SHC) in light of the circular economy to identify gaps and suggest pathways to reduce negative impacts on the sector. The analysis identifies current global patterns of SHC international trade and the main hotspots, in order to build a framework for action. The framework incorporates the main stakeholders and a set of actions aimed at reducing the environmental and social issues associated with the international trade of SHC. The analysis suggests that the framework may reduce risks and facilitate the transition to a just circular economy in the SHC sector.

Introduction
Sustainability and (ultra) fast fashion
In recent decades, studies have shown that current consumption patterns are contributing to environmental degradation and natural resource depletion, endangering both the global equilibrium and well-being. Production and consumption are based on a take-make-dispose model, associated with increased material extraction and waste. Accordingly, the global material footprint has been growing, with research estimating an increase of 113% between the years 1990 and 2000, outpacing growth in population and economic output [1]. Annual waste generation is also showing an upward trend, and scholars have estimated that it will increase by 70% between 2016 to 2050, achieving a final level of 3.40 billion tonnes [2]. These trends reflect that contemporary patterns of consumption have become a threat to sustainable ways of living. The 2030 Agenda of the United Nations emphasises the importance of moderate levels of consumption and production, to achieve sustainable development [3]. Sustainability further implies the minimal use of natural resources and toxic materials and the minimal emission of waste and pollutants over the product life cycle [4]. Therefore, there is an acute need to transform consumption and production through a more efficient use of resources and the reduction of waste.

Fashion is a key sector for sustainability efforts due to its significant environmental and social impact. Studies have shown that many practices throughout the value chain are unsustainable due to their high resource usage and waste generation. In more detail, scholars have estimated that the fashion sector is responsible for 8 to 10% of CO_2 global emissions [5]. Additionally, the sector uses a large amount of fresh water for different processes in the value chain, and this water is subsequently discharged without treatment, with a significant impact on aquatic ecosystems [6]. Textiles further account for approximately 9% of annual microplastic losses to oceans [7]. Moreover, the apparel industry has been criticised for its poor performance on social sustainability markers with regards to human rights and labour conditions [8]. Despite the above-mentioned issues, the fashion sector continues to grow, driven by rising consumer demand. Currently, an average of 26kg of textiles per person are consumed each year in European households, and approximately 11kg are discarded [9]. Studies have estimated

that, by 2030, the consumption of clothing and footwear will increase by 63% [10]. The 'fast fashion' phenomenon has contributed to accelerating these consumption patterns. This model, which is characterised by a high number of product collections each year, stimulates overconsumption and the frequent replacement of garments, leading to significant textile waste. As a result of affordable prices and the drive for newness in the fashion sector, clothing consumption has doubled over the past few years, whilst the utilisation of garments has decreased [11]. Moreover, the emergence of so-called 'ultra-fast fashion' has placed the achievement of a sustainable fashion industry at further risk. Ultra-fast fashion is characterised by the provision of fashion items at an even faster pace relative to fast fashion [12]. While fast fashion introduces 2,000 to 11,000 garments to the market annually, ultra-fast fashion introduces 11,000 to 200,000 garments, supported by lead times as short as only a few days [12]. Thus, while ultra-fast fashion might present some advantages in terms of material efficiency (i.e., reduced inventories, local production, on-demand manufacturing), the large number of items introduced to the market encourages overconsumption, creating new issues in the sector.

Currently, the end-of-life (EoL) phase in the clothing life cycle demonstrates low sustainability, driven by the excessive waste generation attributable to fast and ultra-fast fashion. According to some sources, only 20% of clothing is reused or recycled at the EoL, with the rest deposited in landfills or incinerated [13]. The linear consumption model that is currently evidenced in the fashion industry is not sustainable. Rather, production and consumption models must be redesigned to decelerate resource usage and waste generation in this industry.

Circularity Gaps in the Fashion Sector

The circular economy (CE) represents an alternative to the linear economy model, aligned with environmental sustainability and economic development [14]. Specifically, the model aims at maintaining materials' economic and environmental values for as long as possible, through recirculation, prolonged usage or reuse [15]. This is accomplished via three main principles (i) 'designing out' waste and pollution, (ii) keeping products and materials in use and (iii) regenerating natural systems [16]. Thus, these processes serve as effective guidelines for strategies aimed at transforming production and consumption systems. For technical cycles, the CE proposes different strategies to minimise systematic leakage and negative externalities [16]. The aim is to ensure materials and products are recirculated for as long as possible, by maintaining or prolonging product lifespans, refurbishing or remanufacturing, and recycling [17].

The European Commission aims at scaling up the CE to reach mainstream economic players, in order to support efforts to achieve a climate-neutral society by 2050 and decouple economic growth from resource use [18]. The EU New Circular Economy Action Plan classifies the textile industry as a target sector for such initiatives, since it is among the most resource-intensive sectors and has high circularity potential [19]. To date, some implementations of the CE have emerged in the fashion sector. Resale, rental, repair and remake are increasing. Such business models have the potential to grow from a current market share of 3.5% to achieve 23% of the market by 2030 [20]. However, despite the interest of many stakeholders in moving towards a circular fashion industry, the sector faces numerous challenges. The following section explores a relevant gap in the transition to a circular textile sector, represented by the international second-hand clothing (SHC) market.

Issues in Current Circular Schemes: International Trade in Second-Hand Clothing

The past decade has seen several developments in circular strategies in the fashion sector. Among these, some frameworks have focused on reducing environmental impacts through material recovery (e.g., 'design-for-recycling' strategies [21]), while others have employed a life-cycle perspective to improve production practices and reduce the risk of harm [22]. Still other circular strategies have explored ways of recycling textile waste. However, due to the complexity of these processes and the fact that most of the materials in clothing are mixed [23], less than 1% of clothes are actually recycled as clothing [24]. Sandin and Peters [25] concluded that, in many studies, reuse has been considered more environmentally beneficial than recycling. For this reason, the recovery, redistribution and reuse of garments have been emphasised as the most sustainable and circular alternatives with the lowest environmental impact. However, despite efforts to engage in these activities, the fashion sector still faces many challenges. One of these is the EoL of products, when observed through the lens of global networks.

Economic globalisation has changed the dynamics of value chains. According to the UNCTAD, 80% of international trade is structured through global production networks [26], representing 'organizational platforms through which actors in different regional and national economies compete and cooperate for a greater share of value creation, transformation, and capture through geographically dispersed economic activity' [26]. This fact is useful for unveiling some of the gaps in the CE framework linked to the current imbalance

between garment consumption and production. The fashion supply chain is built upon a complex set of operations (e.g., cultivation and creation of raw materials, fibre processing, clothing manufacturing) that are frequently carried out in different parts of the world [27]. Thus, a global production network approach may contribute insights into the CE and sustainability of the fashion industry by shedding light on the dynamics of the international trade in SHC.

While much previous research has explored the CE concept, less attention has been given to its social dimension, relative to its environmental aspects [28,29]. In particular, only a few studies have analysed the relevance of international trade to circular models. However, researchers have started to explore asymmetries between the Global North and Global South in different sectors (including the fashion industry) [30,31], highlighting the limitations of current models of international trade – particularly in the export of waste, which poses environmental and social justice issues.

Government bodies have also begun to acknowledge the implications of unsustainable practices in the fashion sector. As an example, the European Commission envisioned a pathway to sustainability and circularity in the textile sector by the year 2030 [10], addressing several issues, including improvements in garment durability, green claims assurances, and EoL strategies (i.e., repair and recycling). More recently, a harmonised Extended Producer Responsibility (EPR) scheme for 2030 across European states was proposed. Additionally, the proposal for the amendment to the Waste Framework Directive [32] outlines problems linked to the sorting, commercialisation and export of used textiles, highlighting the need for greater consistency in waste classification and harmonised quantification systems across the region. These legislative initiatives indicate the need for a deeper understanding of current issues pertaining to circular models at the international level, identifying risks and opportunities for closing the loop in the textile sector.

Methods
This section describes the methodology employed for the current research. The study was based on desk research, integrating different qualitative and quantitative sources to gain a broad understanding of the issue. The research proceeded in three main stages: (i) identification and review of the relevant literature, including the scientific and 'grey' literature; (ii) analysis of data from trade databases and (iii) definition of a framework for action based on the results of the analysis. The first stage involved the identification and review of the relevant literature. In this process, grey literature provided an important source of information, given the increased attention to the fashion sector evidenced by NGOs and civil society organisations in recent years. The identification of relevant literature (both scientific and grey) was guided by the aim of deepening our understanding of trajectories of SHC market and relevant stakeholders throughout the value chain.

