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INFLATION MOVEMENTS IN THE EU IN CONDITIONS OF EXTERNAL SHOCKS

ABSTRACT: *This study examines the key factors driving inflation in the European Union (EU) member states, focusing on both cost-push and demand-pull effects. By analysing monthly data from January 2005 to February 2023, the study investigates how inflation dynamics have evolved over time, particularly in response to external shocks such as rising energy prices. Inflation reached its highest levels in recent decades in 2022, driven by a combination of cost-push factors, such as rising crude oil prices, and the demand-pull effects that emerged in late 2021. The study employs fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) methods to analyse long-run inflation determinants. These econometric techniques are used to address potential issues of endogeneity and serial correlation in the dataset, providing robust and reliable estimates of inflation trends across the EU. The findings reveal that inflation was initially driven by cost-push factors, but these pressures subsided as energy price growth decelerated. From October 2021 onwards, demand-pull effects became more pronounced as aggregate demand surged. Additionally, the study highlights significant disparities in how EU member states responded to external energy price shocks, underscoring the need for more coordinated EU energy policy. Its results suggest that EU policymakers need to implement more coordinated fiscal and energy policies to mitigate the impacts of external price shocks. Future research should focus on country-specific drivers of inflation and assess the long-term effects of coordinated energy strategies within the union. This study contributes to the literature by using advanced econometric methods to analyse inflation dynamics over an extended period and provides valuable insights for policymakers, particularly in addressing the varying impacts of external shocks across EU member states.*

KEY WORDS: *inflation, cost-push factors, demand-pull effect, European Union*

JEL CLASSIFICATION: E32, E52, E43, F2

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1. INTRODUCTION

Consumer price inflation surged significantly at the end of 2021, particularly affecting fuel and food bills. This prompted heightened attention from the media and the public. The last comparable inflation spike in the EU occurred during the 2008 financial crisis, but key differences between the two episodes highlight unique underlying factors.

During the 2007–2008 crisis, inflation was primarily driven by rising raw material costs, partly due to China's rapid industrialisation and urbanisation. Domestically, increased demand and labour costs further fuelled inflation. In contrast, the recent inflation spike stems from imported inflation, the recovery in personal consumption, and statistical comparisons with the suppressed prices of 2020 caused by pandemic-related economic disruptions.

The post-pandemic recovery stimulated global demand, leading to higher energy and raw material prices. By the mid-2020, prices of grains, oilseeds, metals, and wood began climbing. Crude oil price increases quickly affected fuel prices and other costs, such as transportation and catering services. Shifting consumption patterns, such as higher demand for IT equipment and cars due to remote work, also contributed to price increases.

While demand recovered swiftly, supply-side disruptions proved more persistent. Global supply chain bottlenecks, including labour shortages, container scarcities, and pandemic restrictions, exacerbated costs. Weather-related issues, such as droughts and floods, further strained food supply chains, impacting raw material prices.

Russia's invasion of Ukraine in early 2022 triggered sharp increases in energy and commodity prices, particularly affecting Europe, which heavily relied on Russian oil and gas. Russia’s use of energy as a geopolitical tool further amplified inflationary pressures, pushing prices to levels not seen in decades, reminiscent of past energy crises.

Energy price increases became a significant driver of inflation divergence among euro area countries. Factors such as energy regulation, government support measures, energy generation mix, and the terms of household utility contracts

influenced inflation outcomes. For instance, countries with fixed utility prices experienced delayed inflation transmission compared to nations with flexible pricing systems.

By October 2022, euro area inflation exceeded 10%, with member states experiencing rates ranging from 7% (France) to over 20% (the Baltic states). Slovenia's inflation stood at 10.3%, close to the euro area average. The pandemic initially caused disinflation in tourism-dependent economies but later drove inflation in countries with robust economic recoveries and labour shortages, which pressured wages.

While inflation variations may appear to disrupt the monetary transmission mechanism, they largely reflect external shocks and national-level differences in aggregate supply and demand reactions. Monetary policy cannot entirely offset external shocks, which interact with national fiscal policies, labour markets, and economic structures.

The analysis of inflation trends across EU member states reveals significant variation in how countries responded to the rising inflationary pressures. These differences can largely be attributed to the interplay of fiscal measures, energy policies, and the underlying economic structure of each nation, which shaped their vulnerability to external shocks, particularly thesurge in energy prices driven by the war in Ukraine

Fiscal measures:

Various EU countries applied fiscal measures to counteract inflation. For example, in 2022, Germany introduced an energy price cap for households and small businesses to mitigate the shock of rising energy costs. The government subsidised up to 80% of the cost of gas for households, capping prices at a fixed rate (Germany's ‘gas price brake’). This measure successfully alleviated inflationary pressures, as evidenced by the fact that Germany's inflation rate stabilised around 10.0% by mid-2022 after peaking at 10.5% in early 2022. Similarly, France implemented a fuel price rebate to help consumers manage soaring fuel costs, which significantly reduced inflationary pressures in the transport sector.

Monetary policy measures:

The European Central Bank (ECB) raised interest rates multiple times starting in July 2022 as part of their efforts to curb inflation. The ECB's interest rate hike from 0% to 1.25% by October 2022 was aimed at controlling demand-side inflationary pressures. This policy was in line with the ECB's mandate to maintain price stability within the euro area. However, the impact on inflation was mixed. Countries with higher inflation, such as Estonia and Lithuania, saw only a moderate slowdown in inflationary trends despite the rate hikes, suggesting that supply-side shocks (e.g., energy price spikes) were still predominant in driving inflation.

Energy policy measures:

Energy policies played a crucial role in shaping inflation trends across EU member states. The rising energy prices driven by the war in Ukraine created divergent inflationary pressures across the region. In countries such as Italy and Spain, where energy price caps were implemented, inflation rates were somewhat stabilised compared to countries with more exposed energy markets, such as the Baltic states. The Lithuanian government, for example, capped electricity prices for households at 22 cents per kWh in early 2022, limiting inflation in the energy sector and, in turn, moderating overall inflation. However, countries without such caps, or those more reliant on Russian energy supplies, experienced more significant inflationary pressure, with Latvia and Estonia's inflation rates peaking at over 20% in 2022.

Energy subsidies and tax measures:

Energy subsidies, particularly in the form of targeted support for low-income households, played a significant role in limiting inflationary pressures on vulnerable populations. The United Kingdom, for instance, introduced direct cash transfers to households to mitigate rising energy costs. The government also reduced VAT on fuel and electricity, which helped curb inflation by easing the burden on consumers. In contrast, Hungary's energy price cuts for households led to higher inflation in non-energy sectors due to the need to finance these subsidies.

Impact of policy on inflation:

In terms of aggregate inflation, these policies had mixed results. Countries with robust fiscal and energy policies, such as France and Spain, managed to keep inflation rates under control, despite global energy price shocks. In contrast, countries such as Estonia and Lithuania, where energy price rises were more abrupt and unmitigated by government measures, saw inflation spike to record levels. For instance, by the end of 2022, inflation in Estonia was recorded at 22.1%, while in Spain, despite high energy price inflation, it stabilised around 8.4% due to effective fiscal interventions, including energy subsidies and tax reductions. Similarly, the variation in inflation between the eurozone's core and peripheral countries illustrates the impact of domestic policy measures. Core countries, with stronger fiscal capacities and energy regulations, such as Germany, had more resilient inflation outcomes.

Aggregate supply elasticity and economic structure:

Aggregate supply elasticity is influenced by several factors, including competition, technological capacity, production flexibility, and the overall economic structure. Energy-intensive, industrial economies (e.g., Germany, Slovakia) were more vulnerable to energy price shocks and supply chain disruptions. Conversely, service-oriented, IT-driven economies (e.g., Ireland) adapted more effectively due to digital sector growth and lower exposure to energy price shocks. This disparity played a significant role in the regional variation of inflation trends.

Regional inflation trends and policy effects:

The Baltic states, heavily impacted by the war and sanctions, experienced sharp inflation increases. Pre-war, gas and electricity costs were relatively low, which amplified percentage increases during the crisis. Flexible price-setting in the region allowed faster pass-through of energy costs to consumer prices, further accelerating inflation. In Estonia, inflation was driven by flexible utility pricing contracts, which allowed immediate cost pass-through. Additionally, the pandemic's limited economic impact in the Baltic states, coupled with strong post-pandemic recovery and expansionary policies, amplified inflationary pressures. Estonia’s 2021 pension system reform, which allowed early withdrawals, boosted private consumption and inflation.

Country-specific energy price dynamics:

Malta maintained low inflation due to fixed energy prices secured through a long-term contract with Azerbaijan. In contrast, the Netherlands experienced an energy price explosion in March 2022, driven by external shocks and national energy policies. The differences in the energy generation mix and the terms of household utilities contracts across these countries also contributed to the divergence in inflation rates.

Inflation dynamics in the EU during 2021–2022 reflect a combination of global external shocks, domestic policy responses, and structural economic factors. Divergences across member states highlight the interplay of supply elasticity, energy policy, and fiscal measures in shaping inflation outcomes. These factors underscore the complexity of addressing inflation in an interconnected economic environment.

To analyse these inflation dynamics, this study employs advanced econometric methods: fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS). These techniques are utilised to address potential issues of endogeneity and serial correlation, providing robust and reliable estimates of the long-run determinants of inflation across the EU.

This study contributes to the empirical literature on inflation determinants in several ways. First, it provides a comprehensive analysis of the interplay between demand-side and supply-side factors driving inflation in the EU, considering both common shocks and country-specific dynamics. Second, it explores various transmission channels behind the recent inflation surge, including energy dependency, fiscal measures, and monetary policy constraints. Third, by examining inflation divergence among EU member states, the study highlights the role of structural economic factors in shaping inflation outcomes. Finally, it offers policy insights on how coordinated EU-wide measures could enhance inflation resilience, particularly in the context of external shocks and global supply chain disruptions.

The remainder of this study is organised as follows: Section 2 provides a brief overview of the relevant literature. Section 3 introduces the data used in the analysis and presents the variables. Section 4 describes our econometric

methodology. Section 5 presents the empirical results and a variety of sensitivity checks aimed to confirm the baseline results and provide a more granular analysis. Section 6 draws conclusions with policy implications.

2. LITERATURE REVIEW

The causes of inflation have been extensively explored in the literature, with various theories offering insights into its underlying dynamics. In this study, we integrate two prominent economic theories – the demand-pull theory and the cost-push theory – to better understand the inflationary pressures observed in European economies.

The demand-pull theory, as proposed by Smith (2016), posits that inflation occurs when aggregate demand outpaces aggregate supply, leading to excess demand pressures in the economy. This theory emphasises the role of consumer spending, investment, and government expenditure as key contributors to inflation. When these components of demand rise too rapidly, they can drive an overheated economy, pushing prices upward. Smith's framework highlights the demand-side factors and their role in fuelling inflation, offering important insights into how consumption and investment behaviours can influence price levels.

In contrast, the cost-push theory, introduced by Gordon and Hall (1985), focuses on the role of rising production costs in driving inflation. According to this theory, inflation results from increases in wages, raw material prices, or other production inputs, which then get passed through the supply chain, leading businesses to raise prices to preserve profitability. Cost-push inflation underscores the significance of supply-side dynamics and suggests that inflation can occur even in the absence of excessive demand. This theory helps explain inflationary trends arising from rising input costs rather than excess demand

Empirical studies differ in their geographical focus: some analyse the entire EU, while others concentrate on the euro area or new EU member states. Methodologically, unit-root testing dominates, with both time-series and panel unit-root tests being common, alongside alternative approaches such as distributional analysis or wavelet methods to study convergence in the time-frequency domain. Benchmarks also vary, ranging from the Maastricht criterion

to Germany's inflation rate, the ECB's 2% target, or cross-sectional averages. Consequently, findings on inflation convergence are diverse.

Given these variations, we focus on studies closely aligned with our analysis and recent contributions. For instance, Brož and Kočenda (2017) analysed inflation convergence in all 28 EU member states using data from 1999 to 2016. They employed three benchmarks: the cross-sectional average, the ECB's medium-term inflation target, and the Maastricht criterion. Using a seemingly unrelated regressions (SUR) framework with augmented Dickey-Fuller tests, they examined the impact of factors such as the global financial crisis and EU monetary policies. Their findings indicate that most EU member states converged toward all three benchmarks during the period. They also highlighted that price stability-oriented monetary strategies likely supported convergence, while the effects of implementing EU legal frameworks (acquis communautaire) were inconclusive.

Erdogan et al. (2020) investigated inflation determinants in 30 European countries from January to July 2020 using spatial panel data methods. Their results revealed that domestic money supply, exchange rate fluctuations, and spatial effects (neighbourhood relations) contributed significantly to inflation. These findings emphasise the role of monetary and exchange rate policies in influencing inflation across Europe.

Čaklovica and Efendić (2020) analysed inflation determinants in 28 transition economies in Europe from 2005 to 2015, employing dynamic panel modelling. They included variables such as economic openness, unemployment, real wages, and external factors such as food and oil prices. The study found that structural variables, such as unemployment and wage growth, played a significant role in both short- and long-term inflation dynamics. External supply shocks, particularly energy prices, had a notable long-term effect, while food prices influenced inflation only in the short term. Their results suggest that structural features and market rigidities amplify inflation inertia in transition economies.

Historical perspectives are provided by Schmelzing (2020) and Bonam and Smadu (2021), who examined the effects of pandemics on inflation using data spanning several centuries. Schmelzing's data, covering six European countries from 1313 to 2018, showed that major pandemics typically induced prolonged

disinflation. However, Bonam and Smadu observed that the COVID-19 pandemic, with its unprecedented fiscal and monetary responses, led to upward inflationary pressures due to rapid economic recovery, supply chain disruptions, and rising costs passed on to consumers.

Binici et al. (2022) explored the post-pandemic rise in consumer price inflation across 30 European countries between 2002 and 2022 using generalised dynamic factor and local projection methods. They found that while global factors remained critical in shaping inflation dynamics, country-specific factors, such as monetary and fiscal policies, gained prominence during the pandemic. These findings highlight the interplay between global and domestic influences on inflation.

Moessner (2022) focused on short-term inflation expectations in the euro area, analysing survey data from 16 member countries using dynamic panel estimation. His study identified that food price inflation, oil prices, and global commodity prices significantly influenced inflation expectations. For instance, a 10% increase in food consumer price inflation raised expectations by 0.5 percentage points. Similarly, a 10% depreciation of the nominal effective exchange rate increased inflation expectations by 0.7 percentage points. Additionally, inflation expectations exhibited persistence and were positively linked to the output gap.

Overall, the literature demonstrates that inflation convergence and dynamics are influenced by a combination of structural, policy, and external factors. While some studies emphasise the role of monetary strategies and institutional frameworks, others highlight the impact of external shocks, global trends, and country-specific policies. These diverse perspectives underline the complexity of inflation behaviour in Europe, warranting further investigation into the mechanisms driving inflation convergence.

3. DATA AND VARIABLES

To analyse the determinants of inflation in EU countries, we construct a sample comprising all 27 EU member states. These include the original members (Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Spain, and Sweden) and the

'newer' member states (Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia). We then employ a panel regression analysis. Maddala and Wu (1999) argue that one of the main advantages of panel data compared to other types of data is that the approach allows for testing and adjustment of the assumptions that are implicit in cross-sectional analyses.

Most empirical studies define inflation as the percentage change in consumer price compared to the previous year (e.g., Catao & Terrones, 2006; Staehr, 2010). Some use GDP deflator changes (Alfaro, 2005) or real money value depreciation (Chrigui et al., 2011). The dependent variable is often logarithmic (logINF) to reduce outliers and account for non-linearities. Our study uses the Harmonised Index of Consumer Prices (HICP), a standardised measure across EU countries, ensuring comparability. The HICP is more reliable than CPI due to its harmonised methodology, broader coverage of goods and services, and inclusion of owner-occupied housing costs.

The first independent variable that we look at is the domestic output gap. Almost all studies that investigate the determinants of inflation as a measure of the output gap use the growth of real GDP, although different transformations of the variable are used in different studies, including primarily the level of GDP per capita (GDPPC), but also the percentage change in GDPPC, the GDP level, or even the GDP gap (Deniz et al., 2016; Staehr, 2010). Given the unavailability of the monthly GDP series in our cases, we will follow Binici et al. (2022) and use the seasonally adjusted Industrial Production Index (IPI) as a proxy to calculate the domestic output gap.