The second stage involved the analysis of trade statistics, using the United Nations Comtrade database [33]. This database provides detailed global trade statistics for individual products and trading partners, shedding light on the dynamics of global trade in the SHC. The database employs a specific 'Harmonised System Code' (HS Code 2017) for 'used textiles' (No. 63), referring to 'Textiles, made-up articles; sets; worn clothing and worn textile articles; and rags'. Since the focus of the research was SHC, the analysis used data specifically from subsection (No. 6309), describing textiles in the form of 'worn clothing and other worn articles', while excluding other subcategories (e.g., bed and table linen, curtains, blankets, travelling rugs, furnishing articles, tents, rags). Due to data asymmetries with regard to import-export value, an additional analysis was conducted comparing bilateral SHC trade values in an effort to shed light on the observed differences.

In the third stage, all of the collected data were analysed to classify the main issues in the value chain and their relative levels of risk. This analysis informed the development of a framework for action accompanied by a set of recommendations. The framework was organised according to individual agents and their potential areas of intervention.

Results and Discussion
International Trade of SHC: Trajectories and Trends
Before proposing alternative practices aimed at increasing the sustainability of the textile sector, it is important to first acknowledge the environmental and social impacts of all steps in the value chain, including post-consumption, and issues associated with current models of circularity from a global perspective. This section presents the results of the analysis of the literature and trading statistics to determine common trajectories in the international trade of SHC. Additionally, it reveals some global asymmetries in the SHC trade flow. Finally,

it explores relevant cases to illustrate important facets of the issue. Excess clothing production and consumption driven by fast and ultra-fast fashion models is the starting point for the global network. In the Global North, discarded items become raw materials for the value chain, with "a vast surplus of used clothing" [34] deposited in the Global South, creating complex dynamics that will be further discussed below. Figure 1 illustrates the stages of the fashion value chain, also showing the geographical locations in which operations occur. It can be observed that, while most of the manufacturing processes are located in the Global South, the products are generally consumed in markets in the Global North – particularly within the United States, the United Kingdom and the EU [5]. This indicates an unbalanced distribution of environmental impacts in the production phase. In addition, once unwanted garments are discarded by consumers in the Global North, there is a high probability that they will travel to the Global South as second-hand items.
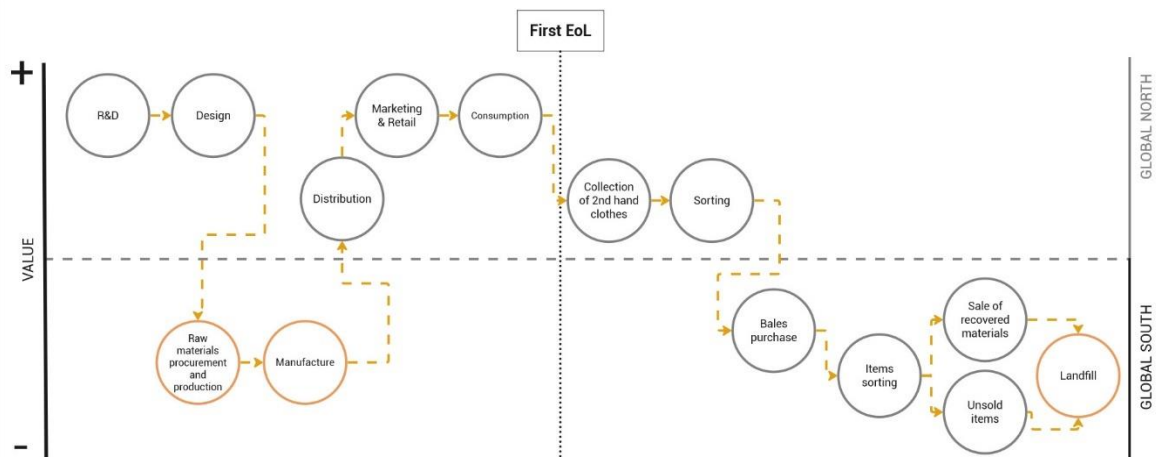

Figure 1. Stages of new and second-hand garments. *Source: own elaboration based on [5,34–37].*

Trajectories: From donation to markets in the Global South

A closer look at the SHC market reveals intricate nodes within a larger global network. Research has identified some of the issues regarding the international trade of SHC, highlighting a dominant trade flow from the Global North to the Global South [34,37,38]. However, the dynamics of the trade activities, as well as the involved agents, have been here analysed with the aim of proposing some cooperation strategies. From the different sources analysed, we were able to unravel the complexity of the international trade of SHC, identifying the main actions and the points at which significant issues arise. Figure 2 presents a synthesis of the findings, illustrating the relevant steps taken by SHC goods from the collection point to the final destination.

Typically, collection occurs in the Global North – normally as a donation [34,36]. These goods are later commercialised when charities sell the majority of the donated goods to private companies, which subsequently export them [39]. Recently, for-profit organisations (particularly in the United Kingdom) have begun to systematically collect SHC, often through textile banks or door-to-door collection [40]. Where SHC is donated to charities, the charities conduct an initial selection of the goods, keeping the best quality items for direct-to-consumer sale and selling the remainder to wholesalers, who initiate a new sorting process. Some companies outsource their sorting processes to operators in other countries [36,41] , in order to minimise costs. However, the energy required to transport the merchandise abroad adds to the carbon footprint.

The classification of garments prior to export has become a complex process. Items must be ranked in quality to determine their potential for local resale or, conversely, their potential for export due to specific characteristics. Some companies employ up to 400 categories in their sorting process [37]. The sorting aims at determining a grade for the quality of items to determine their final destination: items with better quality reach higher-value markets (i.e., East Europe) while those with lower quality reach countries in the Global South (i.e., African countries, Pakistan, Syria) [34]. Although sorting centres have operational rules, their sorting process remains unclear, particularly for importers and local buyers of second-hand clothing.

Sorting and exporting (in the form of bales weighing up to 50kg) is a high-risk activity, due to information asymmetry. Exporters, who design and manage the textile sorting system, hold significantly more information about the characteristics and quality of the items they are selling than the customers who are buying them [42]. Since bales of SHC are sold 'closed', buyers are unaware of what they contain, often with negative effects. Studies have shown that buyers of bales often declare that a large proportion of the contents lack sufficient quality for

sale. Thus, there is a high probability that retailers will discard unsellable items. For example, Rivoli found that many retailers obtained 90% of a bale's value from only 10% of the content [37]. Similarly, Brooks observed that, since the quality of donations is very limited in the United Kingdom, textile merchants commonly include low-grade clothing in high-quality bales in an effort to maximise profit [34]. Such practices hinder the possibility of achieving a fair CE. Improving information symmetry would not only ensure that buyers get what they pay for, but also reduce shipping waste.
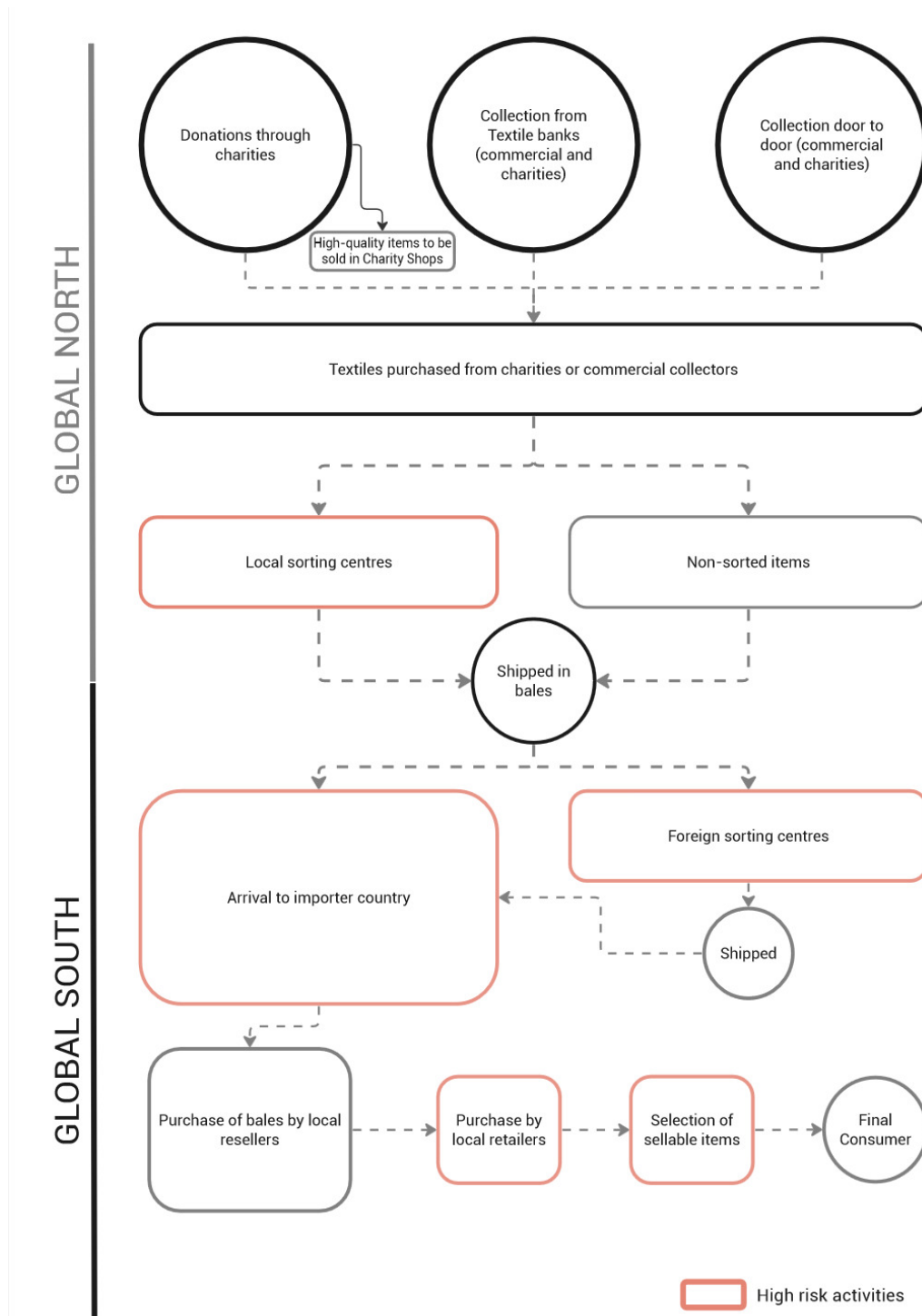

Figure 2. The trajectory of second-hand imported clothing. *Source: own elaboration based on [34,36,37,40].*

Our analysis of the flow of imported SHC highlighted the main risks to achieving a closed loop in the value chain. Figure 3 shows a circular model for goods on the outer circle and, on the inner circle, the real cycle of imported SHC. As previously discussed, SHC does not travel along a closed loop. Instead, many items are discarded during the first process of sorting and, after the bales are acquired by local retailers, more items are discarded in a second process of selecting garments with resale value.
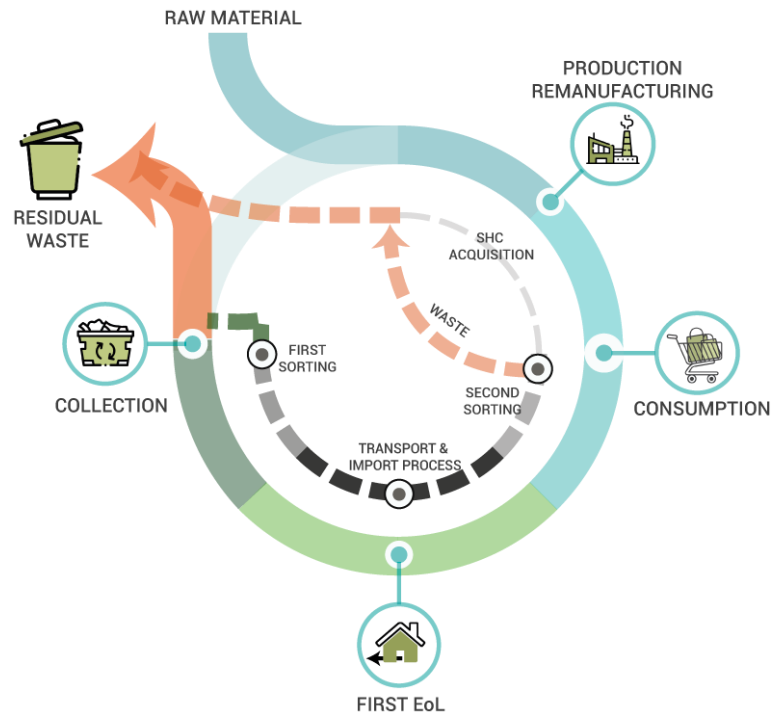

Figure 3. Circular model and the trajectory of second-hand clothing. *Source: own elaboration using Freepik sources.*

Due to the large amount of clothing arriving in destination countries and the constant decrease in clothing quality, it has been estimated that up to 40% of each imported bale ends up in a landfill within a week of receipt. However, one recent field study observed that, in a bale containing 200 garments, only 7 items were considered sellable [43], with the remainder (95%) sent straight to a landfill or illegally dumped. Such numbers help to illustrate current environmental burdens linked to this industry.

Some regions have developed more fair ways of trading SHC. For example, in an effort to reduce the information asymmetry between exporters and importers, Igbo apprentices from West Africa sent apprentices to British exporting companies to inspect items and select those with the greatest probability of being successfully commercialised [42]. Despite the effectiveness of this strategy (in which the importer becomes an active agent of quality assurance), it is infrequently operationalised within the sector, and there are few other alternatives.

Evidence of an Increasing Problem: Trends in the International Trade of Second-Hand Clothing
An analysis of trade data from the UN Comtrade database – specifically with regard to category 6309 (i.e., 'worn clothing and other worn articles' [33] – aimed at identifying the scale of global imports and exports of clothing over the past 10 years. Figure 4 shows the trend in SHC trade between 2011 and 2021, showing a steady increase in both imports and exports over the period, with the exception of the year 2020, which documented a decrease in both exports and imports. This outlier presumably relates to the restrictions on international trade associated with efforts to counteract the spread of COVID-19 as other studies have found significant effects of this phenomenon on international trade [44]. However, the global trade in SHC increased significantly in 2021, showing that, despite the slowdown in 2020, the value of imports and exports quickly recovered, and the upward trend continued.

Of note, Figure 4 also shows significant differences in the reported values for imports and exports. This phenomenon, known as 'bilateral asymmetry', is frequently observed in official statistics. While there are many reasons for such asymmetry, it is commonly attributable to differences in the valuation of goods. Considering

SHC, imports usually include the cost of insurance and freight (CIF), while exports are valued free on board (FOB). However, this variation does not account for the total difference observed in the final quantities, as CIB and FOB margins typically account for approximately 5% of the total value [45], whilst the data for 2011–2021 show an average difference of 22.11%. For this reason, an additional analysis was conducted, comparing the values reported by each country via bilateral trade data for tracking value differences in each import-export transaction, in an effort to identify the source of the observed differences [1].
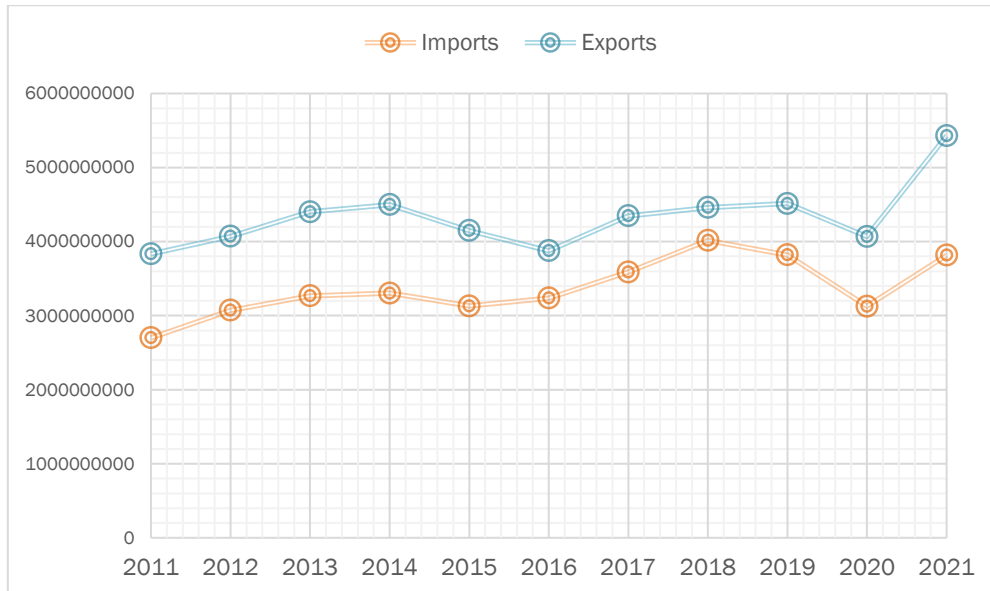

Figure 4. Second-hand clothing global trade value (USD) in the years 2011–2021. *Source: own elaboration based on UN Comtrade data.*

Although this was not the central focus of the analysis, the results helped us to identify issues in the SHC international merchandise trade statistics. Asymmetry in trade statistics is a central concern, as it can lead to misconceptions about trade balances [46]. With respect to the present analysis for the SHC market, the largest asymmetry was demonstrated in the years 2014 and 2015 between Mexico and the United States, whereby the United States reported a large SHC export value while Mexico consistently reported a value of 0 for SHC imports from the United States. Since SHC import is illegal in Mexico, this asymmetry may indicate that illegal imports took place. Another case of consistent asymmetry occurred between Ghana and the United Kingdom, with the United Kingdom reporting a larger export value compared to the import value reported by Ghana. Finally, another interesting case emerged between the United States and Chile, with the United States consistently reporting greater export values than the import values reported by Chile. Although no reason can be identified for such asymmetries from the numerical data alone, the asymmetries may nonetheless point to problematic transactions, especially when they persist over multiple years.