As a labour market factor, we include the rate of unemployment. The connection between unemployment and inflation began to preoccupy economists in the early decades of the last century and has been the subject of academic discussions for almost a whole hundred years. The curve describing this relationship, the Phillips curve, was named after the author of a study on the existence of a negative relationship between unemployment and inflation in the United Kingdom for the period from 1860 to 1957 (Phillips, 1958). More precisely, his work analyses the relationship between unemployment and inflation of nominal wages, but since the latter is closely related to the movement of the general price level, it can be

easily identified. We will follow Kjosevski and Petkovski (2017) and take the logarithm of unemployment and test this relationship for the 27 EU countries.

The inclusion of the nominal exchange rate in inflation equations often represents the effect of monetary policy. According to the standard macroeconomic model, monetary expansion typically leads to a weaker currency, which stimulates growth and moderate inflation, resulting in an expected negative parameter for the EUR/USD exchange rate. However, this parameter reflects more complex relationships.

Depreciation of the domestic currency (e.g., the euro) can show increased demand from expansionary monetary policy but may also act as a cost-push shock. A weaker euro raises the cost of imported energy products, particularly when denominated in US dollars. Additionally, a depreciated euro can fuel inflationary expectations tied to the nominal exchange rate. Conversely, balance sheet effects, such as more expensive foreign currency debt, may contract aggregate demand by increasing debt burdens. Thus, the sign of the EUR/USD exchange rate parameter depends on macroeconomic shocks and economic structures. If negative, it may indicate either standard monetary expansion effects or cost-push dynamics.

This paper examines whether the nominal exchange rate materially affects inflation, thereby constraining the monetary policy of the ECB more than that of the Federal Reserve (the FED) of the United States (US). The inclusion of the EUR/USD exchange rate in the model also accounts for its interaction with oil prices (measured using the Brent benchmark, in US dollars). A weaker euro amplifies the impact of rising oil prices on inflation, while a stronger euro mitigates it. The significant role of oil prices on inflation has been extensively documented (e.g. Ghanem, 2012; Lin & Chu, 2013). Studies by Staehr (2010) and Globan et al. (2016) explored these effects for specific countries, including transition economies, demonstrating the global impact of energy price fluctuations on inflation.

Energy prices significantly influence inflation as they are a critical input across industries and households. Rising energy costs increase production expenses, transportation costs, and household utility bills, reducing disposable income and potentially contracting consumer spending. Central banks closely monitor

energy prices to adjust monetary policy when inflation spikes due to higher energy costs. Higher inflation often leads to tighter monetary policies, slowing economic growth. Therefore, the impact of the global energy price impact on inflation is profound and far-reaching.

The Global Food Price Index also affects inflation, especially in developing economies where food constitutes a large share of household spending. Rising food prices increase living costs and production expenses, driving overall inflation. Trade restrictions often exacerbate local price pressures. Numerous studies (e.g., Ciccarelli & Mojon, 2010; Mohanty & Klau, 2001) highlight the global dimension of food price inflation. This study uses the Global Food Price Index (2016=100, in US dollars) as a variable to analyse its influence.

The Global Supply Chain Pressure Index (GSCPI) further illustrates inflation dynamics. Developed by the Federal Reserve Bank of New York, the GSCPI measures stress in global supply chains through such factors as port congestion, container availability, and transportation costs. Positive GSCPI values indicate supply chain pressures above the norm, often linked to producer price inflation in major consumer markets. Before 2020, the GSCPI rarely featured in economic studies, but supply chain disruptions during the COVID-19 pandemic brought it to prominence. The pandemic-induced shifts in demand, coupled with fiscal and monetary stimuli, strained global production networks. Supply bottlenecks emerged, driven by heightened demand for goods, idiosyncratic disruptions (e.g., weather events), and pandemic-related lockdowns. These bottlenecks contributed to inflationary pressures by limiting supply amid rising demand.

Supply chain disruptions peaked after the 2020 lockdowns eased but surged again in late 2021, with such events as Chinese lockdowns and port congestions exacerbating global inflation. Geopolitical risks further strained supply chains, challenging the globalisation model dominant since the late 20th century. These pressures underscore the interplay between supply chain dynamics and inflation. By analysing the GSCPI, this study sheds light on how global disruptions influence inflationary trends and central bank policymaking.

The role of monetary policy is inevitably included as a determinant of inflation and it is mainly observed through the patterns of monetary aggregates. Inflation is essentially a dynamic term, and by stopping the increase in the amount of

money in circulation, prices are also stopped at a new level, without taking into account the new level of the amount of money in circulation. Inflation can also rise as a result of monetary policy, and this happens if the state issues money for its own account with the purpose of acquiring the purchasing power it lacks. When prices rise while the quantity of goods remains unchanged, the government may meet its needs by issuing more money, which fuels new inflationary cycles. As a result, inflation becomes difficult to control until economic conditions return to equilibrium. The concept of inflation is relative and arises when the quantity of money and the quantity of goods do not increase simultaneously or proportionally. Therefore, inflation can occur when the quantity of goods in circulation decreases, while the amount of money in circulation remains constant (Božina, 2008). The most widely used forms of this variable in the literature are the growth rates of monetary aggregates M2 (Deniz et al., 2016; Eftekhari-Mahabadi & Kiaee, 2015), M1 (Ghanem, 2012; Globan et al., 2016), the ratio of M1 to GDP (Catao &Terrones, 2015), and M3 (Agayev, 2012).

This paper uses M3 as the measure of the monetary aggregate because it encompasses a broader range of financial assets than M2, making it a more comprehensive indicator of inflationary pressures. Unlike M2, M3 includes assets such as stocks, bonds, and other instruments that individuals may use to store wealth during periods of rising inflation. Additionally, M3 can provide a better picture of changes in the money supply over time by including the financial assets not captured by M2. This can be especially important in times of financial instability, when traditional measures of money supply may not fully capture changes in the overall level of liquidity in the economy. Overall, while both M2 and M3 are important measures of money supply, M3 can provide a more comprehensive view of the overall level of liquidity in the economy and is often preferred by economists and central banks as a measure of inflation.

The recent acceleration of consumer inflation is to a certain extent also influenced by the war in Ukraine, primarily by increasing the price of energy and food raw materials. The price of natural gas rose sharply on the European market even before the outbreak of the war, reflecting weaker-than-usual supply, especially from Russia, and consequently low stock levels. Since the beginning of the war, the price of crude oil has also increased. In addition, since late February 2022, the prices of a number of other raw materials – mainly food supplied to the world

market by Russia and Ukraine – have also risen. Taking this into account, we introduced a dummy variable in our model that has a value of 1 for the period 2022M2 to 2023M2, and 0 for the rest of the period.

The data for the selected variables were obtained from Eurostat (2024), the Federal Reserve Bank of St. Louis (FRED, 2024), and the Federal Reserve Bank of New York (2024). Table 1 presents the variables used in the model, along with their definitions, units, and data sources.

Table 1. Definition of variables.

Variables	**Symbol**	**Units**	**Source**
Harmonised Index of Consumer Prices	HICP	Index, 2015=100	Eurostat (2024)
Rate of unemployment	UNP	Percentage of population in the labour force	Eurostat (2024)
Industrial Production Index	IPI	Volume index of production Index, 2015=100	Eurostat (2024)
Nominal exchange rate	NER	EUR/USD	FRED, Federal Reserve Bank of St. Louis (2024)
Price of oil	OIL	Crude oil prices: Brent – Europe, dollars per barrel	FRED, Federal Reserve Bank of St. Louis (2024)
Global price of energy	GPEN	Global Price of Energy Index, Index 2016 = 100,	FRED, Federal Reserve Bank of St. Louis (2024)
Global Food Price Index	GPFI	Global price of Food index, Index 2016 = 100	FRED, Federal Reserve Bank of St. Louis (2024)
Global Supply Chain Pressure Index	GSCPI	This is a composite index that takes into account various factors such as port congestion, container availability, and customs clearance procedures.	Federal Reserve Bank of New York (2024)
Monetary aggregate	M3	Broad money	Eurostat (2024)

We also present descriptive statistics (see Table 2) for all the countries, and we additionally discuss the main trends in the evolution of the selected variables over time.

Table 2. Descriptive statistics

	HICP	UNP	IPI	NER	OIL	GPEN	GPFI	GSCPI	M3
Mean	98.265	8.4330	102.8	1.2442	75.577	107.2	173.1	0.1927	0.4218
Median	99.6	7.4	102.1	1.2306	71.14	103.51	160.64	-0.1	0.38
Maximum	158.08	28.1	213.4	1.5774	132.72	161.81	376.41	4.31	1.95
Minimum	62.52	1.7	51.3	0.9799	18.38	73.19	55.89	-1.64	-0.99
Std. Dev.	11.008	4.2573	16.287	0.1307	25.116	17.647	58.803	1.097	0.4098
Observations	5885	5886	5861	5859	5886	5886	5886	5886	5832

Source: Authors' calculations.

Summary statistics for all the variables used in the analysis, presented in Table 1, show considerable heterogeneity across countries and over time. For example, as measured by the Harmonised Index of Consumer Prices, average inflation in Europe is 98.2, with a minimum of 62.52 and a maximum of 158.08. The domestic output gap is on average 102.8. In addition, the variance of the unemployment indicates significant differences among European countries. With regard to energy and non-energy prices, energy prices exhibit more frequent fluctuations than non-energy prices, suggesting a potentially significant role for energy prices in explaining inflation developments in Europe. Although global supply-chain pressures appear to be relatively stable overall, the pandemic and the war in Ukraine have caused more volatile supply-chain disruptions.

4. METHODOLOGY

The existing literature reports a number of methodologies used to analyse determinants of inflation, including: a time series approach based on VAR models by Payne (2002); a structural VAR model by Jankov et al. (2008), Krznar and Kunovac (2010), and Globan et al. (2016); a Bayesian VAR by Jovičić and Kunovac (2017); and a model of the Phillips curve by Krznar (2011). Among the studies employing a dynamic panel model in the analysis of inflation determinants are Agayev (2012) and Deniz et al. (2016). In addition, recent studies have employed the ordinal probit model, as demonstrated by Dąbrowski et al. (2025).

Our empirical strategy is based on a panel data analysis. Before proceeding with the econometric method, we need to verify the stationarity of the variables selected. In this paper, we perform a panel analysis and apply panel unit root tests – the Im, Pesaran, and Shin (IPS) test (2003) and two alternatives of a Fisher-type test (the augmented Dickey–Fuller [ADF] and the Phillips–Perron [PP] tests), as outlined by Maddala and Wu (1999). These allow for the deterministic and dynamic effects differing across the panel members. In this paper, a 10% level of significance was applied as a critical value for determining whether the time series is stationary.

According to Baltagi (2001), Fisher-type tests have several advantages: (1) the cross-sectional dimension can be either finite or infinite; (2) each group can include both non-stochastic and stochastic components; and (3) the time-series dimension can vary across cross-sections. An additional advantage is that, unlike the IPS tests, Fisher-type tests do not require a balanced panel and allow for the use of different lag lengths in the individual ADF regressions. Although we prefer the Fisher-type tests, we also report the results of the IPS tests to provide an additional robustness check.

Furthermore, to estimate the existence of a long-run relationship between the dependent variable and the explanatory variables, we test the cointegration equations in the panel. We use two cointegration tests – Pedroni (1999) and Kao (1999) – to verify the null hypothesis of no cointegration between the selected determinants. Pedroni (1999) derives seven panel cointegration test statistics, of which four are based on the within-dimension and three are based on the between-dimension approach. Namely, the first of the simple panel cointegration statistics is a type of non-parametric variance ratio statistic. The second is a panel version of a non-parametric statistic that is analogous to the familiar Phillips and Perron rho-statistic. The third statistic is also non-parametric and is analogous to the Phillips and Perron *t*-statistic. The fourth statistic is a simple panel cointegration test corresponding to the augmented Dickey–Fuller *t*-statistic (Pedroni, 1999). The rest of the statistics are based on a group mean approach. Namely, the first of the simple panel cointegration tests represents a non-parametric variance ratio approach. The second extends this by providing a panel-based version of a non-parametric test comparable to the well-known Phillips–Perron rho-statistic. Similarly, the third test is non-parametric and

aligns with the logic of the Phillips–Perron *t*-statistic. The fourth is structured as a panel cointegration test, similar to the augmented Dickey–Fuller *t*-statistic (Pedroni, 1999). The remaining tests are derived using a group mean framework. Furthermore, in our empirical analysis, we use additional cointegration tests, such as the Kao (1999) test, which is based on the Engle-Granger two-step procedure and imposes homogeneity on the members in the panel. The null hypothesis of no cointegration is tested using an ADF-type test.

Having established the cointegration tests, the next step is to estimate the long-term relationship between the variables. The literature proposes different estimation methods for panel cointegration models. In this paper, we use the FMOLS and the DOLS estimators. We choose these methods for several reasons. Firstly, the OLS estimator is a biased and inconsistent estimator when applied to a cointegrated panel. On the other hand, DOLS and FMOLS take care of both small-sample bias and endogeneity bias by taking the leads and lags of the first-differenced regressors (Kao & Chiang, 2001). Secondly, for panels that have a larger time dimension (T), the dynamic estimator of the generalised method of moments (GMM) is not very effective as it is more applicable when the number of the cross-sectional units is higher than the time periods (Roodman, 2009). In this study, the time dimension (T=218) is much greater than the cross-sectional dimension (N=27). Thirdly, these estimators allow for a greater flexibility in the presence of heterogeneity in the examined cointegrated vectors (Pedroni, 1999, 2001).

However, the DOLS parametric approach is preferred to the FMOLS non-parametric approach because the latter imposes additional requirements of all variables being integrated of the same order I(1) and the regressors themselves not being cointegrated (Masih & Masih, 1996). Additionally, according to Kao and Chiang (2000), the FMOLS estimator is complicated by the dependence of the correction terms upon the preliminary estimator, which may be very biased in finite samples with panel data. The DOLS estimator also has the additional advantage of controlling the endogeneity in the model, as augmentation of the lead and lagged differences of the regressor suppresses the endogenous feedback (Lean & Smyth, 2010). This indicates that the DOLS estimator may be more promising than the OLS or FMOLS in estimating cointegrated panel regressions.

With a view to explaining the idea of the FMOLS estimator, we refer to the following fixed-effects model:

$$CMD_{i,t} = \alpha_i + x'_{i,t}\,\beta + u_{i,t}, \tag{1}$$

where i (=1, 2,…, N) and t (=1, 2, ..., T) index the cross-sectional units and time series units, respectively, $CMD_{i,t}$ is the dependent variable, β is the vector of parameters, α_i are intercepts and $u_{i,t}$ are the stationary disturbance terms. Here, $x_{i,t}$ is assumed to be the matrix of explanatory variables, which are I(1) for all cross-section units. It is assumed that it follows an autoregressive process in the following form:

$$x_{i,t} = x_{i,t-1} + \varepsilon_{i,t}, \tag{2}$$

with an innovation vector: $w_{i,t} = (u_{i,t}, \varepsilon_{i,t})$.

Given that $w_{i,t} = (u_{i,t}, \varepsilon_{i,t}) \sim I(0)$, the variables are said to be cointegrated for each member of the panel with the cointegrating vector β. The asymptotic distribution of the OLS estimator is the condition for the long-run covariance matrix of the innovation vector. The FMOLS estimator is derived by making an endogeneity correction (by modifying the variable $CMD_{i,t}$) and a serial correlation correction (by modifying the long-run covariance of the innovation vector, $w_{i,t}$). The resulting final estimator is expressed as follows:

$$\beta_{FMOLS} = \left[\sum_{i=1}^{N}\sum_{t=1}^{T}(x_{it} - \overline{x})(x_{it} - \overline{x}_i)'\right]^{-1} * \left[\sum_{i=1}^{N}(\sum_{t=1}^{T}(x_{it} - \overline{x})\hat{CMD}_{it} - T\hat{\Delta}_{\varepsilon U})\right]^{-1} \tag{3}$$

The DOLS estimator has been extended to panel analysis by Kao and Chiang (2001), who developed finite sample properties of the OLS, DOLS, and Pedroni's FMOLS. The DOLS estimator in a panel case environment is obtained by running the following regression:

$$CMD_{i,t} = \alpha_i + \beta_i x_{i,t} + \sum_{k=-p_1}^{p_2} \delta_k \Delta CMD_{i,t-k} + \sum_{k-q_1}^{q_2} \lambda_k \Delta x_{i,t-k} + u_{i,t} \tag{4}$$

where p and q denote the numbers of leads and lags typically chosen using certain information criterion (e.g., Akaike, Hansen).

Based on all the above, our further analysis will evaluate the results of the FMOLS and DOLS estimations.

5. EMPIRICAL RESULTS

In this section, we present the results of the econometric analysis of the determinants of inflation in the 27 EU member states.

The first step of our empirical analysis is to perform panel unit root tests (Table 3). As already mentioned in the previous section, we applied panel-IPS unit root tests and Fisher-type tests using the ADF and PP tests, as outlined by Maddala and Wu (1999).

These tests are conducted on both levels and first differences for all variables in the models. Bearing in mind the traditional null hypothesis of stationarity, the results indicate acceptance of stationarity at first difference and rejection of stationarity at levels, indicating that all series are *I(1)*.

Table 3. Panel unit root tests

	Im, Pesaran, and Shin W-stat		ADF-Fisher Chi-square		PP-Fisher Chi-square		Conclusion
Variables	At a level of	First differentiation	At a level of	First differentiation	At a level of	First differentiation	
HICP	11.4218	-46.5466***	5.08447	1429.75***	25.8044	1824.11***	I(1)
UNP	-0.96296	-25.0091***	72.7023	807.858***	47.1114	1983.40***	I(1)
IPI	0.50807	-35.6466***	56.9720	1223.35***	103.885***	2884.68***	I(1)
NER	-1.56792	-26.8533***	49.5211	809.875***	51.3039	3025.20***	I(1)
OIL	-0.71539	-7.87456***	35.9627	155.868***	45.3927	165.254***	I(1)
GPEN	-2.98800***	-29.0025***	67.4391	906.665***	66.4362	1850.52***	I(1)
GPFI	-0.42973	-4.23847***	45.4030	793.296***	62.2152	115.717***	I(1)
GSCPI	0.49281	-6.69124***	41.6270	131.660***	44.5629	140.391***	I(1)
M3	-0.56225	-4.17612***	37.4717	83.4418***	977.966***	1110.43***	I(1)

Note: *, ** and, *** indicate that the test statistic is significant at the 10%, 5%, or 1% level, respectively.
Source: Authors' calculations.

Following the panel unit root tests results for all series of interest, the null hypothesis of a unit root cannot be rejected. Since the null hypothesis of a unit

root holds for all series of interest, we continued with panel cointegration tests as the next step.

Table 4. Results of the panel cointegration tests of Pedroni and Kao

Statistics	New EU member countries (NMS - 11)
Panel v-statistic	-2.749116
Panel rho-statistic	-105.3884
Panel PP-statistic	-130.9643
Panel ADF-statistic	-64.5233
Group rho-statistic	-111.264
Group PP-statistic	-145.146
Group ADF-statistic	-63.3234
Kao residual cointegration test (*p*-value)	0.000

Note: *, **, and *** indicate that the test statistic is significant at the 10%, 5%, or 1% level, respectively.
Source: Authors' calculations.

As presented in Table 4 the majority of Pedroni's (1999, 2001) tests indicate that there is a cointegration relationship in all models. Kao's (1999) test in Table 4 also indicates a cointegration relationship in all models.

Keeping in mind that all the determinants in all the models are co-integrated, in the next step we test long-run linkage among the inflation and other selected determinants using the FMOLS and DOLS tests. The results are presented in Table 5 below.

Table 5 Empirical results

Variable	FMOLS	DOLS
LUNP	-0.018 (0.004)	-0.021 (0.005)
LIPI	0.105*** (0.011)	0.101*** (0.012)
LEURUSA	-0.021 (0.018)	-0.023** (0.022)
LOIL	0.084** (0.015)	0.125*** (0.020)
LFI	0.053 (0.013)	0.045*** (0.007)
LEN	0.161*** (0.015)	0.197** (0.022)
GSCPI	0.024** (0.005)	0.049** (0.006)
M3	0.028 (0.003)	0.050 (0.004)
DUMMY	0.034*** (0.010)	0.079*** (0.012)
Adjusted *R*-squared	0.71	0.87
Observations	5751	5736

Notes: *, **, and *** indicate that the test statistic is significant at the 10%, 5% or 1% level, respectively.
Standard errors in parentheses.
Source: Authors' calculations.

The findings of this study highlight the multifaceted determinants of inflation in EU countries, emphasising the roles of industrial production, energy prices, currency valuation, and external shocks. Our results align with existing literature, reinforcing the complex interplay between supply and demand-side factors in shaping inflation dynamics.

1. Industrial production and inflationary pressures

The industrial production index significantly impacts inflation, a trend that can be attributed to several mechanisms:

- Production costs and pass-through effects: Rising producer prices (Producer Price Index [PPI]), driven by higher raw material, energy, and labour costs, directly feed into consumer inflation. Energy prices in the EU surged by 92.9% in May 2022 compared to the previous year, while non-energy industrial products increased by 16.0%. Countries such as Denmark (+59.8%), Romania (+59.2%), and Belgium (+52.6%) experienced the highest price increases, whereas Ireland (+24.2%) and Slovenia (+25.7%) saw more moderate growth.
- Post-pandemic demand recovery: The inflationary effects of industrial production were amplified in the post-COVID recovery phase, as pent-up consumer demand and supply-side bottlenecks placed upward pressure on prices.
- Currency depreciation: Changes in PPI influence currency values, affecting import prices and further fuelling inflation. The euro's depreciation in 2022, driven by the slower rate hikes of the ECB compared to the Fed, increased imported inflation. On average, euro depreciation added 0.36 percentage points to inflation per month in 2022.

2. Energy prices as a key inflationary driver

Our analysis confirms that energy price fluctuations exert a profound influence on inflation:

- Oil price transmission mechanism: A 1% increase in oil prices raises inflation by 0.84% (FMOLS method) and 0.125% (DOLS method), underlining oil's pivotal role in EU inflation dynamics. The war in Ukraine intensified oil price volatility, particularly affecting diesel and gasoline costs.
- Electricity and natural gas prices: EU electricity prices are linked to natural gas prices via the merit order system, causing energy shocks to disproportionately impact inflation. A 1% rise in global energy prices leads to inflation increasing by 0.161% to 0.197%, depending on the estimation method.
- Government interventions and policy effectiveness: To curb inflation, some governments introduced fuel subsidies and tax reductions (e.g., France, Germany, and Poland). However, due to persistent energy dependency on Russian oil and gas, inflationary pressures remain significant.

These results are consistent with previous studies (Aziz & Dahalan, 2015; Masso & Staehr, 2005) which confirm the systemic impact of oil price shocks on inflation. LeBlanc & Chinn (2004) and Cunado and Perez de Gracia (2005) further emphasise nonlinear and long-term effects of oil price fluctuations, reinforcing the need for adaptive policy responses.

3. Food price inflation and supply chain disruptions

Our findings also indicate that food price inflation plays a notable role in overall inflation trends, with a 1% increase in food prices raising inflation by 0.045% on average.

- Supply chain vulnerabilities: The Ukraine war disrupted global grain and staple exports, leading to record-high food prices. While the EU's Common Agricultural Policy (CAP) ensures food security, reduced imports of Ukrainian grain have increased production costs, particularly for livestock feed and processed food.
- Social and economic consequences: Rising food prices have disproportionate effects on lower-income households and increase the burden on government social protection programmes. The need for targeted fiscal responses to support vulnerable groups becomes essential in mitigating the socio-economic fallout.

These findings align with Sek et al. (2015), who emphasise the heightened sensitivity of inflation to global food and energy price shocks, particularly in economies with weaker financial stability.

4. Policy implications

Given the complexity of inflationary drivers, a coordinated policy approach is essential for stabilising inflation in the EU:

- Monetary policy adjustments: The ECB's monetary policy needs to strike a balance between inflation control and economic stability. While interest rate hikes can curb demand-driven inflation, they may have limited effects on supply-side inflation stemming from energy shocks. A gradual and data-driven tightening strategy could mitigate unintended economic slowdowns.

- Energy market reforms and diversification: To reduce vulnerability to energy price shocks, the EU must accelerate the transition to renewable energy sources and diversify energy imports. Strengthening strategic reserves and improving energy efficiency will help moderate inflationary pressures in the long run.
- Targeted fiscal policies: Rather than broad subsidies, targeted support measures for lower-income households and energy-intensive industries would help cushion inflation's regressive effects without fuelling excess demand.
- Supply chain resilience strategies: Strengthening EU-wide logistics networks, enhancing local production capacity, and reducing external dependencies on food and raw materials can improve economic resilience against global supply shocks.

Inflation in the EU is driven by a combination of rising industrial and energy costs, currency fluctuations, and external shocks. Our findings highlight the nonlinear and persistent nature of inflationary pressures, emphasising the need for coordinated monetary and fiscal policies. Given the ongoing uncertainties, policymakers should prioritise energy diversification, adaptive monetary strategies, and targeted fiscal interventions to mitigate inflation risks and enhance economic stability.

6. CONCLUSION

This analysis of the inflationary process, based on variations in relative prices, reveals key insights into the factors driving inflation in the European Union. Initially, cost-push factors were the dominant drivers of inflation largely due to sharp increases in energy prices. However, this effect gradually weakened as crude oil price growth slowed compared to the same period in the previous year. By October 2021, there was a noticeable shift, with aggregate demand (demand-pull) playing a more significant role in driving inflation. This demand contribution to inflation remained relatively stable, around two percentage points, until March 2022. In the months following, approximately one percentage point of inflation remained unexplained, suggesting the possibility of inflationary expectations playing a role. However, proving the influence of inflationary expectations remains challenging, and alternative explanations, such as relative price

variations, supply chain disruptions, and the geopolitical impact of the Russian invasion of Ukraine, provide plausible contributing factors.

One of the novel aspects of this study is the examination of the divergent reactions of EU member states to the external energy price shock. The analysis shows significant heterogeneity in inflation outcomes across euro area countries. This divergence began as early as 2020, when the pandemic induced disinflationary pressures in tourism-dependent countries. As the pandemic receded, inflationary pressures mounted most notably in countries with a more resilient economy and labour shortages. The Baltic states were disproportionately affected by the war and sanctions, which disrupted supply chains and halted imports from Russia. Prior to the war, gas and electricity were relatively cheaper in the Baltic states compared to the broader euro area, amplifying the percentage increases in energy prices. Differences in energy generation mixes and household utility contracts also contributed to the varied inflation experiences across countries. In some countries, where utility prices were fixed for longer periods, inflationary effects were delayed.

The results of this study highlight an important consideration for monetary policy in the euro area. If central bankers focus too heavily on the role of aggregate demand and overlook the persistent influence of energy prices and relative price variations, there is a risk of tightening monetary policy prematurely. Overly aggressive interest rate hikes could unnecessarily slow down economic growth or even trigger a recession, potentially exacerbating inflationary pressures. The transition to a new definition of target inflation, based on medium-term forecasts, further complicates the ability to respond to inflationary shocks accurately. This analysis underscores the challenges of forecasting inflation in the face of multiple external shocks, such as the pandemic and the war in Ukraine, which reduce the effectiveness of traditional inflation models.

In comparison to the existing literature, this study offers additional insights by emphasising the continued importance of energy price shocks in driving inflation, even as demand-pull factors begin to play a more substantial role. The literature often focuses on the interplay between demand and supply-side factors, but this paper provides a clearer picture of how geopolitical and global supply chain disruptions exacerbate inflation in an interconnected economic

environment. While previous studies have explored the impact of oil prices and supply chain disruptions, the specific effects observed in the EU during the pandemic and the war in Ukraine suggest that these factors have a more profound and complex influence on inflation than has traditionally been acknowledged. Thus, the findings challenge the conventional understanding of inflation dynamics and underscore the need for more nuanced monetary and fiscal policies that account for the evolving nature of inflation drivers in the current global context.

In conclusion, while inflation in the EU has been largely driven by external shocks, the interaction between demand-pull factors, energy prices, and supply chain disruptions underscores the complexity of managing inflation. The findings suggest that monetary policy should be cautious in responding to inflationary pressures, recognising the dominant role of energy prices and the uncertainty surrounding inflationary expectations. Future monetary policy should focus on a more balanced approach, taking into account the varied impacts of external shocks and the nuanced dynamics of inflation across different EU member states.

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EXCHANGE RATE PASS-THROUGH AND INFLATIONARY DYNAMICS IN BANGLADESH: A COINTEGRATION AND VECM ANALYSIS

ABSTRACT: *This paper analyses how deviations in nominal exchange rates have an effect on domestic prices – also known as exchange rate pass-through (ERPT) to inflation – in Bangladesh using time series data from 1989 to 2022 and employing the econometric methods of the Engle–Granger 2-step cointegration model and the Vector Error Correction (VECM) model. Understanding the extent of ERPT is important as it has consequences for domestic and export prices and exchange rate stability. This paper confirms the significant negative impact of escalating nominal exchange rates on inflation, i.e., devaluation of the taka leads to inflationary burdens within the internal economy. The VECM model shows that a one-per-cent decrease in the nominal exchange rate tends to raise inflation by 0.76 per cent, while the corresponding long-run impact as reflected through the Engle–Granger estimation is 0.89 per cent. These results bear important policy implications for managing prices and incentivising exports.*

KEY WORDS: *exchange rate pass-through, inflation, Engle–Granger 2-step cointegration, Vector Error Correction Model (VECM), Bangladesh.*

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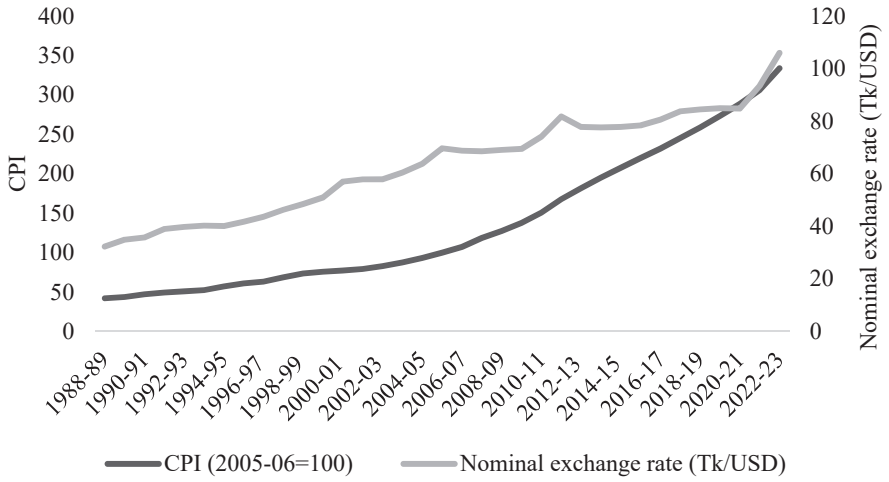
1. OVERVIEW

Bangladesh has made significant progress in trade development over the past decades by adopting various exchange rate policies. Since independence, the country has actively pursued an exchange rate policy that frequently adjusts trade measures, including currency devaluation (Aziz, 2012; Islam, 2002; Younus & Chowdhury, 2006). According to Islam (2002), the Bangladeshi taka (Tk.) underwent 89 exchange rate adjustments against the U.S. dollar between 1983 and 2002, with 83 aimed at currency depreciation. Aziz (2003) found that the taka was devalued 41 times between 1991 and 2000. Similarly, Younus and Chowdhury (2006) reported 130 devaluations between 1972 and 2002 to address balance of payment imbalances.