The UN Comtrade data contains not only trade values but also trade quantities. In the case of textiles, quantity was measured in kilograms. Since the present study aimed at identifying the amount of waste derived from the international trade of SHC, we also tracked patterns in the quantity of traded clothing, in consideration that this quantity might not be linked to the financial value of the imported goods. In this analysis, asymmetry once again emerged between the declared exports and imports. As shown a Figure 5[2], the declared imports were lower than the declared exports. This asymmetry may be linked to the factors previously mentioned (i.e., underreported activity, illegal trade). The literature on waste trade (and particularly SHC trade) describes that illegal imports may occur on borders with weak regulatory measures and in countries that have banned the importation of SHC [36,47]. However, such asymmetries are not visible in Figure 4. This might be explained

---

[1] For this analysis, the import and export data were processed using R Studio, which generated the differences in value reported by the exporting versus importing countries, including the bilateral trade flows of all countries.

[2] For this analysis, Mozambique was excluded, as the reported amount for this country was not coherent with the other reported numbers in the data.

by either difference in the prices per kilogram reported by the exporting and importing countries or a loss of monetary value during the process of importation.
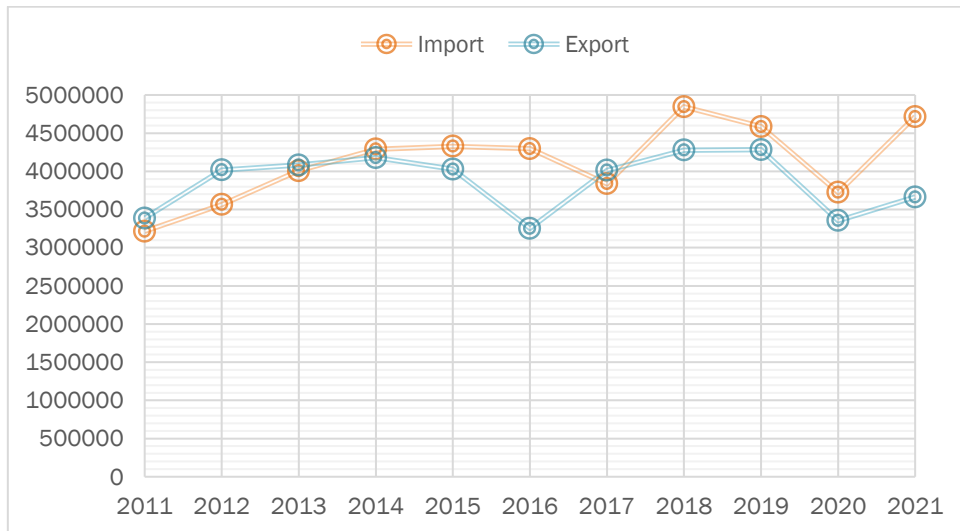

Figure 5. International trade of second-hand clothing by weight (tonnes) in the years 2011–2021. *Source: own elaboration based on UN Comtrade data.*

Both figures (i.e., Figures 4 and 5) contribute to a full picture of SHC trade. What is remarkable is that, despite any asymmetries they reveal, both point to a similar trend: SHC trade has consistently grown (aside from in 2020, when all trading activity decreased). In addition, the combined data on value and volume suggest that, although patterns can be identified, the quantification of clothing imports and exports must be improved, in order to generate a precise picture of activities in each country. The observed asymmetries further highlight the need for an improved and shared system for collecting and reporting relevant statistics.

In terms of the leading export countries, the results of the present analysis corroborate previous research, showing a dominant SHC trade flow from the Global North to the Global South [34,38,43]. However, some new insights may also be gleaned. As shown in Figure 6, the top exporting countries remained relatively stable between 2015 and 2021. In particular, the United States was the main global exporter from 2015 to 2020, followed by the United Kingdom, Germany and the Republic of Korea (all located in the Global North). China represented the sole exception to this pattern as a dominant exporter located in the Global South. This country has rapidly increased its export volume, and the value of its exports has also risen significantly in line with its economic power. This generates uncertainty about the SHC trading situation and its potential environmental and economic impacts, due to the complexity of multilateral international cooperation.
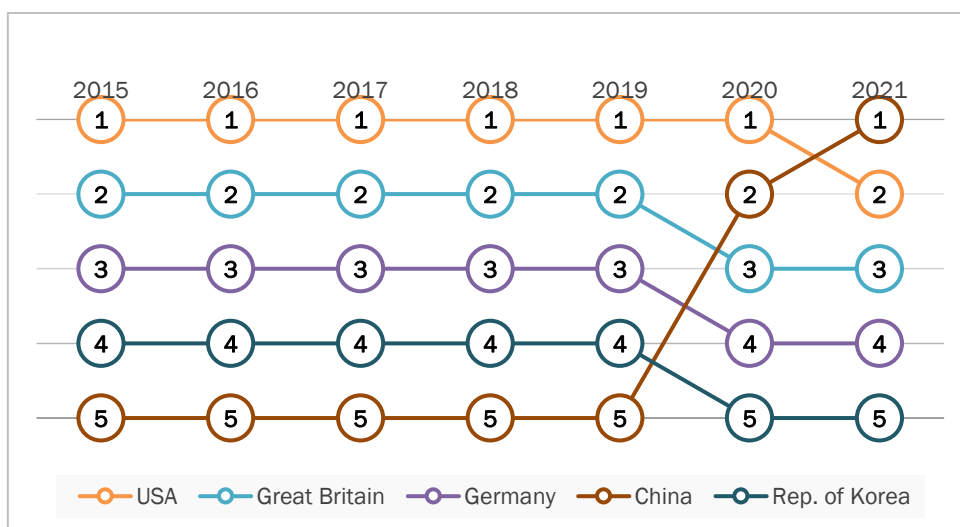

Figure 6. Main exporter countries in the years 2015–2021 (according to value). *Source: own elaboration with data from UN Comtrade.*

Figure 6 further shows that the top exporting countries were dominant throughout the entire period. In the year 2020, most SHC was exported by only 24 countries [48]. Considering also that the leading exporting countries make use of specific geographically and economically convenient trade routes [34], the data helped us to consider specific cooperation frameworks by region, taking into account the characteristics of the involved parties. Different global regions face similar situations, but two countries that have gained recent relevance by increasing their SHC imports are Ghana and Chile. Figure 7 presents the import data for both countries in the years 2007 to 2018 (the latest available data), which show an upward trend (particularly pronounced in the case of Chile). To estimate the potential impact of increased imports on these countries, it is essential not only to acknowledge the recent surge but also to consider the cumulative effect on textile waste resulting from imports that do not achieve a second use. This situation poses a risk for these countries, as well as for others experiencing a rising trend in SHC imports."

Between the 1980s and 1990s, economic liberalisation policies emerged in both Chile and Ghana. These policies helped to open the respective markets to foreign goods, including second-hand items. In Chile, restrictions on the import of second-hand items were – and continue to be – very limited [49]. Ghana also has nearly no restrictions on trade in SHC, except for one prohibiting the import of undergarments. From these examples, it can be concluded that certain characteristics may make countries more vulnerable to issues caused by a surplus in SHC imports and their associated waste.
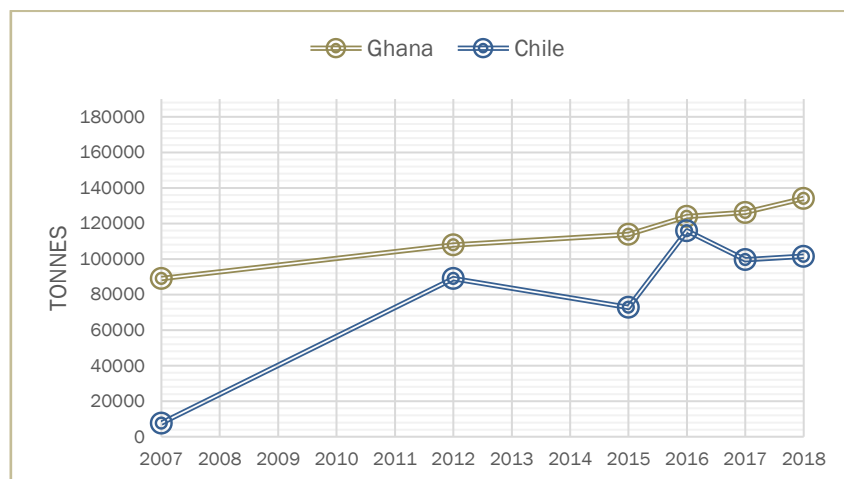

Figure 7. Total imports for Chile and Ghana (2007, 2012, 2015–2018) in weight (tonnes). *Source: own elaboration with data from UN Comtrade.*

Both lesser-developed and developing economies face several market issues, including a lack of formal contract enforcement and information sharing, unorganized retailer systems and low consumer awareness of products [50]. In addition, waste treatment capacity in developing regions is very low [51], due to a lack of resources to establish the required infrastructure [52,53]. Given insufficient infrastructure and a lack of resources to properly treat waste, water bodies in these areas are often polluted with imported items that have not been sold [54]. Indeed, clothing arriving in destination countries can generate a great burden for local authorities, if the quantities of textile waste are unmanageable. More research is needed to better understand the implications of the second-hand market and generate policies aimed at establishing just and sustainable international trade activities under these conditions.

According to Brooks [41], different factors influence the export destination for SHC, including transportation costs, local political contexts and trade liberalisation. In many cases, and as previously discussed for Chile and Ghana, the market liberalisation that occurred widely in the 1980s boosted SHC imports through the removal of trade restrictions. According to the analysed data, the top exporter countries have remained the same since the beginning of the 2010s [33], thereby providing support for Brooks's identified factors in import-export dynamics.

Ongoing Discussion on the International Trade of Second-hand Clothing: Benefits and Negatives
The complexity of the international SHC trade has been shown in previous sections. It is precisely this complexity that fuels ongoing discussion about whether the economic benefits prevail over the environmental and social

negatives associated with this activity. Some studies have explained that SHC imports benefit importer countries by providing access to affordable garments for those living in conditions of poverty and by generating new jobs in retail and importation [55,56]. In East African countries alone, the used clothing sector has created approximately 355,000 jobs, supporting 1.4 million people [39] and improving livelihoods.

In terms of granting access to clothing, trade in SHC may be considered positive. In Africa, worn garments are the major source of clothing in many countries. In Uganda, for example, 81% of clothing purchases are of second-hand items [34]. However, studies highlighting the benefits of increased access to clothing have generally failed to address the dependency that second-hand imports create on internal markets. Of note, research has shown that the benefits of SHC trade may fail to consider its impact on the high-value creation activities occurring in the Global North. However, recent studies have begun to identify fewer positive traits in SHC trade with the aim of identifying possible actions to offset its impacts.

Among the adverse issues caused by large SHC imports is the detrimental effect on local textile economies. Studies have shown that, during the years 1981 to 2000, SHC imports explained approximately 40% of the decline in production and 50% of the decline in employment [57]. Without a doubt, other factors influenced the poor performance of local industry (i.e., ageing infrastructure, weak local production policies) (Collier and Gunning 1999; Easterly and Levine 1997; Fafchamps 2004, cited in 56) However, these do not fully explain the speed with which the reduction in local garment production occurred.

Lacking conclusive evidence for the economic aspects of the international trade of SCH, we may instead turn to the environment and social aspects. The fact that more people can access affordable clothing should not be perceived as a mere act of satisfying basic needs, as, from a social justice perspective, access to quality clothing comes at a high environmental cost. In addition, a small proportion of countries are facing the majority of the negative effects of the waste trade, with implications for fairness and dignity.

Studies focused on the positive aspects of SHC trade have generally failed to consider the environmental issues associated with an excess of clothing, which tend to accumulate. As research has shown, SHC imports are rising. As long as imports are subjected to minimal control, the risk of increased waste production is high. Since 2015, the large increase in imports seems to have been correlated with a large increase in discarded waste in the Global North. Given evidence of an upward trend in clothing consumption, there is a high probability that imports of SHC to the Global South will also rise. The environmental conditions of areas with significant SHC markets are already ecologically critical, with aquatic and land ecosystems presenting alterations caused by the illegal dumping of textile waste. Studies on the environmental aspects of waste dumps and textile degradation have shown that uncontrolled dumping causes land degradation and pollution, since a wide range of pollutants (e.g., leachate) are released into the environment [58]. Research on the structure of fashion value chains has observed that the geographical shift in manufacturing activities to developing countries (in pursuit of cheap labour) has shifted the location of pollution [59]. A similar phenomenon is evident in the international trade of SHC, since unwanted items are not processed in their places of origin. The export of garments that are unlikely to achieve a second life results in the export of pollution to regions that lack the proper structures to transform materials into valuable input. Hence, respecting environmental limits in both the Global North and the Global South is a matter of environmental justice.

Pathways for a Just Circular Fashion Industry through Cooperation in Second-Hand Clothing Trade: A framework for Action

Considering the above-described dynamics of the distribution of SHC and the steps involved in this value chain, we developed a framework to develop solutions based on international cooperation between the Global North and Global South. This framework (Figure 8) encompasses all agents involved in the international trade of SHC and suggests a set of actions to reduce risks and manage identified hotspots.

Role of Agents

The framework presents the main agents involved in the international trade of SHC. Each agent intervenes at a different moment, providing input and output for the other agents, to create synergy. Prior to implementing specific strategies, it is important to first raise awareness – that is, to give visibility to the issues involved in the export of SHC and its implications for circular fashion models. Current evidence suggests that, since the recovery and reuse of clothing are circular strategies, the quantification of exported items might be included as 'green

numbers' on official reports, without acknowledging the failure to achieve a circularity loop in importing regions of the world.

Role of the Private Sector

One of the strategies that might increase the accountability of fashion brands relates to extended producer responsibility. This strategy relies on the 'polluter pays' principle, which encourages manufacturers to assume responsibility for the impact of their products throughout the lifespan [51]. According to this scheme, producers hold responsibility for the products they produce that are not properly discarded. Fees or cooperation programmes can be used to collect funds in accordance with the environmental pollution connected with companies' profitable activities. Another critical agent in the private sector is the clothing sorter. Studies have shown that the more symmetric and transparent participation of importer countries in the sorting process is likely to increase the quality and appropriateness of the traded garments [42] Since sorting has become highly profitable for wholesalers, the quality of imported garments has decreased, resulting in larger volumes of textile waste that never achieve a second life. Hence, the private sector must implement quality assurance programmes to guarantee that the items bought by importers are indeed able to be commercialised. To increase the efficacy of this strategy, other agents (e.g., governments, international non-profit organisation) must intervene to ensure implementation of the quality sorting process. In addition, the SHC collection take-back programmes managed by fashion brands may serve as starting points for the classification and quality assurance of items for export.