Like many developing countries following an export-led growth strategy, Bangladesh has frequently adjusted its exchange rate to remain competitive. In the early stages, the country employed various pegged exchange rate regimes: pegging to the pound sterling (1972–1979), to a basket of key trading partners' currencies (1980–1999), and a crawling band system (2000–2002). In 2003, Bangladesh transitioned to a managed floating exchange rate regime to boost exports, curb imports, and improve trade balances (Aziz, 2012; Hossain & Alauddin, 2005). This transition was initially stable, with less than a 1% devaluation in the first year (2003–2004). However, from mid-2004, the exchange rate began depreciating steadily, rising from Tk. 58/USD in 2003 to Tk. 84/USD in 2018. Since then, the exchange rate has remained relatively stable, fluctuating between Tk. 84/USD and Tk. 86/USD in the period 2018–2021 (Hossain & Ahmed, 2009). The variability of the consumer price index (CPI) and nominal exchange rate (NER) from 1989 to 2023 in Bangladesh is exhibited in Figure 1.

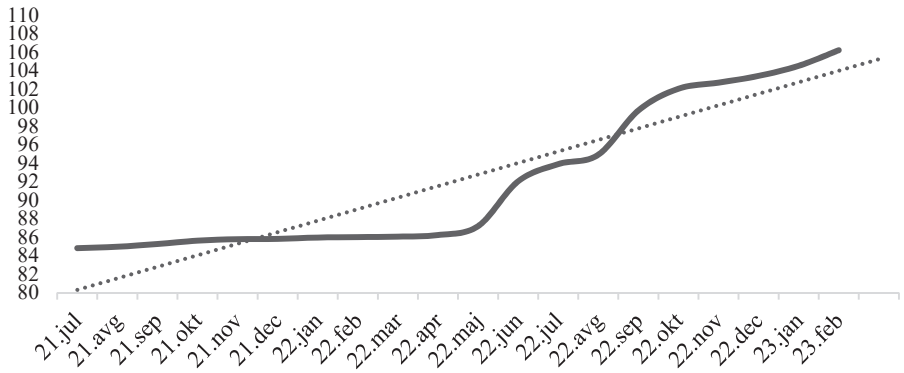
Figure 1: Consumer price index (CPI) and nominal exchange rate (NER) of Bangladesh



Note: The nominal exchange rate is measured in dollars per taka unit at the end period.
Source: Bangladesh Bureau of Statistics (BBS) and Bangladesh Bank (BB). Date:27/7/2024

If we examine the exchange rate against the consumer price index, we can see the CPI closely follows the exchange rate in terms of Tk./USD (Figure 1) This implies that the domestic prices are closely correlated with the devaluation of the domestic currency. The recent monthly trend of the exchange rate reveals that Bangladesh is gradually devaluing its currency (Figure 2), which might have an inflationary impact.

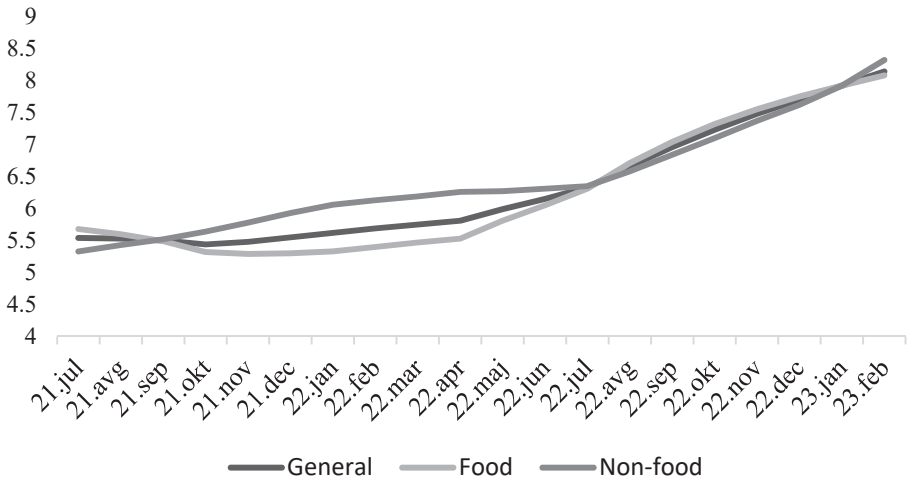
Figure 2: Monthly Trend of Exchange Rate



Source: Bangladesh Bank Date:27/7/2024

At present, Bangladesh is experiencing a general upsurge in the price index. Although it is seen as a supply-side effect, it is also related to the currency value, as a currency that has already been devalued has lower purchasing power compared to the other currencies. Consequently, import prices have been rising, causing production costs to increase to a larger extent. Food and non-food inflation rates have been rising alongside general inflation (Figure 3). As of November 2023, the overall inflation rate of Bangladesh rose to 9.49% along with the food inflation rate (10.76%) and the non-food inflation rate (8.16%) (Bangladesh Bureau of Statistics, BBS), making life difficult for people in the fixed-income group.

Figure 3: Recent monthly trend of inflation in Bangladesh



Source: Bangladesh Bureau of Statistics (BBS)

Currency depreciation can directly affect inflation, and the impact will depend on the level of the exchange rate pass-through (ERPT) effect. Import prices are a key channel through which exchange rate changes affect domestic prices (Marazzi et al., 2005; Olivei, 2002). Therefore, it has become crucial to study the effect of ERPT on inflation in Bangladesh. ERPT explains the extent to which domestic currency prices adjust in response to comparative changes in the foreign exchange rate between the exporting and importing countries. It is the degree to which changes in the exchange rate affect the prices of imported and exported goods along with inflation. This has become especially relevant in countries such as Bangladesh, where inflationary pressures have been frequent in recent years. Therefore, analysing second-stage pass-through – referring to changes in domestic prices resulting from increased expenditure on imports – is crucial. In contrast, first-stage pass-through refers to changes in exchange rates that directly impact import prices. Understanding the second stage of the pass-through effect is essential for accurately forecasting inflation and designing effective regulatory policies (Aziz et. al., 2013). A low ERPT can be helpful for pursuing and implementing independent monetary and inflation-targeting policies. On the other hand, a high degree of pass-through means the relative prices of the commodities in the domestic market will change rapidly.

Against the above backdrop, the objective of this study is to analyse the impact of ERPT on the domestic price (inflation) in the context of Bangladesh. Our study seeks to undertake an empirical analysis of the sensitivity of domestic price to changes in the nominal exchange rate of Bangladesh using time series data from 1989 to 2022. While existing studies have explored ERPT's effects on Bangladesh's export and import prices, this paper focuses on ERPT's impact on domestic inflation using updated data, an extended study period, additional variables, and robust econometric methods. Specifically, the analysis employs the Engle–Granger (1987) two-step cointegration method and vector error correction methodologies on time series data from 1989 to 2022. Key objectives include estimating the speed and elasticity of ERPT to domestic prices, analysing long-run relationships among variables, examining the pace of exchange rate shocks, and quantifying domestic price changes due to exchange rate fluctuations. To the best of the authors' knowledge, no existing studies have comprehensively addressed these objectives in the context of Bangladesh. Given the ongoing dollar crisis, many advocate currency devaluation, yet its potential long-run inflationary effects make this study particularly timely and policy-relevant.

The remainder of the paper is organised as follows: Section 2 provides a review of the relevant literature, while Section 3 outlines the theoretical framework, Section 4 describes the data and variables used in the analysis, Section 5 details the methodology employed, and Section 6 presents the empirical results, along with a discussion of the estimated coefficients. Finally, Section 7 concludes with closing remarks and general policy recommendations.

2. LITERATURE REVIEW

The concept of ERPT has gained significant attention in recent years, with extensive theoretical and empirical research exploring its impact on various domestic prices. According to Taylor (2000), the degree of price responsiveness to exchange rate fluctuations is positively correlated with inflation. In country-specific studies, Anyoka (2020) found a significant positive relationship between exchange rates and inflation in Ghana, using a vector auto-regressive (VAR) model for the period 2005–2015. In contrast, Chowdhury and Siddique (2006) found no significant evidence of ERPT to domestic prices in Bangladesh. However, in a comparative analysis of inflation determinants, Siddiqui et al. (2024), using the autoregressive distributed lag (ARDL) model, found a negative

and significant relationship between exchange rates and inflation in Bangladesh. Contradictory results were reported by Islam et al. (2022), who used dynamic and quantile regression analysis on monthly data from 2013M01 to 2019M06, finding a positive and significant relationship between exchange rates and inflation. Muktadir-Al-Mukit (2018), in an analysis of Bangladesh's inflation determinants, identified exchange rates as a key factor using the cointegration and error correction model.

In Egypt, the pass-through effect of exchange rates was found to be incomplete, with a stronger impact on the CPI. Helmy et al. (2018) employed a structural vector auto-regression (SVAR) model for the period 2003–2015 to examine this effect. Similarly, Elsharkawy and Elroukh (2023), using a nonlinear autoregressive distributed lag (NARDL) model, found an incomplete pass-through effect during currency depreciation, while it was statistically insignificant during currency appreciation. In Vietnam, pass-through elasticity was found to be incomplete (Xuan, 2021), whereas Thailand exhibited only partial and modest pass-through to inflation (Jiranyakul, 2018). During the COVID-19 pandemic, Indonesia experienced incomplete ERPT to the CPI, as observed by Sari et al. (2023). Similarly, during the pandemic, Tiamiyu (2022) found that in Nigeria, exchange rates had a stronger explanatory power for inflation compared to money supply. Ha et al. (2020) suggest that central banks can use the exchange rate as a buffer against external shocks to help stabilise inflation. They also emphasise the importance of closely monitoring the nature of these external shocks, which drive currency fluctuations, in order to better manage inflationary responses.

For emerging economies, Ejaz and Khalid (2024) found a direct relationship between exchange rate fluctuations and inflation. Using the generalised autoregressive conditional heteroscedasticity-X (GARCH-X) and SVAR models, they observed that countries with high exchange rate volatility, such as Pakistan, India, Indonesia, the Philippines, and Türkiye, experienced a strong positive relationship between exchange rates and inflation. Meanwhile, economies with flexible exchange rate regimes and lower volatility exhibited minimal or negative effects. Kassi et al. (2019), in their study covering 1995Q1–2016Q4, used the NARDL approach and found significant and complete ERPT for currency appreciation in the long run across emerging and developing Asian economies.

Their results suggested that a 1% appreciation in the local currency led to an average price increase of 0.90%.

Some studies also highlight evidence of incomplete ERPT to import prices in South Asian countries (Anderton, 2003; Campa & Goldberg, 2005; Sengupta & Roy, 2023). Using the system generalised method of moments (SYS-GMM) model, they found that pass-through elasticity depends on currency appreciation and depreciation in Bangladesh, India, Iran, Pakistan, and Sri Lanka. In Bangladesh, Islam (2013) found no significant impact of inflation on imports.

The effect of ERPT on export prices appears to be mixed. Hoque and Razzaque (2004) found full ERPT to export prices in Bangladesh, whereas Shahriar et al. (2024), using the NARDL model, found a significant negative long-run effect of ERPT on inflation and exports. They showed that a 1% decrease in the exchange rate led to a 2.09% reduction in exports. Dash and Narasimhan (2011), using the Johansen–Juselius cointegration and error correction models, found evidence of partial pass-through to exports and more than complete pass-through to imports, with long-run coefficients being larger than short-run estimates.

Historical data from the USA during the 1980s and 1990s indicate that a decline in the exchange rate was associated with lower inflation (Shintani et al., 2013). Saha and Zhang (2011), after analysing China and India, concluded that exchange rate fluctuations were less likely to drive up domestic prices. In Nigeria, ERPT was found to be higher for import prices than for consumer prices (Aliyu et al., 2009), with a 1% exchange rate fluctuation resulting in a 14.3% pass-through to import prices and 10.5% to consumer prices. The External Sector Division (2012) estimated pass-through elasticity at 76.0% in the short run and 31.0% in the long run, confirming that ERPT in Nigeria is incomplete. Adeyemi and Samuel (2013) found that ERPT to domestic prices in Nigeria reached 83% in the long run. For India, Ghosh and Rajan (2007) estimated long-run price pass-through elasticity at 40%, with only 10% in the short run.

The frequent increases in commodity prices and currency depreciation in Bangladesh make this study particularly relevant. While numerous studies have been conducted on ERPT, they have primarily focused on its effects on exports and imports rather than inflation. Those that have analysed inflation have often relied on monthly data and lacked a broad scope. To address this gap, our study

employs recent long-term data and an updated methodology to extend the literature on ERPT to domestic inflation. Specifically, we apply cointegration and the Vector Error Correction Model (VECM) to analyse Bangladesh's case, using advanced econometric techniques on long time-series data spanning 1989–2022. This research aims to provide a clearer understanding of ERPT's impact on inflation, contributing valuable insights for formulating exchange rate policies and diversifying trade strategies. Additionally, the study will assess how these policies have influenced Bangladesh's monetary policy framework.

3. THEORETICAL FRAMEWORK

The theoretical basis of ERPT stems from the law of one price (LOOP) and purchasing power parity (PPP), which implies that under perfect competition with no trade barriers and transaction costs, identical goods should have the same price when expressed in a common currency. Under these conditions, a complete ERPT is expected. The algebraic expression of PPP with zero transportation costs and trade barriers is given by:

$$P_q = EXC^{q,r} * P_r \,, \tag{3}$$

where, P_q and P_r are the domestic and foreign prices of a good, and EXC_t is the nominal exchange rate between the currencies of country q and country r.

However, imperfections such as trade barriers, transportation costs, pricing-to-market strategies, and local costs (e.g., tariffs), often lead to incomplete ERPT, where domestic prices adjust only partially to exchange rate changes (Taylor, 2000). This is particularly relevant for small open economies such as Bangladesh, where import dependence amplifies the impact of exchange rate fluctuations on domestic inflation, sticky prices (e.g., contractual rigidities) delay full pass-through, and monetary policy credibility may influence inflation expectations, further dampening ERPT (Ghosh & Rajan, 2007).

The study's empirical model builds on this by incorporating control variables (e.g., producer price index of the U.S., Bangladesh's real gross domestic product) to account for external shocks and domestic demand pressures, addressing the gap between LOOP/PPP assumptions and real-world dynamics.

4. DATA AND VARIABLES

The study uses an annual time series data for the period from 1989 to 2022. The main variable of interest is the nominal exchange rate (*NER*), defined as Tk/USD; the *CPI* of Bangladesh serves as a proxy for the domestic price level, while the producer price index (*PPI*) of the United States is used as a proxy for world import price. Real GDP (*RGDP*) of Bangladesh is included as a control variable. *PPI_US* has been chosen as a proxy of world import prices as the USA is one of the largest trading partners of Bangladesh. A devaluation in domestic currency (an increase in NER in our case) causes imports prices to rise. A rise in import prices can result in an increase in overall domestic prices. An increase in the price of foreign goods with respect to domestic goods and services reduces the demand for foreign goods, which may affect the demand in the domestic market and thus influence prices. RGDP shows the real purchasing power of an economy. Hence, any changes in the RGDP can influence the domestic price level.

Most of the data for the variables were collected from various sources. The CPI was collected from the Bangladesh Bureau of Statistics (BBS), the PPI of the USA (PPI_US) from Federal Reserve Economic Data (Fred), the NER from the Bangladesh Bank, and RGDP from the World Development Indicators (WDI). The NER variable was constructed using the following formula, with the exchange rate expressed in dollars per Tk unit: $NER = \frac{\$1}{EXC_{it}}$

Table 1: Description of the variables used in the model

Variable	Mean	Med	Max	Min	Std.
CPI	87.84	66.86	195.53	27.87	53.14
PPI_US	162.52	161.08	264.48	112.24	39.53
NER	123.69	104.92	216.19	77.33	40.00
RGDP	1.11E+11	9.56E+10	1.73E+11	8.49E+10	2.69E+10

Note: CPI, NER, and PPI_US are index values, whereas RGDP is a real value expressed in billions of taka.

5. ECONOMETRIC MODEL AND ESTIMATION METHODS

5.1. Model specification

Our methodology of ERPT draws its strength from the LOOP theory. First, consider this law in absolute terms. Let us take commodity Y exported by country B to country A.

$$P_Y^A = EXC_B^A * P_Y^B, \tag{5.1.1}$$

where *EXC* is the exchange rate between the two nations and P_Y^A and P_Y^B are prices of the exported commodity *Y* in each nation's respective domestic currency. The total differential of Equation (5.1.1) is:

$$dP_Y^A = dEXC_B^A + dP_Y^B \tag{5.1.2}$$

If $P_Y^B = 0$, then the adjustment in the exchange rate is fully transferred into A's import prices and the ERPT effect is complete, whereas if $P_Y^B \neq 0$, the pass-through effect is incomplete.

Equation (5.1.1) needs to be augmented by proper control variables to operationalise the model. The major control variables are the cost conditions in the exporting nation's market and demand conditions in the importing nation's market. We consider ERPT using the bilateral–US dollar exchange rate. The pass-through elasticity of Bangladesh is measured by using the following equation – the bilateral nominal exchange rate – as articulated by Ghosh and Rajan (2007):

$$\ln(P_i)_t = \alpha_0 + \alpha_1 \ln(E_{ij})_t + \alpha_2 \ln(RGDP_j)_t + \alpha_3 \ln(PPI\_US_j)_t + \alpha_{it}, \tag{5.1.3}$$

where *i* is Bangladesh, *j* is the USA or rest of the world, P_i is the CPI of Bangladesh, E_{ji} is the bilateral exchange rate of the Bangladeshi taka per US dollar, *PPI* is the producer price index of the USA or world import price, and *RGDP* is the real gross domestic product of Bangladesh.

PPI_US is treated as an exogenous variable representing global import prices. This is justified theoretically and empirically, as the U.S. is a major trading partner of Bangladesh. *PPI_US* captures external cost shocks that affect import prices in small open economies. Given Bangladesh's limited influence on global price

formation, its domestic conditions are unlikely to impact U.S. producer prices, supporting the assumption of weak exogeneity. Treating *PPI_US* as an exogenous proxy variable for world import price aligns with standard practice in the ERPT literature (Bada et.al., 2016), particularly for small economies where external price trends areassumed to be determined independently of domestic macroeconomic variables.

As our model, we choose the bilateral NER of the US dollar to the Bangladesh currency (Equation 5.1.3 as a proxy of the exchange rate. Thus, the ERPT into Bangladesh's import and consumer prices is estimated for the US dollar NER with the equation:

$$\ln(CPI_i)_t = \alpha_0 + \alpha_1 \ln(ER_{ij})_t + \alpha_2 \ln(RGDP_j)_t + \alpha_3 \ln(PPI\_US_j)_t + \alpha_{it}, \qquad (5.1.4)$$

where CPI_i is the consumer price index of Bangladesh, *ERji* is the bilateral exchange rate of the Bangladesh taka against the US dollar (Tk/USD), *PPIj* is the producer price index of the USA, and *RGDPi* is the real gross domestic product of Bangladesh. If the ERPT elasticity coefficient is $\alpha_1 = 1$ then pass-through is complete, while pass-through is incomplete if $\alpha_1 < 1$.

Most of the studies conducted so far have applied the technique of cointegration and VAR methodology to investigate ERPT in many countries. We employed the Engle–Granger two-step cointegration and VECM model in line with the works of Aliyu et al. (2009), Ca'Zorzi et al. (2007), and McCarthy (2007).

Our study used four variable VECM models. The model includes *CPI*, *NER*, real output (*RGDP*), and import prices (*PPI_US*). The depreciation of the currency and increased inflation are caused by higher import and consumer prices. Consequently, we set an *a priori* expectation that the coefficient of the *NER* variable will be negative, while import prices and *RGDP* will be positive. A domestic currency depreciation reduces the *NER* value. Different models are used for checking the stability of the estimated results across the paper.

5.2. Estimation method

The analysis started with checking the stationarity of the key variables using the Augmented Dickey–Fuller (ADF) test (Dickey & Fuller, 1979) and the Phillips–

Perron (PP) test (Phillips & Perron, 1988) to establish an order of integration before proceeding to the Johansen and Juselius (1990) cointegration tests in multivariate form. As our data set is very small compared to other traditional approaches, the VECM test will be a suitable choice.

5.2.1. Unit root test

Two of the most used unit root tests – the ADF and the PP tests – are used to confirm whether one of the variables contains a unit root or not. The equation form of the ADF test using only intercept and trend and intercept has been given below:

$$\Delta y_t = \alpha + \delta_t + \sum_{i=1}^{k} \gamma \Delta y_{t-1} + u_t \quad (5.2.1.1)$$

$$\Delta y_t = \alpha + \delta_t + \beta y_{t-1} + \sum_{i=1}^{k} \gamma \Delta y_{t-1} + u_t, \quad (5.2.1.2)$$

where Δy_t represents the first difference of y, u_t shows the serial correlation errors and α, δ, β, and γ are parameters of the model. The null and alternative hypotheses are:

$H_0 = \beta = 1$,

$H_1 = \beta < 0$.

If the null hypothesis is not rejected, then we have the problem of a unit root in the series.

On the other hand, the equation of the PP test is:

$$\Delta y_t = \alpha + \delta y_{t-1} + u_t \quad (5.2.1.3)$$

5.2.2. Engle–Granger two-step cointegration

The cointegration analysis is a single-equation model that requires each of the variables to be stationary at first difference or, in other words, integrated of order one. A long-run relationship among the variables can be identified if the residuals

of the model are stationary (I(1)). Then the model is not spurious[1] and represents a long-run relationship. If the variables are cointegrated, we can run the Error Correction Model (ECM)[2].

In the first step of the Engle–Granger two-step procedure, the long-run equilibrium relationship among the variables is estimated. The equation form is as follows:

$$Y_t = \hat{\alpha} + \widehat{\beta} X_t + \hat{\varepsilon}_t \qquad (5.2.2.1)$$

We then obtain the residuals, whose equation form is:

$$\hat{\varepsilon}_t = Y_t - \hat{\beta}_1 - \widehat{\beta}_2 X_t .$$

If $\hat{\varepsilon}_t \sim I(0)$, then the variables Y_t and X_t are said to be cointegrated and OLS regression yields consistent estimators of $\hat{\beta}$ parameter. Then the residuals found from the equilibrium regression can be used to estimate the ECM and to analyse the long-run and short-run effects of the variables as well as their adjustment coefficient identified in step two. If the variables are not cointegrated, then the regression results will be spurious. Lastly, diagnostic tests will be performed to check the accuracy of the model.

5.2.3. Johansen and Juselius cointegration test

The long-run relationship among the variables has been checked by the Johansen and Juselius (1990) cointegration test procedures. Using the likelihood ratio (LR) trace test statistic suggested by Johansen (1988), we determined the order of *r*:

$$\lambda_{trace}\,(q) = -T \sum_{i=q+1}^{k} \ln\left(1 - \hat{\lambda}_{q+1}\right) \qquad (5.2.3.1)$$

---

1 A spurious regression model is the regression of a non-stationary time series on another non-stationary time series without proper transfomation. One common indicator of a spurious regression is when the *R-squared* value is high and the Durbin–Watson statistic is low. A spurious regression model is not desirable.

2 The ECM is a single-equation model used to show one-way causation. The ECM corrects the disequilibrium in the system or shows the speed at which it is correcting disequilibrium.

Here, $r = 0, 1, 2, \ldots..k\text{-}1$; T is the number of observations used for estimation; λ_i is the ith largest estimated eigenvalue.

The maximum eigenvalue (LR) test statistics proposed by Johansen are:

$$\lambda_{max}\ (\ q, q+1) = \ -T \ln\{1 - \hat{\lambda}\ _{q+1}\} \tag{5.2.3.2}$$

Rejecting the null hypothesis means that there is no cointegration relation among the variables ($r = 0$) and not rejecting the null hypothesis means there is the existence of one cointegrating relation between the variables ($r \leq 1$).

5.2.4. Vector error correction

In multivariate time series analysis, the VECM is one of the primary models used. ECM is the simplest univariate modelling used to determine the long-run relationship between the variables. ECM will be applied when a cointegration analysis is possible. The Error Correction Term (ECT) is used to measure the speed of adjustment to the equilibrium and is expected to be negative or convergent.

The regression equation form for VECM is as follows:

$$\Delta Y_t = \alpha_0 + p_1 e_1 + \sum_{i=0}^{n} \beta_i \Delta y_{t-i} + \sum_{i=0}^{n} \delta_i \Delta x_{t-i} + \sum_{i=0}^{n} \gamma_i Z_{t-i} + \zeta 1 i ECT_{t-1} + \varepsilon_{1t} \tag{5.2.4.1}$$

$$\Delta X_t = \alpha_1 + p_2 e_{i-1} + \sum_{i=0}^{n} \beta_i \Delta y_{t-i} + \sum_{i=0}^{n} \delta_i \Delta x_{t-i} + \sum_{i=0}^{n} \gamma_i Z_{t-i} + \zeta 2 i ECT_{t-1} + \varepsilon_{2t} \tag{5.2.4.2}$$

$$ECT_{t-1} = Y_{t-1} - b_0 - b_1 X_{t-1}\ , \tag{5.2.4.3}$$

where α_0 and α_1 are constant and ECT is the error correction term. We use the stationary time series to formulate the VECM of the following form:

$$\Delta \ln CPI_t = \sum_{i=0}^{n} \beta_{11i} \Delta \ln CPI_{t-i} + \sum_{i=0}^{n} \beta_{12i} \Delta \ln NER_{t-i} + \sum_{i=0}^{n} \beta_{13i} \Delta \ln PPI\_US_{t-i} + \sum_{i=0}^{n} \beta_{14i} \Delta \ln RGDP_{t-i} - \zeta_{11} ECT_{1,t-1} + \varepsilon_{1t} \tag{5.2.4.4}$$

$$\Delta \ln NER_t = \sum_{i=0}^{n} \beta_{21i} \Delta \ln CPI_{t-i} + \sum_{i=0}^{n} \beta_{22i} \Delta \ln NER_{t-i} + \sum_{i=0}^{n} \beta_{23i} \Delta \ln PPI\_US_{t-i} + \sum_{i=0}^{n} \beta_{24i} \Delta \ln RGDP_{t-i} - \zeta_{21} ECT_{1,t-1} + \varepsilon_{2t} \tag{5.2.4.5}$$

$$\Delta \ln PPI\_US_t = \sum_{i=0}^{n} \beta_{31i} \Delta \ln CPI_{t-i} + \sum_{i=0}^{n} \beta_{32i} \Delta \ln NER_{t-i} + \sum_{i=0}^{n} \beta_{33i} \Delta \ln PPI\_US_{t-i} + \sum_{i=0}^{n} \beta_{34i} \Delta \ln RGDP_{t-i} - \zeta_{31} ECT_{1,t-1} + \varepsilon_{3t} \quad (5.2.4.6)$$

$$\Delta \ln RGDP_t = \sum_{i=0}^{n} \beta_{41i} \Delta \ln CPI_{t-i} + \sum_{i=0}^{n} \beta_{42i} \Delta \ln NER_{t-i} + \sum_{i=0}^{n} \beta_{43i} \Delta \ln PPI\_US_{t-i} + \sum_{i=0}^{n} \beta_{44i} \Delta \ln RGDP_{t-i} - \zeta_{41} ECT_{1,t-1} + \varepsilon_{4t} \quad (5.2.4.7)$$

$$ECT_{1,t-1} = \ln CPI_{t-1} + b_{11} \ln NER_{t-1} + b_{12} \ln PPI\_US_{t-1} + b_{13} \ln RGDP_{t-1} + c_1 \quad (5.2.4.8)$$

Eqs. (5.2.4.4-5.2.4.8) correspond to the components of the VECM. The coefficients β_{ji} are constants that represent a short-run relationship with the dependent variable and ζji denotes the speed of adjustment of each equation to equilibrium. The equation for $ECT_{i, t-1}$ is the cointegrating equation that enters the VECM. Lastly, b_{ji} are coefficients of the long-run relationships.

5.2.5. Engle–Granger causality test

The direction of causality has been captured utilising the Engle–Granger causality test articulated first by Granger (1981). The test involves estimating the following pairs of equations:

$$Y_t = \alpha_1 + \sum_{i=1}^{n} \alpha_i \Delta X_{t-i} + \sum_{j=1}^{m} \beta_j \Delta Y_{t-j} + \varepsilon_{1t} \quad (5.2.5.1)$$

$$X_t = \alpha_2 + \sum_{i=1}^{n} \gamma_i \Delta X_{t-i} + \sum_{j=1}^{m} \delta_j \Delta Y_{t-j} + \varepsilon_{2t}, \quad (5.2.5.2)$$

where ε_{1t} & ε_{2t} are uncorrelated white noise errors. The first equation implies at time *t*, the dependent variable (*Y*) depends on the past values of itself and that of the other independent variables (*X*). However, the second equation shows that at time *t*, the other independent variables (*X*) depend on the past values of themselves and of the dependent variable (*Y*).

6. ESTIMATED RESULTS

6.1 Unit root test

The results from the unit root test using both the ADF and PP tests reveal that none of the variables are stationary at the level (Table 2). However, all the

variables are stationary at the first difference, i.e. $\Delta\ln CPI \sim I(1)$, $\Delta\ln NER \sim I(1)$, $\Delta\ln PPI\_US \sim I(1)$ and $\Delta\ln RGDP \sim I(1)$. This implies that all the variables are integrated of order one, i.e. I(1). The unit root results are presented in Table 2.

Table 2: Unit root analysis

	Level, I(0)		First difference, I(1)	
Variables	**ADF**	**PP**	**ADF**	**PP**
lnCPI	0.01	4.58	-3.51***	-6.32***
	[0.95]	[1.00]	[0.01]	[0.00]
lnNER	-5.67	-3.48	-3.50***	-6.81***
	[0.07]	[0.05]	[0.01]	[0.00]
lnPPI_US	0.47	0.36	-4.14***	-4.03***
	[0.98]	[0.98]	[0.00]	[0.00]
lnRGDP	-0.00	-0.00	-5.21***	-6.29***
	[0.95]	[0.95]	[0.00]	[0.00]

Note: The numbers in the parentheses indicate the *p*-value. Note: ***$p < 0.01$ denotes significance at the 1% level, **$p < 0.05$ denotes significance at the 5% level, *$p < 0.10$ denotes significance at the 10% level.
Source: Authors' estimation.

6.2. Engle–Granger two-step cointegration

One approach to examine the cointegrating relationship among variables is to use the Engle–Granger two-step procedure (Engle & Granger, 1987). The ADF test of the residual of the long-run equation confirms the long-run cointegrating relationship among the variables. The coefficient of the nominal exchange rate is statistically significant.

The long-run coefficients in Table 3 offer important insights into the inflationary dynamics of Bangladesh. The nominal exchange rate (ln*NER*) has a statistically significant negative coefficient of -0.89, indicating that a 1% depreciation of the domestic currency is associated with a 0.89% increase in the *CPI*. This high pass-through effect suggests that exchange rate movements have strong inflationary consequences in the long run. The positive and significant coefficient of *PPI* confirms that rising global producer prices – representing external cost shocks – also exert upward pressure on domestic inflation. The coefficient of *PPI* is 0.49, indicating that in the long run if the import price rises by 1 per cent, the domestic

price level will increase by 49 per cent. Furthermore, the coefficient of *RGDP* (1.13) indicates that domestic output growth is positively associated with price levels, likely reflecting demand-side inflationary effects.

Table 3: Engle–Granger two-step cointegration

Dependent variable: lnCPI							
Long-run cointegration				**Short-run dynamics**			
Variables	**Coefficients**	**t-statistics**	***p*-value**	**Variables**	**Coefficients**	**t-statistics**	***p*-value**
C	-22.64***	-10.91	0.00	C	0.05***	9.36	0.00
lnNER	-0.89***	-9.63	0.00	D(lnNER)	0.03	0.28	0.78
lnPPI_US	0.49***	3.67	0.00	D(lnPPI_US)	0.17**	2.10	0.04
lnRGDP	1.13***	13.69	0.00	D(lnRGDP)	0.32***	3.70	0.00
				U(-1)	-0.26**	-2.90	0.01

Residual unit root test: ADF		
	***t*-statistic**	***p*-value**
U	-5.73***	0.00

Diagnostic tests			
	***F*-Stat**	**n*R^2**	**Prob. *F***
LM test	0.12	0.28	0.89
BPG test	2.59	7.00	0.07

Note: LM test – Lagrange multiplier test; BPG test – Breusch-Pagan-Godfrey test**.**
Source: Authors' estimation.