Finally, a third strategy may be implemented as a reactive measure to manage the existing textile waste in importer countries: the creation of value from upcycling, recycling and redesigning. Currently, initiatives are in place to foster the upcycling and recycling of garments. This is a positive measure, as long as it provides a source of income for the resellers and manufacturers of these items. However, it should only represent a temporary remedial measure, since it is not sufficient to stop or change the current textile waste stream, but only capable of deviating a minimum percentage of the imported goods. Such activities may provide opportunities for economic growth and innovation if they are managed properly. However, exporter countries should be encouraged to build the basic technological infrastructure to support the specialised labour involved.
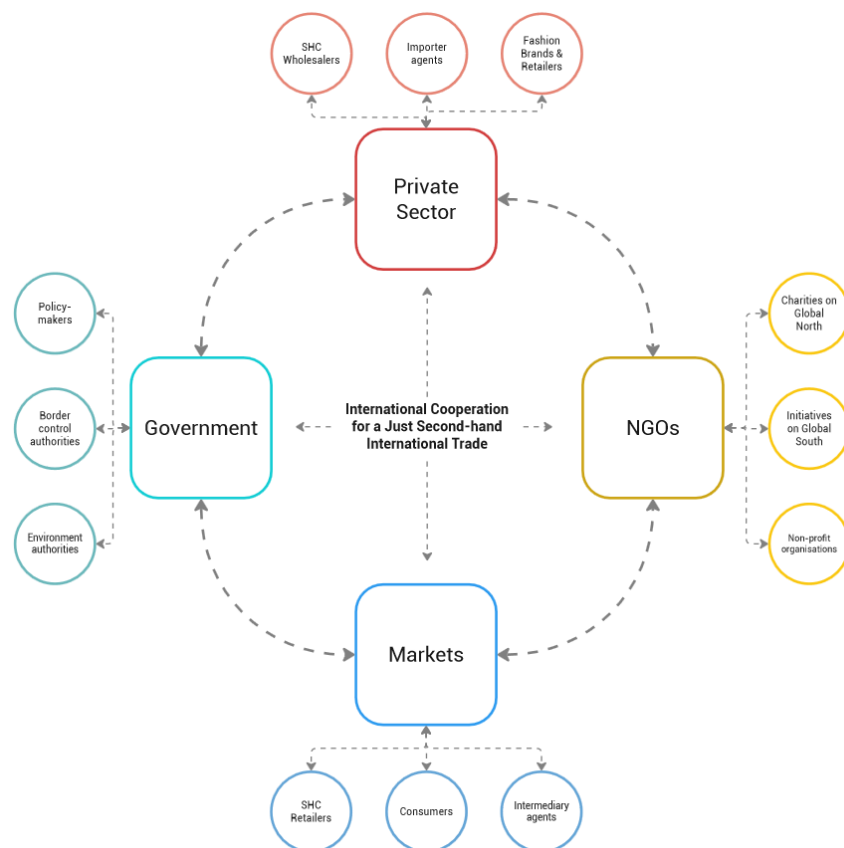

Figure 8. Agents involved in the framework for a just SHC international trade. *Source: own elaboration.*

Role of Governments

Trade policies are decisive for the effectiveness of trade in any given region or country, as advantages, benefits and negative effects are determined by the way in which trade occurs. Evidence suggests that import bans are not effective for local economies, as such prohibitions may create illegal trade. Thus, governments are challenged to find ways to guarantee positive trade growth by establishing a set of preconditions to account for aspects that have historically been ignored. As countries differ in their conditions for trade, a set of regulations must be established to serve as an equity base for trade and global value chain interactions. This idea relies on some examples discussed throughout the paper, demonstrating that aspects such as geographical characteristics, income levels, and power relationships between countries (among others) are significant in determining the positive or negative impacts of international trade.

Additionally, governments must ensure healthy policies and institutions in order to foster, rather than hinder, openness and new ways of doing trade. A country's internal capacity to adopt and implement fair trade agreements also depends on the extent to which its institutions are prepared to do so. Importer countries must ensure a minimum set of preconditions for trade agreements to work, especially in high-risk border areas. The present study has demonstrated that trade data may be used to identify the interactions between specific regions (i.e., the United Kingdom and Ghana, the United States and Chile), which may inform the design of protocols to monitor 'high risk' interactions by the government of the importer country.

Role of Markets

Market regulation must always involve consumers. While one of the long-term strategies for reducing the number of discarded garments is to stop overconsumption, even short-term strategies (e.g., 'polluter pays' systems [23]) must involve consumers, in addition to fashion brands. Critically, governments should establish and administer a waste disposal fee for garments that are discarded by consumers. This strategy may serve to disincentive overconsumption, and the monetary funds collected could be used to support programmes of cooperation between the Global North and Global South. In importer countries, retailers and intermediary agents are pivotal for preventing unsold clothing from reaching landfills or being subject to uncontrolled dumping. However, given the complexity of the challenge, collaboration with local authorities and NGOs is necessary. Retailers and intermediary agents may be able to create value, but they will require support from other institutions in order to successfully divert waste and transform unwanted textiles into valuable items, thereby becoming upcyclers or recyclers of unsold garments.

Role of NGOs

Charities in the Global North play a major role in SHC trade dynamics. Frequently, the journey of a traded item starts with the donation of the unwanted item to a charity. Subsequently, many of these items are sold to wholesalers, which make a profit from exporting the goods. Therefore, charities must improve their system of selecting buyers and redistributors on the basis of responsible behaviour. Some criticism of charities has emerged in connection with their advantageous position in society. Hence, charities should also seek to improve communication with donors in order to make their processes of collection and sale more transparent. NGOs in the Global South can promote different actions to involve relevant stakeholders in fostering on-site circular strategies. It is worth noting that, thus far, NGOs in this region have had a positive impact on promoting changes and demanding assistance from authorities and private companies. Nonetheless, the potential of these organisations is limited, and additional support is required to counterbalance the negative impacts. Local NGOs are a major agent for raising awareness and promoting regional participation.

Other Guidelines and Key Actions: Fair Trade Standards for Second-Hand Markets to Avoid Information Asymmetries and Export Regulations

From an economic perspective, second-hand items are considered 'regular goods' that are able to be locally or globally traded. Similar to brand-new items, second-hand garments are produced (or classified, in the case of SHC), packed, shipped, sold and bought, and they reach retailers and final consumers from different parts of the globe. However, the same items may also be treated as discarded goods, and this may prevent them from being carefully packed or properly sanitised, categorised and, most importantly, traded fairly. Currently, second-hand items are not subject to any kind of voluntary or obligatory certification. However, they have value, a target market and, as with any other type of good, a specific offer-demand dynamic. The World Fair Trade Organisation [60] prescribes ten principles for assuring fair trade, most of which can be applied to the trade in SHC: (i) creating opportunities for the economically disadvantaged, (ii) transparency, (iii) accountability, (iv) fair payment, (v)

ensuring no child labour (vi) ensuring no forced labour, (vii) commitment to non-discrimination, (viii) commitment to gender equity, (ix) ensuring good working conditions and (x) providing capacity building and respect for the environment. Frequently, these principles are not followed in the SHC market. Hence, they may provide the basis for a more detailed framework aimed at ensuring fair trade.

South-to-South Cooperation

The investigated data revealed similarities between countries in the Global South with respect to the environmental and social challenges they face in connection with SHC imports. Shared knowledge and solutions may help to ease these negative effects. In more detail, South-to-South cooperation should involve the creation of 'institutional spaces where actors converge to contest prevailing global norms and construct new visions of development' [61]. Diverse strategies have already emerged in countries facing issues associated with SHC imports. South-to-south cooperation may enhance the potential of these strategies through amplification or development based on partners' experiences.

Research and Development

As described above, the current composition of textiles represents a challenge for the circularity of materials. Thus, research and development into raw materials and post-consumer textile treatments in the fashion sector represents a key multi-sectoral strategy to reduce the negative impacts of trade in SHC and, more specifically, the EoL of garments. To this end, intersectoral cooperation is required between governments, the private sector and other agents.

In the short term, research and development may contribute to improving existing recycling systems. Currently, the composition of fabrics limits the realisation of recycling, as different fabric mixes make recycling difficult and expensive. This is one of the primary reasons why recycled textiles are frequently downcycled. The development of effective recycling systems may reduce the amount of landfilled waste. Furthermore, cooperation between the Global North and Global South may result in the establishment and use of infrastructure to treat existing textile waste. Over the long term, research and development – particularly with respect to circular bioeconomy strategies – may help to decrease the environmental footprint of garments, in the production and EoL phases. In the production phase, such reductions may be achieved by avoiding the use of non-renewables. In the EoL phase, reductions may be achieved by increasing the use of bio-based textiles. While some initiatives in these directions have already begun, further research is needed to increase their accessibility and competitiveness.

The proposed framework only briefly describes the steps needed to implement the different strategies. However, it is significant in at least three ways: First, it provides a comprehensive overview of the relevant issues and agents involved in the international trade of SHC. Second, it suggests new ways of cooperating that may be more effective than traditional international relations. Third, it advocates for a global just transition to the circular economy, with potential benefits for all parties.

Impact

The present study investigated a sector with high potential for contributing to sustainability through circularity. The proposed framework identifies the most important areas of transformation in the international trade of SHC to foster a just and circular transition, including all agents and covering social, environmental and economic aspects. The proposed collaboration between agents will support the creation of multi-stakeholder strategies, promoting interaction, generating additional value for the solutions and acknowledging the voices of all parties – in particular those that have been previously overlooked. This aspect is crucial for transforming the fashion industry into one that is fairer and more circular. In terms of regional impacts, the present study highlighted gaps in the circularity model in the fashion industry. By framing the issue from a Global North–Global South perspective, material flow patterns in the international trade of SHC emerged. In addition to unveiling asymmetries in fashion value chains, the study also identified specific regions in which SHC imports have been mainly detrimental to society and the environment. The identification of these hotspots may inform strategies to address these negative impacts, where relevant.

The study also highlighted the social issues associated with the international trade of SHC, particularly within importer countries – which, due to the current conditions of SHC markets, frequently find themselves at a disadvantage compared to exporter countries. Information asymmetry and the import of low-quality items have not only environmental impacts, but also social impacts on the people who work in this sector.

The proposed framework suggests different actions for improving these social conditions in the transition to a circular and fair SHC trade, seeking to reduce the vulnerability of agents in the Global South.

The reduction of negative environmental impact of the fashion industry is of vital importance to sustainability goals, and the SHC market may represent a critical target for minimising the footprint of this sector. By extending the lifespan of garments in a fair way, the negative impact of the EoL stage may be reduced. More specifically, this transformation of the SHC sector could contribute positively in at least three ways: (i) by reducing the number of items that are disposed of in landfills (or uncontrolled dumping sites) or incinerated, thereby preventing the release of harmful toxins; (ii) by promoting the effective recirculation of items (e.g. recycling, repurposing), in order to close the loop and prevent pollution shifting; and (iii) by promoting the use of alternative materials (i.e., bio-based fabrics), thus reducing the environmental impact of the EoL stage.

In terms of the economic impact, recirculation has the potential to generate new and diversified products and services, creating new jobs and contributing to decoupling economic value from the extraction of raw materials. Hence, both the creation of a positive economic impact and the reduction in asymmetry between high- and low-value creation activities are possible. Although SHC markets are a source of income for many, the present study identified populations that are also harmed by the international trade of SHC, suggesting actions to reduce inequalities. Finally, the results of the present study may provide valuable information for policymakers. Although new regulations for international trade and the CE have been emerging, many factors have not yet been addressed, particularly from the perspective of global sustainability and environmental justice in international trade. By highlighting the gaps in current models of circularity, the present study has provided in-depth information on trade activities to inform new regulatory measures for SHC import and export. As a total ban on SHC imports is not optimal, guidelines and policies are necessary to address the missing aspects of current circularity and international trade policies.

Conclusions

The present study aimed at filling knowledge gaps pertaining to the international trade of SHC, identifying the environmental and social issues that have emerged as a result of outdated market dynamics. The analysis identified how these market dynamics are incompatible with the notion of a CE, as aspects that are critical for ensuring a closed-loop economy are being overlooked by the different actors involved in the international SHC trade. Furthermore, the analysis found that this trade is characterised by asymmetries between the Global North and Global South, in alignment with previous research [34,36,38,41,43]. Therefore, the international trade of SHC can be classified as a form of global inequality and environmental injustice. In addition, the analysis promoted a better understanding of textile degradation and the release of toxic components into the environment as threats to systemic ecological equilibrium posed by textile waste. Because the economic benefits of SHC markets in developing regions are not sufficient to outweigh the environmental costs caused by import surpluses, immediate action is needed to reduce any irreversible damage to global ecosystems. In the literature, trade and its economic benefits have been analysed from various perspectives, encompassing environmental concerns, power dynamics and international justice, among others. While these analyses are gradually extending into the realm of sustainable fashion, the analysis of specific cases may improve our understanding of the main issues involved in the international trade of SHC. Undoubtedly, this trade has some positive effects, including increased access to affordable garments in importer countries, employment generation and environmental benefits associated with longer clothing lifespans. A complete ban on SHC importation is not advisable, given evidence that such prohibitions are associated with illegal trade and corruption at borders [37]. However, as the value chain becomes more complex, involving an increasingly diverse array of agents, further research will be needed to discern both the failures and the successes of past experiences. One useful step in the transition towards a just circular fashion industry may be to consider the participation of different sectors and institutions. The present study endorsed this principle by proposing a comprehensive framework for developing strategies to address current issues and mitigate new potential risks. Future work could focus on developing specific procedures for implementing the suggested strategies, which are currently framed in general terms. Additionally, it may be worthwhile to investigate whether similar patterns apply to different types of second-hand goods traded internationally. Nonetheless, the proposed framework may serve as a promising starting point for the transition towards a more equal and just circular economy.

Conflict of interest

There are no conflicts of interest to declare.

References
[1]   United Nations, The Sustainable Development Goals Report 2019, 2019. https://www.un.org/en/desa/sustainable-development-goals-report-2019

[2]   The World Bank, Urban Development, Solid Waste Management, World Bank Gr. (2013). http://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management.

[3]   Transforming our world: the 2030 Agenda for Sustainable Development, United Nations, New York, 2015.

[4]   S. Lorek, P.J. Vergragt, Sustainable consumption as a systemic challenge: Inter- and transdisciplinary research and research questions, Edward Elg, Cheltenham, 2015. https://doi.org/10.4337/9781783471270.00008.

[5]   K. Niinimäki, G. Peters, H. Dahlbo, P. Perry, T. Rissanen, A. Gwilt, The environmental price of fast fashion, Nat. Rev. Earth Environ. 1 (2020) 189–200. https://doi.org/10.1038/s43017-020-0039-9.

[6]   P. Senthil Kumar, K. Grace Pavithra, Water and Textiles, in: Water Text. Fash. Consum. Footprint, Life Cycle Assess., Elsevier, 2018: pp. 21–40. https://doi.org/10.1016/B978-0-08-102633-5.00002-6.

[7]   UN Environment, Mapping of Global Plastics Value Chain and Plastics Losses to the Environment: With a Particular Focus on Marine Environment, United Nations Environ. Program. (2018).

[8]   M.E. Bubicz, A.P.F. Dias Barbosa-Póvoa, A. Carvalho, Social sustainability management in the apparel supply chains, J. Clean. Prod. 280 (2021) 124214. https://doi.org/10.1016/j.jclepro.2020.124214.

[9]   EEA/Eionet, Textiles and the environment in a circular economy. Retrieved 5 December 2020, Eur. Environ. Inf. Obs. Netw. (2019). https://www.eea.europa.eu/themes/waste/resource-efficiency/textiles-in-europe-s-circular-economy.

[10]   Directorate-General for Environment, EU Strategy for Sustainable and Circular Textiles, (2022). https://ec.europa.eu/environment/publications/textiles-strategy_en.

[11]   D. Iowe, A new textiles economy: Redesigning fashion's future, Ellen MacArthur Found. (2017) 1–150. https://ellenmacarthurfoundation.org/a-new-textiles-economy.

[12]   L.R. Camargo, S.C.F. Pereira, M.R.S. Scarpin, Fast and ultra-fast fashion supply chain management: an exploratory research, Int. J. Retail Distrib. Manag. 48 (2020) 537–553. https://doi.org/10.1108/IJRDM-04-2019-0133.

[13]   Global Fashion Agenda (GFA) & The Boston Consulting Group (BCG), Pulse of the fashion industry. globalfashionagenda.com, (2017).

[14]   J. Korhonen, A. Honkasalo, J. Seppälä, Circular Economy: The Concept and its Limitations, Ecol. Econ. 143 (2018) 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041.

[15]   M.C. den Hollander, C.A. Bakker, E.J. Hultink, Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms, J. Ind. Ecol. 21 (2017) 517–525. https://doi.org/10.1111/jiec.12610.

[16]   E. MacArthur, Towards the Circular Economy: Vol. 1: Economic and business rationale for an accelerated transition, Ellen MacArthur Found. 1 (2014) 21–34.

[17]   J. Potting, M. Hekkert, E. Worrell, A. Hanemaaijer, Circular Economy: Measuring innovation in product chains | PBL Netherlands Environmental Assessment Agency, PBL Netherlands Assess. Agency, Hague. (2017). https://www.pbl.nl/en/publications/circular-economy-measuring-innovation-in-product-chains.

[18]   C.E.A. Plan, For a cleaner and more competitive Europe, Eur. Comm. Brussels, Belgium. (2020) 28.

[19]   European Commision, Proposal for a targeted revision of the Waste Framework Directive, (2023). https://data.europa.eu/doi/10.2760/858144.

[20]   Ellen Macarthur Foundation, Rethinking business models for a thriving fashion industry, Ellen Macarthur Found. (2021). https://www.ellenmacarthurfoundation.org/fashion-business-models/overview.

[21]   K. Niinimäki, Sustainable Fashion in a Circular Economy, Alto Univ. Sch. Arts Des. Archit. (2018) 128–228.