The results from the error correction model of the long-run equation show that the error correction term is negative, less than one in absolute value and statistically significant. Therefore, any deviation from the long-run equation will be corrected in the subsequent periods. The speed of adjustment of -0.26 indicates that about 26% of any short-term disequilibrium is corrected in each period. Therefore, it will take significant time to restore the equilibrium. The short-run exchange rate elasticity of domestic price is insignificant. However, domestic prices will adjust with the changes in import prices and real GDP to get back to the equilibrium. The diagnostic test results reveal that the estimated model is not serially correlated and does not have a heteroscedasticity problem.

The findings underscore the vulnerability of Bangladesh's inflation to both external and internal shocks. The strong long-run ERPT suggests that persistent currency depreciation could erode purchasing power and fuel inflation.

Policymakers should therefore adopt measures that stabilise the exchange rate and manage import price volatility – such as diversifying trade partners or using hedging mechanisms. Additionally, monetary policy should account for domestic demand pressures when targeting inflation. The adjustment speed of 26% also implies that policy responses to inflation shocks should be proactive rather than reactive, given the gradual nature of price correction over time.

6.3. Johansen and Juselius cointegration

The Engle and Granger (1987) cointegration techniques have some shortcomings as they ignore the possibility of more than one cointegrating equation when more than two variables are included in the model. In contrast, Johansen and Juselius (1990) apply a multivariate approach to cointegration, in which more than one cointegrating equation can be identified. Hence, our study also employed the Johansen–Juselius cointegration test using both the trace statistic and the maximum eigenvalue statistic. The summary results of the Johansen and Juselius cointegration tests are given in Table 4. The value of both the trace statistic and maximum eigenvalue reject the null hypothesis of $r = 0$ (no cointegrating vectors) and $r \leq 1$ (at most one cointegrating vector), respectively, against the alternative hypothesis $r > 0$ (one or more cointegrating vectors) and $r > 1$ (two or more cointegrating vectors) at the 5% level of significance.

Table 4: Johansen and Juselius cointegration test

No. of cointegrating equations	Eigen-value	Trace	Critical value (trace)	Max. eigen statistic	Critical value (max. eigen statistic)
$r = 0$	0.71	57.02	47.86	39.29	27.58
$r \leq 1$	0.30	17.73*	29.80	11.23*	21.13
$r \leq 2$	0.18	6.50	15.50	6.18	14.26
$r \leq 3$	0.01	0.32	3.84	0.32	3.84

Note: The trace test indicates one cointegrating equation at the 0.05 level, * denotes rejection of the hypothesis at the 0.05 level, ** denotes MacKinnon-Haug-Michelis (1999) *p*-values.

Consequently, there is one cointegrating relationship in our model, as the trace statistic value for $r \leq 1$ is less than the critical value. Thus, the dependent and independent variables exhibit a long-run association.

6.4. Lag length selection criteria

The optimal number of lags in this paper is determined using various criteria, including the sequential modified LR test statistic, Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), and Hannan–Quinn Information Criterion (HQ). For lag selection, the lowest AIC and HQ values are preferred, as the lower the AIC and HQ values, the better fit the model is. The results are presented in Table 5.

Table 5: Lag length selection criteria

VAR lag order selection criteria						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	-26.61	NA	0.35	1.78	1.83	1.78
1	71.30	183.19	0.00	-4.47	-4.38	-4.44
2	74.92	6.53*	0.00*	-4.64*	-4.50*	-4.59*

Note: * Indicates lag order selected by the criterion

The majority of the lowest values across different criteria i.e., FPE, AIC, SC, and HQ, were found at lag length number 2. Therefore, we select two lags for our model.

6.5. Vector error correction estimates

As mentioned earlier, the Engle and Granger (1987) cointegration techniques possess limitations, particularly when more than two variables are involved, as they overlook the potential for multiple cointegrating equations in the model. To overcome this challenge, the Johansen-Juselius (1990) multivariate approach to cointegration was employed in our study, confirming the presence of one cointegrating vector among our variables. As there is evidence of one cointegrating equation in our model, we applied the VECM to our analysis to estimate both the long-run relationships and short-run dynamics. Table 6 provides a summary of the long-run cointegration equation results for the model. The empirical results indicate that all variables have their anticipated signs.

Table 6: Long-run VECM estimates

Variables	**Coef.**	**Std. Err.**	***z***	***p*-value**
LNNER	-.76***	.06	12.41	0.00
LNPPI_US	.87***	.10	-8.31	0.00
LNRGDP	.96***	.05	-18.31	0.00
$ECM_{1, t-1}$	-.18*	.10	-1.76	0.08
Diagnostic tests				
	Chi-sq	**p-Value**		
LM test	19.54	0.24		
Heteroscedasticity test: Harvey	182.13	0.44		
Normality/JB test	11.26	0.18		

Note:
a H0: No serial correlation versus H1: Serial correlation.
b H0: Homoscedasticity versus H1: Heteroscedasticity.
c H0: Normally distributed H1: Not normally distributed
LM test – Lagrange multiplier test; JB – Jarque–Bera normality test.
The numbers in parentheses indicate the *p*-values. ***$p < 0.01$ denotes significance at the 1% level, **$p < 0.05$ denotes significance at the 5% level, *$p < 0.10$ denotes significance at the 10% level.
Source: Authors' estimation using the VECM.

The long-run VECM estimates confirm a statistically significant and negative long-run relationship between *NER* and inflation (in the form of *CPI*), with a coefficient of -0.76 (Table 6). This suggests that a depreciation of one per cent in the nominal exchange rate in Bangladesh results in a 0.76 per cent increase in domestic prices, confirming a high but incomplete pass-through effect of the exchange rate on domestic prices. Notably, these results align with those obtained using the Engle–Granger two-step procedure, further supporting the observed incomplete pass-through effect. The strong positive coefficients for *PPI_US* (0.87) and *RGDP* (0.96) suggest that both imported inflation and domestic demand pressures are substantial long-run drivers of inflation, meaning an increase of one per cent in both the world import price and real GDP tends to raise the inflation rate by 87 and 96 per cent, respectively.

The validity of the model is checked through various diagnostic tests, including the Lagrange multiplier test for serial correlation, the Harvey test for heteroscedasticity, and the Jarque–Bera normality test. The results indicate the absence of serial correlation and heteroscedasticity in the residuals and demonstrate that the model conforms to the normal distribution.

Table 7: Short-run VECM estimates

C	ΔlnCPI	ΔlnNER	ΔlnPPI_US	ΔlnRGDP
0.04***	0.40**	0.22	-0.02	-0.1 4
[0.00]	[0.03]	[0.14]	[0.80]	[0.16]

Note: The numbers in the parentheses indicate the *p*-value. Note: ***$p < 0.01$ denotes significance at the 1% level, **$p < 0.05$ denotes significance at the 5% level, *$p < 0.10$ denotes significance at the 10% level.
Source: Authors' estimation using the VCEM.

The estimated results from the short-run VECM equation show that the error correction term is correctly signed, less than one in absolute value, and statistically significant (Table 7), suggesting convergence towards a long-run equilibrium following a disturbance. Specifically, the coefficient of the error correction term is -0.18, indicating that 18 per cent of errors are corrected annually to rectify any disequilibrium in the model. The relatively modest speed of adjustment implies that it will take more than 5 years to restore the equilibrium for any changes in the *NER*. The coefficient of the *NER* in the short-run VECM equation is statistically insignificant, thus implying that the nominal exchange rate does not influence domestic prices in the short run. Therefore, we can say *CPI* has a short-run effect in the model, but *NER*, *PPI_US*, and *RGDP* have an insignificant short-run effect in the model.

The relatively weak and statistically insignificant short-run effects of exchange rate changes on inflation can be attributed to price rigidities, delayed contract adjustments, and the structure of import transactions in Bangladesh. In the short term, many import prices are pre-determined through contracts, limiting the immediate transmission of exchange rate fluctuations to consumer prices. Moreover, administrative controls, subsidies, and inventory buffers often dampen short-run price responses. From a policy perspective, this suggests that while exchange rate changes may not trigger immediate inflationary responses, their cumulative impact materialises over time, underscoring the importance of

sustained monetary and fiscal coordination to manage long-run inflation risks. The long-run and short-run results carry several economic implications. First, the strong long-run pass-through suggests that sustained exchange rate depreciation can contribute significantly to inflationary pressures in Bangladesh. Second, the slow speed of adjustment implies that inflationary effects accumulate gradually, requiring forward-looking policy responses. Third, the short-run disconnect between exchange rate changes and inflation provides temporary policy space, but also necessitates caution to avoid long-run inflation spirals. Therefore, a stable and credible exchange rate policy, combined with coordinated inflation-targeting and trade strategies, is critical to price stability.

6.6. Robustness check: how valid are the results?

The model selected has demonstrated robust results, as confirmed by the previous tests. The unit root test indicates that all variables are integrated of the first order. Additionally, the Johansen and Juselius cointegration test identified one cointegrating equation, with trace statistics and maximum eigenvalue recorded at 17.73 and 11.23, respectively, establishing a long-run association among the variables. Furthermore, in the VAR lag selection process, all three criteria – the Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), and Hannan-Quinn Information Criterion (HQ) – converged on a lag length of two, as they yielded the lowest values of -4.64, -4.50, and -4.59 across all variables, confirming the appropriateness of the selection. All the diagnostic tests conducted, including the Lagrange multiplier test for serial correlation, the Harvey test for heteroscedasticity, and the Jarque-Bera normality test, confirm the absence of serial correlation and heteroscedasticity in the residuals, indicating that the model conforms to a normal distribution. Additionally, the impulse response function and variance decomposition tests were performed to further validate the model's robustness.

6.7. VEC Granger causality

The Granger (1969) causality test examines the short-run causal relationships among the four variables employed in the regression equation. The null hypothesis is that *X* does not Granger-cause *Y*, while the alternative hypothesis is *X* does Granger-cause *Y*. The result of the test is given in Table 8.

Table 8: VEC Granger causality

	ΔlnCPI	**ΔlnNER**	**ΔlnPPI_US**	**ΔlnRGDP**
ΔlnCPI		1.42	4.74*	1.33
	–	[0.49]	[0.09]	[0.52]
ΔlnNER	2.27		4.93*	6.61**
	[0.87]	–	[0.09]	[0.04]
ΔlnPPI_US	5.97*	5.54*		5.28*
	[0.05]	[0.06]	–	[0.07]
ΔlnRGDP	4.63	0.78	12.11***	
	[0.10]	[0.68]	[0.00]	–

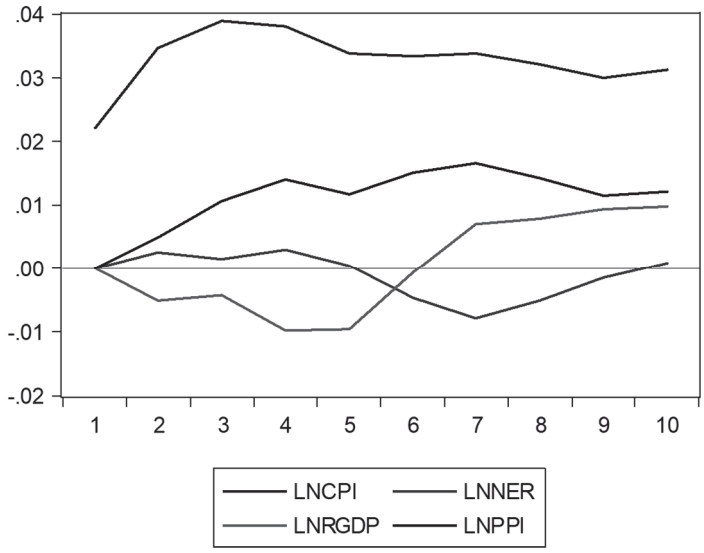
Note: The numbers in the parentheses indicate the *p*-value. Note: ***$p < 0.01$ denotes significance at the 1% level, **$p < 0.05$ denotes significance at the 5% level, *$p < 0.10$ denotes significance at the 10% level.
Source: Authors' estimation.

The Granger causality test statistic reveals that *NER* does not Granger-cause the *CPI* and *RGDP* of Bangladesh but *CPI* and *PPI_US* have short-run bidirectional causality from ln*CPI*⟸⟹ln*PPI_US*. Moreover, nominal exchange rate change causes the import price of the product of the country to change. Similarly, import prices can also bring fluctuations in NER. Thus, there lies a short-run bidirectional causality from ln*NER* ⟸⟹ln*PPI_US*. Moreover, any changes in *RGDP* can influence both *NER* and *PPI_US*.

6.8. Impulse response function

The study uses impulse response functions (IRF) to trace the effect of shock on variables in the VECM model. The IRF results presented in Figure 4 show the response of *CPI*, *RGDP*, and *PPI_US* to a one-per-cent shock in the *NER*. The *CPI* increases for up to two quarters then starts to decline, but remains positive throughout the ten quarters. The *NER* responds positively at first, but after the fourth quarter begins to decline, continuing this trend for the remainder of the ten quarters. However, the response of the *PPI_US* to the shock remains positive, continuing to increase over the entire ten quarters. In contrast, *RGDP* is negative for up to six quarters and then becomes positive for the rest of the period. This further supports the view that pass-through to consumer prices in Bangladesh was relatively high.

Figure 4: Response of price indices to a shock in the NER



6.9. Variance Decomposition

The results of the variance decomposition show that in the short run (by the second quarter), a shock to *CPI* accounts for a 96.66 per cent variation of the fluctuations in the *CPI* but this influence steadily declines from the fourth to the tenth quarter (Table 9). Likewise, a shock to *NER* causes a 37 per cent fluctuation in *CPI,* with its impact rising over the ten quarters. Therefore, we can state that the CPI inflation in Bangladesh is significantly influenced by exchange rate fluctuations.

Table 9: Variance Decomposition

	2 quarters	4 quarters	6 quarters	8 quarters	10 quarters
lnCPI	96.66	90.45	87.65	84.67	83.91
lnNER	0.37	0.33	0.50	1.23	1.03
lnPPI_US	1.35	6.42	8.81	10.86	11.03
lnRGDP	1.62	2.81	3.04	3.24	4.03

The magnitude of the pass-through effects of the exchange rate in Bangladesh indicates that the fluctuations of the exchange rate on the trade balance may be quite large. Similarly, shocks from external global markets may have insightful implications for inflation and other economic activities. Consequently, the central bank may need to apply appropriate monetary policy responses to pass-through effects to ensure exchange rate and price stability and minimise economic fluctuations in the domestic market.

7. CONCLUDING REMARKS AND POLICY RECOMMENDATIONS

This paper sought to conduct an empirical analysis of the sensitivity of inflation to changes in the nominal exchange rate of Bangladesh using time series data from 1989 to 2022 to confirm the research hypothesis. The findings reveal that there is an existence of exchange rate pass-through to inflation in Bangladesh, which is confirmed by the Engle–Granger 2-step cointegration and VECM approaches. It implies that the exchange rate has a role in determining prices in the long run.

Currency devaluation typically benefits exports by lowering prices for imported goods in the destination country. Additionally, it tends to reduce imports due to increased costs of imported commodities. While depreciation appears advantageous for export expansion, it may also exert an upward pressure on domestic prices, potentially exacerbating inflation. This begs the question: would currency devaluation be prudent for Bangladesh? Results from the econometric model reveal that the exchange rate pass-through to domestic prices in Bangladesh is incomplete or near complete. Our findings are consistent with those of Islam et al. (2022) and Siddiqui et al. (2024). However, they differ from the results of Chowdhury and Siddique (2006), who found no significant evidence of exchange rate pass-through to domestic prices in Bangladesh. Moreover, the error correction term suggests that the adjustment period from a short-term deviation is more than 5 years.

Hence, it can be inferred that devaluation will indeed result in inflation, albeit with a less than one-to-one relationship. This implies that the increase in domestic prices will be proportionally lower than the extent of the devaluation. Such a scenario provides policymakers with some room when their objectives include promoting exports and remittances. Should exports and remittances

respond positively to devaluation, then a devaluation of the domestic currency in Bangladesh could prove beneficial for bolstering reserve levels, as devaluations are likely to stimulate export growth and make imports more expensive, thereby dampening import demand.