[22]   M.& Company, G.F. Agenda, Fashion on climate: How the fashion industry can urgently act to reduce its greenhouse gas emissions, McKinsey & Company and Global Fashion Agenda, 2020. https://www.mckinsey.com/~/media/mckinsey/industries/retail/our%0Ainsights/fashion%0Aon%0Aclimate/fashion-on-climate-full-report.pdf.

[23]   M.P. Mizrachi, A. Tal, Regulation for Promoting Sustainable, Fair and Circular Fashion, Sustain. 14 (2022) 502. https://doi.org/10.3390/su14010502.

[24]   United Nations Environment Programme, Sustainability and Circularity in the Textile Value Chain, Glob. Stock. (2020) 19. https://www.oneplanetnetwork.org/sites/default/files/unep_sustainability_ and_ circularity_in_the_textile_value_chain.pdf.

25] G. Sandin, G.M. Peters, Environmental impact of textile reuse and recycling – A review, J. Clean. Prod. 184 (2018) 353–365. https://doi.org/10.1016/j.jclepro.2018.02.266.

[26] H.W. chung Yeung, N.M. Coe, Toward a Dynamic Theory of Global Production Networks, Econ. Geogr. 91 (2015) 29–58. https://doi.org/10.1111/ecge.12063.

[27] E. Koberg, A. Longoni, A systematic review of sustainable supply chain management in global supply chains, J. Clean. Prod. 207 (2019) 1084–1098. https://doi.org/10.1016/j.jclepro.2018.10.033.

[28] R. Merli, M. Preziosi, A. Acampora, How do scholars approach the circular economy? A systematic literature review, J. Clean. Prod. 178 (2018) 703–722. https://doi.org/10.1016/j.jclepro.2017.12.112.

[29] F. Jia, S. Yin, L. Chen, X. Chen, The circular economy in the textile and apparel industry: A systematic literature review, J. Clean. Prod. 259 (2020) 120728. https://doi.org/10.1016/j.jclepro.2020.120728.

[30] F. Rossi, P. Morone, North–South Waste Trade: Prime Example of the Circular Economy or Major Environmental Threat?, Circ. Econ. Sustain. (2023). https://doi.org/10.1007/s43615-023-00262-5.

[31] B. Cotta, What goes around, comes around? Access and allocation problems in Global North–South waste trade, Int. Environ. Agreements Polit. Law Econ. 20 (2020) 255–269. https://doi.org/10.1007/s10784-020-09479-3.

[32] European Commision, Proposal for a targeted revision of the Waste Framework Directive, (2023). https://data.europa.eu/doi/10.2760/858144.

[33] United Nations, UN Comtrade Database (28.06.2016), (2016). http://comtrade.un.org/data/.

[34] J. Cameron, Clothing Poverty: The Hidden World of Fast Fashion and Second-Hand Clothes, Aust. Fem. Stud. 30 (2015) 316–320. https://doi.org/10.1080/08164649.2015.1107949.

[35] WRAP, Valuing our clothes: The cost of UK fashion | WRAP, (2019) 4125764. https://wrap.org.uk/resources/report/valuing-our-clothes-cost-uk-fashion?_ga=2.86011480.1701529797.1581356684-697904570.1581241658.

[36] L. Norris, The limits of ethicality in international markets: Imported second-hand clothing in India, Geoforum. 67 (2015) 183–193. https://doi.org/10.1016/j.geoforum.2015.06.003.

[37] P. Rivoli, The Travels of a T-shirt in the Global Economy, Second, Wiley, New Jersey, 2009. http://books.google.com/books?id=0bdUHkbEZqQC.

[38] P. Morone, G. Yılan, A.G. Encino, Transition to a Circular, Sustainable, and Equitable Fashion Industry: The Case of Second-hand Clothing Trade in African Countries, Africa E Mediterr. 94 (2021).

[39] K. Khurana, R. Tadesse, A study on relevance of second hand clothing retailing in Ethiopia, Res. J. Text. Appar. 23 (2019) 323–339. https://doi.org/10.1108/RJTA-12-2018-0063.

[40] Wrap, Wood Waste Market Situation Report, 2011. https://doi.org/https://wrap.org.uk/sites/default/files/2021-03/WRAP-textiles-market-situation-report-2019.pdf.

[41] A. Brooks, Stretching global production networks: The international second-hand clothing trade, Geoforum. 44 (2013) 10–22. https://doi.org/10.1016/j.geoforum.2012.06.004.

[42] O. Abimbola, The international trade in secondhand clothing: Managing information asymmetry between west African and British traders, Text. J. Cloth Cult. 10 (2012) 184–199. https://doi.org/10.2752/175183512X13315695424310.

[43] L.A. Manieson, T. Ferrero-Regis, Castoff from the West, pearls in Kantamanto? A critique of second-hand clothes trade, J. Ind. Ecol. 27 (2023) 811–821. https://doi.org/10.1111/jiec.13238.

[44] K. Hayakawa, H. Mukunoki, The impact of COVID-19 on international trade: Evidence from the first shock, J. Jpn. Int. Econ. 60 (2021) 101135. https://doi.org/10.1016/j.jjie.2021.101135.

[45] G. Miao, F. Fortanier, Estimating Transport and Insurance Costs of International Trade, (2017). https://doi.org/10.1787/8267bb0f-en.

[46] M. Javorsek, Asymmetries in International Merchandise Trade Statistics: A case study of selected countries in Asia-Pacific, Stat. Div. (2016).

[47] A. Brooks, D. Simon, Unravelling the Relationships between Used-Clothing Imports and the Decline of African Clothing Industries, Dev. Change. 43 (2012) 1265–1290. https://doi.org/10.1111/j.1467-7660.2012.01797.x.

[48] The Observatory of Economic Complexity, Used Clothing, Net Trade, (2020). https://oec.world/en/profile/hs/used-clothing.

[49] S. Calvo, G. Williams, Ropa usada: mercado nacional y regulación en Chile y extranjero., Bibl. Del Congr. Nac. Chile/ BCN. (2022).

[50] S. Guo, T.M. Choi, J. Zhang, Second-Hand-Clothing Imports in Least-Developed-Countries: The Collapse of Local Clothing Manufacturing and Remedial Measures, in: IEEE Trans. Eng. Manag., 2023: pp. 1774–1793. https://doi.org/10.1109/TEM.2021.3061528.

[51]   OECD, Towards a More Resource-Efficient and CE - The Role of the G20, 2021. https://www.oecd.org/environment/waste/OECD-G20-Towards-a-more-Resource-Efficient-and-Circular-Economy.pdf.

[52]   L. Ricketts, B. Skinner, Stop Waste Colonialism: Leveraging Extended Producer Responsibility to Catalyze a Justice-led Circular Textiles Economy., Or Found. (2023).

[53]   Katende, E. Magezi, The Impact of Second Hand Clothes and Shoes in East Africa, WTO Fish. Subsid. Negot. Main Issues Interes. Least Dev. Ctries. (2017) 5–39. http://repository.eac.int/handle/11671/1848.

[54]   A. Priya, Impact of Second-Hand Clothing Waste in Ghana, Issue 2 Int'l JL Mgmt. Human. 5 (2022) 1679.

[55]   K.T. Hansen, Helping or hindering? Controversies around the international second-hand clothing trade, Anthropol. Today. 20 (2004) 3–9. https://doi.org/10.1111/j.0268-540x.2004.00280.x.

[56]   S. Haggblade, The Flip Side of Fashion: Used Clothing Exports to the Third World, J. Dev. Stud. 26 (1990) 505–521. https://doi.org/10.1080/00220389008422167.

[57]   G. Frazer, Used-clothing donations and apparel production in Africa, Econ. J. 118 (2008) 1764–1784. https://doi.org/10.1111/j.1468-0297.2008.02190.x.

[58]   M.D. Vaverková, A. Maxianová, J. Winkler, D. Adamcová, A. Podlasek, Environmental consequences and the role of illegal waste dumps and their impact on land degradation, Land Use Policy. 89 (2019) 104234. https://doi.org/10.1016/j.landusepol.2019.104234.

[59]   S. Mair, A. Druckman, T. Jackson, Global inequities and emissions in Western European textiles and clothing consumption, J. Clean. Prod. 132 (2016) 57–69. https://doi.org/10.1016/j.jclepro.2015.08.082.

[60]   World Fair Trade Organization (WFTO), Ten Principles of Fair Trade, (2020).

[61]   P. O'Reilly, T. Heron, Institutions, ideas and regional policy (un-)coordination: The East African Community and the politics of second-hand clothing, Rev. Int. Polit. Econ. 30 (2023) 608–631. https://doi.org/10.1080/09692290.2022.2062614.