Prudent exchange rate management is essential for Bangladesh in formulating effective monetary policy rules and implementing inflation-targeting strategies. To enhance the competitiveness of the external sector, the central bank must adopt a well-calibrated monetary policy response to mitigate exchange rate pass-through effects. Rather than relying on frequent currency devaluation, the government should focus on strengthening the export base by diversifying its export basket, boosting export earnings, offering tax incentives on imports, adopting import substitution policies, and sourcing production materials from cost-effective markets. Establishing a robust foundation for the national currency is crucial to shield domestic consumers, particularly those in fixed, middle, and low-income brackets, from price shocks during economic disruptions. Simply devaluing the currency and providing broad import subsidies is not a sustainable development strategy; instead, it risks fuelling inflation and increasing unemployment over time. Therefore, a well-structured monetary policy is necessary to minimise exchange rate pass-through effects on inflation in Bangladesh.

While this study offers valuable insights into how exchange rate pass-through affects inflation in a small open economy such as that of Bangladesh, there are a few limitations that should be noted. First, although the dataset covers the period from 1989 to 2022 and is therefore fairly extensive, it still constitutes a relatively small sample size, which may affect the accuracy and reliability of the results, particularly when applying a VECM model. Second, the quality and availability of the data present some constraints. For instance, some key variables, such as import prices, had to be represented using broad indices, which may not fully reflect detailed sectoral or product-level changes. Third, potential endogeneity among key macroeconomic variables, such as exchange rates, inflation, and GDP, could bias results. Fourth, the model does not account for structural breaks or regime shifts during the sample period – such as the global financial crisis or the COVID-19 pandemic – that could influence the ERPT mechanism. Finally, as the analysis is confined to Bangladesh, the findings may not be generalised to other

economies with different monetary, trade, or inflation-targeting regimes. Exploring the relative importance of these factors in determining the pass-through to CPI would be an interesting topic for future research. Moreover, future researchers may consider examining the effect of import taxes, export duties, and interest rates on inflation and extend the analysis to a regional context, such as South Asian, Next Eleven (N-11), and Developing Eight (D-8) countries, using time series data.

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THE EFFECTS OF ENVIRONMENTAL PROTECTION AND SOCIAL SPENDING ON SOCIETAL WELL-BEING: PANEL EVIDENCE FROM SELECTED OECD COUNTRIES

ABSTRACT: *The increasing prominence of environmental protection reflects its integral role in shaping global economic and social agendas. As the consequences of human activity increasingly extend beyond financial implications to affect broader societal well-being, environmentally conscious policy design has become essential. In this regard, proactive environmental strategies are crucial not only for ecological sustainability but also for strengthening the overall quality of human capital. This study investigates the relationship between environmental protection efforts and human development through a panel data analysis of 15 OECD member states, from 2010 to 2021. The empirical findings reveal a long-term equilibrium relationship among the variables, with environmental protection expenditures contributing positively to improvements in the Human Development Index. Conversely, long-run coefficients for public expenditures on education and health appear to have a negative association with human development. Furthermore, causality tests indicate the presence of unidirectional causal links between the examined variables. Based on these results, the study offers policy insights that underscore the importance of effectively channelling resources toward environmental initiatives to support sustainable human development.*

KEY WORDS: *environmental protection expenditures, Human Development Index, panel cointegration test, panel causality test*

JEL CLASSIFICATION: Q56, I31, C23, C33

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1. INTRODUCTION

Human development is a key indicator of a country's social well-being, as individuals are considered the core elements and ultimate goal of a nation's development (United Nations Development Programme [UNDP], 2018). The Human Development Index (HDI) is a sophisticated metric that assesses performance in key aspects of life. The HDI is treated as a key indicator of economic performance and societal well-being, and it provides a broader understanding of individuals' quality of life and overall levels of well-being. As such, it goes beyond economic measurements and promotes a people-oriented development model (Banday & Kocoglu, 2023). The UNDP (2018) reports that despite significant global population growth in recent decades, the number of individuals with low levels of human development has declined considerably. In contrast, the number of individuals with very high levels of human development has increased considerably, and the population of this group has tripled.

The HDI deals not only with the growth and contraction of economies but also with the expansion or contraction of people's options (Fakhri et al., 2024; Javaid et al., 2018). The HDI is a statistical method that comprehensively assesses a nation's socioeconomic achievements. This index sheds light on the variation in human development among countries with the same per capita income. While this in-depth information provided by the HDI enables governments to shape policy development processes and design social policies in line with the needs of society (Vıcıl & Konukman, 2022), it also focuses on countries' key social and economic indicators, such as health, education, and living standards (Linhartová, 2020; Omodero, 2019). It transforms the minimum and maximum values of these indicators into a scale of 0 to 1 with a geometric mean and divides countries into four categories in terms of human development levels: very high (HDI above 0.800), high (HDI from 0.700 to 0.799), medium (HDI from 0.550 to 0.699), and low (HDI below 0.550) (UNDP, 2020). A critical update was made to the HDI calculation methodology in 2010. Since then, the education component of the HDI has been redefined using broader indicators, prioritising metrics such as the mean and expected duration of schooling, rather than such earlier measures as adult literacy or school enrolment rates (Gulcemal, 2020). This methodological change provided a more detailed and broader perspective on educational quality and access, allowing for a more accurate assessment of countries' educational performance. Therefore, it is significant to consider the post-2010 period in this

study in terms of updated and comparable HDI data. This innovation renders the education index component of the HDI more up-to-date and inclusive, thus reflecting the role of education in human development more effectively.

Whereas the HDI of OECD countries outperforms the world average and other regional groups, an analysis of average annual growth trends in different regions reveals that significant progress has been made in Asia and Africa. While HDI disparities are decreasing at the global level, factors such as the 2008–2009 global economic crisis, infectious diseases, and regional conflicts have slowed this improvement process (Vıcıl & Konukman, 2022). These and similar global and regional barriers remain key challenges to HDI progress.

It is essential to consider the impact of public expenditures in key areas such as health, education, and the environment when addressing the relationship between economic models and human development. Attaining sustainable development requires that investments in these fields be strategically guided to foster not only economic advancement but also societal well-being and environmental preservation. While health and education expenditures directly affect human capital development (Agu et al., 2024), environmental expenditure is critical for protecting the quality of life of future generations (Fakhri et al., 2024).

Since the 1990s, the protection and improvement of environmental quality have become an increasingly significant policy area (Fendoğlu & Konat, 2023). Environmental protection expenditure (EPE) refers to the allocation of financial resources by the public and private sectors to prevent, reduce, and eliminate environmental externalities (Barrell et al., 2021; Broniewicz, 2011; Eurostat, 2017). EPE covers a variety of direct environmental protection activities, such as waste management, wastewater treatment, air pollution control, and noise abatement, but it does not directly include investments in the management of natural resources (Soukopová & Struk, 2011). Nevertheless, the level of expenditure alone is not a sufficient indicator of environmental performance; it is influenced by multiple factors, and that higher expenditure does not necessarily lead to better environmental outcomes (Barrell et al., 2021; Georgescu & Cabeça, 2010; Onofrei et al., 2020). However, negative externalities arising from environmental problems limit the efficiency of market mechanisms, making EPE

a central instrument for the success of environmental policies (He et al., 2018). In fact, environmental expenditures within the scope of CEPA (classification of environmental activities and expenditure) 2000 may have indirect effects on key aspects of the HDI – namely health, educational outcomes, and living conditions – highlighting the role of strategic public spending in enhancing human development (Biggeri & Mauro, 2018). Thus, environmental protection may contribute to the comprehensive development of countries by integrating the three core components of the HDI. However, it remains unclear whether EPE is a factor that directly affects human development. In this respect, this study examined the impact of EPE on HDI through cleaner air and water, waste management, and biodiversity conservation. This will allow us to better understand the role of environmental finance in human welfare and will contribute to shaping policies in this area. Moreover, government education and health expenditures are included as explanatory variables in our analysis.

This paper is structured as follows: Section 2 outlines the relevant literature. Section 3 explains the econometric approach, including discussions on cross-section dependence, unit root testing for panel data, homogeneity assessments, and cointegration analysis. Section 4 reports the empirical results, describes the data, and explains the implementation process. Lastly, Section 5 provides the concluding remarks.

2. LITERATURE REVIEW

While the literature has intensively examined the relationship between EPE and economic growth, studies on the relationship between EPE and HDI components are relatively limited. Accordingly, Young et al. (2012) examined EPE in Brazil between 2003 and 2010 and its relationship with the HDI through correlation analyses. The study's findings indicated that EPE decreased at the federal level but increased at the state level. Furthermore, a positive relationship was found between EPE and the HDI. In this context, a panel cointegration analysis conducted by Tomić et al. (2025) on 15 European countries from 2014 to 2021 found that EPE supports both economic growth and sustainable development. The study revealed that these expenditures increase not only per capita income but also reduce the green GDP gap, highlighting their significance for both classical growth targets and environmental sustainability goals. In their study, Edeme and Nkalu (2019) analysed the distribution of government expenditure

among various policy areas, including education, healthcare, agriculture, rural infrastructure, water management, energy supply, housing, and environmental initiatives, on the HDI. They used a fixed effects panel regression model based on data from 20 Nigerian states for the period 2007–2017. The study revealed that directing public resources towards improving basic services, such as educational opportunities, medical support, food production, local infrastructure, and access to clean water, tended to yield greater benefits for human development. In contrast, budgetary emphasis on such sectors as power supply, housing programmes, and ecological measures showed relatively weaker contributions. Interestingly, spending on environmental protection displayed a negative correlation with the HDI in this context. Edeme (2023) examined the effects of environmental protection and R&D expenditures on health-adjusted life expectancy in 40 countries with various levels of human development between 2000 and 2019 using a fixed effects panel regression model estimated with robust standard errors. The results revealed that environmental protection and R&D expenditures have a positive and statistically significant interaction with health-adjusted life expectancy. These findings suggest that EPE has the potential to indirectly improve life expectancy, a key component of the HDI. As a final contribution to this line of inquiry, Fadly and Edward (2023) explored how subnational fiscal allocations influenced human development outcomes over the 2007–2021 period, focusing specifically on the Indragiri Hilir district located in Indonesia's Riau province. While revealing these differential effects among the various functions of government expenditure, their study showed, using the Error Correction Model (ECM), that overall, government expenditure had no significant ameliorative effect on the HDI. The study also found that education, health, and infrastructure expenditure did not have a significant impact on HDI. Nevertheless, it was observed that environmental protection-related spending tended to contribute favourably to improvements in human development outcomes, whereas allocations made under social protection categories appeared to coincide with a decline in HDI performance.

Since existing research provides limited insight into the variables considered in this study, the effects of EPE on the HDI are evaluated under three primary dimensions: physical well-being, educational access, and quality of economic conditions. These dimensions correspond to the fundamental components of human development. Studies examining the impact of education and health

expenditures on the HDI are also included in this literature review. In this context, Wiratmoko and Purwanti (2023) examined how government spending in sectors such as health, education, housing, public infrastructure, and social protection affected the HDI in Indonesia during the 2008–2021 period, utilising multiple linear regression. Their analysis showed that public expenditures on education and social protection had a positive and significant effect on human development, while health spending was negatively associated with the HDI. In a separate 2017 study, Pahlevi used panel data to examine how institutional quality and public outlays on healthcare and education influenced human development outcomes in 33 Indonesian provinces from 2008 to 2012. Her study explored how public investments in the health and education sectors affect human development, while also considering the mediating influence of institutional quality in this relationship. In this respect, expenditures on governance and education were found to have a positive effect on HDI, while expenditures on health had a negative effect on HDI. Lantion et al. (2023) examined the effects of government expenditure on education and health and their impact on the HDI in five Southeast Asian countries – the Philippines, Thailand, Malaysia, Indonesia, and Singapore – from 2000 to 2019. Their analysis, using the panel least-squares method, revealed that education expenditure had a significant and positive effect on HDI. However, the effect of health expenditures on the HDI was not statistically significant. Miranda-Lescano et al. (2023) empirically analysed the effects of central and local government expenditures on the HDI using a sample covering 57 countries from 2000 to 2018. The study focused on the effects of public expenditures on health and education on the HDI and its dimensions. Their findings confirmed a positive effect of health expenditures on the overall HDI, whereas education expenditures showed a positive effect only on the education dimension. Fadilah et al. (2018), analysing data from East Java for the 2010–2015 period, found that increased public funding for the health and education sectors was positively associated with improvements across the key dimensions of human development. Finally, Özdoğan Özbal (2021) analysed the effects of higher education expenditures and participation rates on the HDI and national income per capita in 29 OECD countries between 1995 and 2018, using the panel vector autoregression method. Their findings indicated that higher education participation and the HDI responded positively to an increase in higher education expenditure with a two-period lag.

Rahimi et al. (2022) analysed the effect of health expenditures on the HDI in 187 countries between 2005 and 2018, using a panel data regression method. The findings revealed that health expenditure had a positive and significant effect on the HDI in Europe, South America, Africa, and Oceania, but this effect was found to be negative and significant in Asia. In their 2021 study, Akbar et al. examined the bidirectional causality relationship between health expenditures and CO_2 emissions on the HDI in 33 OECD countries from 2006 to 2016. They concluded that health expenditures positively affect HDI, whereas CO_2 emissions negatively affect it. Bhowmik (2020) highlighted that health expenditures in India from 1990 to 2017 not only increased per capita GDP and literacy rates by reducing infant mortality but also raised the country's HDI level. Similarly, Craigwell et al. (2012) analysed health expenditures for 19 Caribbean countries for the period 1995–2007. Their study found a positive correlation between public expenditure on the health sector and the HDI. Alin and Marieta (2011) examined the relationship between health spending as a share of GDP, health system outcomes, and the HDI in EU countries. They determined that the HDI is positively associated with health spending and health outcomes, but not with spending efficiency. In the study, countries were categorised into three groups: those with a high HDI and high spending (e.g., the Nordic countries, Germany, France, and Italy); those with a low HDI and low spending (e.g., Bulgaria, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, and Slovakia); and those undergoing balanced adaptation (e.g., Belgium, Ireland, Portugal, Luxembourg, and Slovenia). However, some studies contend that the effect of health expenditures on the HDI is not always decisive. Prasetyo and Zuhdi (2013) reported that government expenditures on subsidies, transfers, education, and health were not effective in improving the HDI between 2006 and 2010 for 81 countries. Similarly, in their analysis covering 1990, 1997, and 2003 for 91 countries, Rajkumar and Swaroop (2008) found that the allocation of public resources to health, education, and infrastructure was not always significantly correlated with the HDI.

To conclude, studies analysing the impact of EPE on human development in a holistic and multidimensional manner are limited. Most existing research is limited to single country cases and focuses only on specific components of the HDI. This study aims to contribute to the existing literature by providing a more structured evaluation of the relationship between EPE and human development, utilising recent and comparable panel data from the post-2010 period.

Accordingly, the following section will discuss the dataset, variables, and econometric methodology in this study.

3. ECONOMETRIC METHODOLOGY

In the empirical section of the study, a series of econometric tests were conducted, including analyses for cross-section dependence, stationarity, panel cointegration, and long-term relationships, in addition to causality analyses to determine the direction of linkages among variables. This section provides an overview of the theoretical foundations of the methodological tools used in the analysis.

3.1 Cross-section dependency

Cross-section dependence analysis investigates whether a macroeconomic shock affecting one country in a panel also affects the other countries in the panel equally (Mercan, 2014). It is a crucial step for ensuring the validity of econometric analysis (Breusch & Pagan, 1980; Pesaran, 2004). The hypotheses for this analysis are formulated as follows:

H_0: There is no cross-section dependence among the units
H_1: There is cross-section dependence among the units

Some tests have been developed to investigate cross-section dependency (Güloğlu & İvrendi, 2010; Koçbulut & Altıntaş, 2016; Mercan, 2014). The Lagrange multiplier (LM) test developed by Breusch and Pagan (1980) assumes that the time dimension T is larger than the cross-section dimension N. This test has $\frac{N(N-1)}{2}$ degrees of freedom and a χ^2 asymptotic distribution. This is represented in Equation (1) below.

$$CD_{LM1} = T\sum_{i=1}^{N-1}\sum_{J=i+1}^{N}\rho_{ij}^2 \quad (1)$$

The CD_{LM} test, developed by Pesaran (2004), assumes that both the time dimension T and the cross-section dimension N are large. The test statistic is expressed as follows in Equation (2).

$$CD_{LM} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{J=i+1}^{N} (T\hat{\rho}_{ij}^2 - 1) \quad (2)$$

Pesaran's (2004) CD (cross-section dependence) method, suitable when the number of cross-section units exceeds the time span ($N > T$), is shown in Equation (3).

$$CD = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{J=i+1}^{N} \hat{\rho}_{ij}^2 \quad (3)$$

Another test developed by Pesaran et al. (2008) is the bias-adjusted LM_{adj} test. This test, showing that the mean and variance of $(T-k)\hat{\rho}_{ij}^2$ are also included in the calculation, is formulated as shown in Equation (4).

$$LM_{adj} = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{J=i+1}^{N} T\hat{\rho}_{ij} \frac{(T-k)\hat{\rho}_{ij}^2 - \mu_{Tij}}{\sqrt{v_{Tij}^2}} \quad (4)$$

The hypothesis obtained from the tests determines the unit root test method to be applied. Accordingly, the acceptance of hypothesis H_0 means that there is no cross-section dependency between the units. This result implies that the analysis should continue with the first-generation unit root tests. Rejecting hypothesis H_0 implies that there is cross-section dependency between the units, and this result indicates that the analysis should continue with second-generation unit root tests (Baltagi, 2008).

3.2 Panel unit root test

When selecting unit root tests for panel data analysis, the choice largely depends on the presence of cross-section dependence among the panel units (Yerdelen Tatoğlu, 2018). When cross-section independence is assumed, first-generation unit root tests are typically employed. However, when cross-section dependence is present, second-generation tests are more appropriate.

In this study, the detection of cross-section dependence required the use of a second-generation unit root test. Specifically, the cross-sectionally Augmented Dickey–Fuller (CADF) test was applied. The CADF test enhances the traditional ADF regression by including both the lagged differences and the cross-section

means of the series. It yields individual test statistics (CADF) for each unit, as well as an overall panel statistic (cross-sectionally Augmented Im–Pesaran–Shin [CIPS]) through aggregation across units (Pesaran, 2006). The CADF test is considered a robust choice for panel datasets, as it is appropriate regardless of whether the time series length is greater than the number of cross-section units or the opposite holds (i.e., $T > N$ or $N > T$). One of its strengths lies in its robustness, even when applied to datasets with relatively limited observations (Pesaran, 2006).

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + d_i \Delta \bar{y}_t + e_{it} \tag{5}$$

Equation (5) presents the CADF regression. Then, the critical values (Δy_{it}) representing the CADF test are calculated separately for three different cases: without constant ($y_{i,t-1}$), with constant ($\overline{y}_{t-1}$), and with constant-trend ($\Delta\overline{y}_t$). In practice, table critical values are determined based on 1%, 5%, and 10% significance levels, according to the size of T and N (Pesaran et al., 2008). The unit root test statistic for the panel as a whole was calculated using the CIPS test by averaging the unit root test statistics for each unit or cross-section. In the CIPS test shown in Equation (6), $t_i(N,T)$ is the CADF statistic for the i-th cross-section unit (Pesaran et al., 2008).

$$CIPS(N,T) = N^{-1} \sum t_{i=1}^{N} CADF_i \tag{6}$$

3.3 Homogeneity test

The homogeneity test is used to determine whether the slope coefficients in a cointegration relationship are consistent across cross-section units, that is, whether the βi parameters vary between different sections. Originally proposed by Swamy (1970), this approach was later refined by Pesaran and Yamagata (2008). The hypotheses of the test are as follows:

H_0: $\beta_i = \beta$, the slope coefficients are homogeneous.
H_1: $\beta_i \neq \beta$, the slope coefficients are not homogeneous.

Hypotheses for large samples: $\hat{\Delta} = \sqrt{N}\left(\frac{N^{-1}S-k}{2k}\right) \approx \chi_k^2$ (7)

Hypotheses for large samples(adj): $\hat{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}S-k}{v(T,k)}\right) \approx N(0,1)$ (8)

Pesaran and Yamagata's (2008) dual test approach was used to assess slope homogeneity.

3.4 Panel cointegration analysis

First-generation panel cointegration tests should be used in the absence of a cross-section dependency, while second-generation panel cointegration tests should be used in the presence of a cross-section dependency. In this context, the Westerlund (2007) panel cointegration test is a prominent second-generation test that can yield robust critical values at the end of the bootstrap process in the presence of cross-section dependency (Yerdelen Tatoğlu, 2018).

Westerlund (2007) developed four distinct panel cointegration tests within an error correction framework to evaluate long-term equilibrium relationships among variables: the Gt and Ga statistics are designed to capture individual-level heterogeneity across cross-section units, whereas the Pt and Pa statistics are appropriate when homogeneity across the panel is assumed (Yerdelen Tatoğlu, 2017).

Following the application of the above unit root and cointegration tests, the fully modified ordinary least squares (FMOLS) method, which is applicable to both homogeneous and heterogeneous models, was used to estimate the final deviation-free coefficient relationships between variables (Pedroni, 2001; Yerdelen Tatoğlu, 2018). The panel dynamic least squares (PDOLS) long-term coefficient estimator developed by Stock and Watson (1993) provides unbiased results by eliminating endogeneity and autocorrelation problems (Işık et al., 2017). The FMOLS method corrects for estimator biases in the estimators (Gülmez, 2015). The group-mean panel fully modified ordinary least squares (PFMOLS) method can be characterised by the following equation (Pedroni, 2001).

$$Y_{it} = \alpha_i + \beta X_{it} + \mu_{it} \quad (9)$$

$$X_{it} = X_{it-1} + e_{it} \quad (10)$$

In Equation (9), Y_{it} denotes the dependent variable, X_{it} indicates independent variables, and α_i denotes fixed effects. Since the error terms in Equation (9) are stationary, there is a long-run cointegration relationship between Y_{it} and X_{it} if Y_{it} is integrated of the first-order. β denotes the estimated long-run cointegration vector (Gülmez, 2015).

3.5 Panel causality analysis

Chang (2004) recommended the use of robust probability values in the case of cross-section dependency between units in the panel dataset. The Dumitrescu–Hurlin panel causality analysis is preferable in many respects: it accounts for cross-section dependency among the units in the panel, it may also be used when the time dimension is either smaller or larger than the cross-section dimension, and it can be used in unbalanced panel datasets (Dumitrescu & Hurlin, 2012). When performing a causality analysis, the focus is on the direction of the relationship between variables rather than on distinguishing between dependent and independent variables (Akyüz, 2023; Tarı, 2015). A causal relationship is said to exist if one variable can be accurately predicted by the current or past values of another (Akyüz, 2023; Yılmaz & Akıncı, 2011). This relationship can be either unidirectional (one-way) or bidirectional (two-way). In this test, the null hypothesis Ho states that there is no causality between variables. The alternative hypothesis is that causality exists in at least one cross-section (Gülmez, 2015).

4. ECONOMETRIC ANALYSIS

Data from 15 OECD countries[1] were used in the econometric analyses, the aim of which was to determine the effects of EPE on the HDI. EPE, which includes expenditures on waste management, pollution reduction, biodiversity and habitat protection, and research and development activities (IMF, 2019), is expected to have comprehensive effects. Therefore, using the HDI as the dependent variable in the study was deemed appropriate in terms of its effects on quality of life and longevity, literacy rate, children's rights, education, and standard of living (UNDP, 2020). Government health expenditure (GHE) and government

[1] The number of countries was determined based on the countries with relevant data and these are Denmark, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Poland, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom.

education expenditure (GEE) were also included in the study as explanatory control variables in the study.

4.1 Dataset

Panel data analysis is a comprehensive analysis method that integrates both time and cross-section dimensions. This technique provides more reliable estimates by increasing the number of observations and degrees of freedom, thus increasing the reliability of the analysis results (Baltagi, 2008). In this context, the cross-section dimension is larger than the time dimension ($N > T$) in the study, which examines the relationship between EPE, GEE, GHE, and the HDI in a data set of 15 OECD countries for the years 2010–2021. The specific variable names, their abbreviations, and their data sources are detailed in Table 1.

Table 1: Overview of variables included in the analysis

Variable name	Abbreviation	Source
Human Development Index	HDI	UNDP (2025)
Environmental Protection Expenditure	EPE	OECD (2025)
Government Health Expenditures	GHE	World Bank (2025)
Government Education Expenditures	GEE	World Bank (2025)

The research on the definitions and effects of the variables can be summarised through the following empirical model, as shown in Equation (11)[2].

$$HDI_{it} = c + EPE_{it} + GHE_{it} + GEE_{it} + e \quad (11)$$

4.2 Implementation

As an initial step, the presence of cross-section dependence among the units in the data set was assessed, as this is crucial prerequisite for selecting the appropriate econometric analyses (Pesaran & Yamagata, 2008). The null hypothesis for this purpose is: "H_0: There is no cross-section dependence." Identifying the correct dependence structure is essential because it determines whether first- or second-generation unit root tests will be used, which in turn

[2] The information provided in Equation (11) indicates the variables in the study and the method to be used. The subscripts given for the variables in the equation represent the *i* sections, or units, required for a panel data model, and *t* represents the time dimension.

ensures the consistency, efficiency, and robustness of subsequent analyses (Yerdelen Tatoğlu, 2017).

Table 2: Cross-section dependence test findings

Cross-section dependency test								
	HDI		EPE		GHE		GEE	
	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
Breusch-Pagan CD_{LM1} (1980)	976.344	0.000	597.011	0.000	535.682	0.000	318.823	0.000
Pesaran scaled CD_{LM} (2004)	59.0933	0.000	32.916	0.000	28.684	0.000	13.7201	0.000
Pesaran CD (2004)	31.0186	0.000	19.617	0.000	18.017	0.000	8.23713	0.000
Bias-adjusted scaled LM_{adj} Pesaran et al. (2008)	58.4115	0.000	32.235	0.000	28.003	0.000	13.0382	0.000

Note: ***$p < 0.01$, **$p < 0.05$, and *$p < 0.10$ indicate the statistical significance of the estimated coefficients.

The results presented Table 2 indicate the test statistics and corresponding *p*-values for the CD_{LM1}, CD_{LM}, CD and adjusted LM (LM_{adj}) tests. Based on the results ($p < 0.05$), the null hypothesis (H_0), which assumes no cross-section dependence among the panel units, is rejected. The statistical significance of these tests suggests that there is cross-section dependence in the data.

Based on the requirement for second-generation tests, Pesaran's CADF test and the corresponding CIPS statistic were applied to the dataset to examine the stationarity properties of the variables. The results of these tests are presented in Table 3. Both the CADF and CIPS methods are specifically designed to accommodate cross-section dependence.

Table 3: Panel unit root test results

Human Development Index (HDI)						
	t-bar	cv10	cv5	cv1	*Z*[*t*-bar]	*p*-value
Pesaran's CADF HDI	-1.913	-2.160	-2.280	-2.520	-0.651	0.257
Pesaran's CADF DHDI	-3.117***				-4.930	0.000***
	CIPS*	cv10	cv5	cv1		
CIPS	-3.117***	-2.160	-2.280	-2.520		
Environmental Protection Expenditure (EPE)						
	t-bar	cv10	cv5	cv1	*Z*[*t*-bar]	*p*-value
Pesaran's CADF EPE	-1.847	-2.160	-2.280	-2.520	-0.415	0.339
Pesaran's CADF DEPE	-3.394***				-5.914	0.000***
	CIPS*	cv10	cv5	cv1		
CIPS	-3.394***	-2.160	-2.280	-2.520		
Government Education Expenditure (GEE)						
	t-bar	cv10	cv5	cv1	*Z*[*t*-bar]	*p*-value
Pesaran's CADF GEE	-2.074	-2.160	-2.280	-2.520	-1.223	0.111
Pesaran's CADF DGEE	-3.290***				-5.541	0.000***
	CIPS*	cv10	cv5	cv1		
CIPS	-3.290***	-2.160	-2.280	-2.520		
Government Health Expenditure (GHE)						
	t-bar	cv10	cv5	cv1	*Z*[*t*-bar]	*p*-value
Pesaran's CADF GHE	-1.653	-2.160	-2.280	-2.520	0.274	0.608
Pesaran's CADF DGHE	-3.399***				-5.930	0.000***
	CIPS*	cv10	cv5	cv1		
CIPS	-3.399***	-2.160	-2.280	-2.520		

Note: ***$p < 0.01$, **$p < 0.05$, and *$p < 0.10$ indicate the statistical significance of the estimated coefficients.

In this study, stationarity in the series was investigated using unit root tests. For series that did not exhibit stationarity at the level, stationarity was achieved by

examining their first differences. In this study, the tests were applied to models exhibiting stationarity, with first differences used for any series that were not stationary at the level. The statistics in Table 3 provide information on the results for the CADF test at I(0) and I(1) levels, along with the CIPS test results calculated over the overall average of the panel. The test statistics and the probability values of the variables are also presented. According to the results of Pesaran's CADF statistics, none of the variables were stationary at their levels, i.e. I(0). However, stationarity was achieved at the first difference, that is, at I(1). The results of the CIPS test confirm these findings. As all variables are integrated of order I(1), their first differences are stationary; thus, the series are considered free of unit roots after differencing.

Assessing parameter homogeneity plays a critical role in selecting suitable methods for cointegration, causality, and related estimations. In this study, the Swamy S homogeneity test was employed to determine whether the slope coefficients exhibit homogeneity or heterogeneity across panel units (Yerdelen Tatoğlu, 2017). The outcomes of the test are reported in Table 4.

Table 4: Testing for slope heterogeneity

$\boldsymbol{DHDIit = \alpha + \beta_1 DEPEit + \beta_2 DGHEit + \beta_3 DGEEit + u}$		
	Delta	*p*-value
Δ	0.669	0.504
Δ_{adj}	0.905	0.365
H_0: the slope coefficients are homogenous.		

Note: $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.10$ indicate the statistical significance of the estimated coefficients.

According to the coefficient results and statistical information from the Swamy S test in Table 4, the probability was not significant at α = 0.01, 0.05, and 0.10, respectively. In such a case, the null hypothesis, H_0: the parameters are homogeneous, cannot be rejected. Since the null hypothesis, H_0: the series are homogeneous, was not rejected, the results of the Westerlund cointegration test are interpreted based on Panel_tau and Panel_alpha test statistics (Aydın, 2019; Doğanay & Değer, 2017).

In light of the presence of cross-section dependence identified in the data, we apply the Westerlund (2007) panel cointegration test, which uses a bootstrap procedure tailored to account for cross-section dependence (Yerdelen Tatoğlu, 2018). The results of the test are presented in Table 5.

Table 5: Westerlund cointegration test

Statistic	Value	*Z*-value	*p*-value	Robust *p*-value
Group_tau	-2.453	-2.811	0.003	0.135
Group_alpha	-3.501	2.672	0.996	0.023**
Panel_tau	-7.953	-2.176	0.015	0.083*
Panel_alpha	-3.323	0.581	0.719	0.038**

Note: ***$p < 0.01$, **$p < 0.05$, and *$p < 0.10$ indicate the statistical significance of the estimated coefficients.

Based on the Panel_tau and Panel_alpha cointegration test statistics in Table 5, a long-term cointegration relationship between the variables can be concluded on the basis of the robust *p*-values. The long-term coefficients of the cointegration relationship were obtained using the PFMOLS and PDOLS methods and are presented in Table 6. The validity of the results was tested using the Wald test.

Table 6: PFMOLS and PDOLS test results

	PFMOLS			PDOLS		
Dependent variable: DHDI						
Independent variables	Coefficient	*t*_statistic	Prob.	Coefficient	*t*_statistic	Prob.
DEPE	0.0124*	1.8180	0.071	0.0178**	2.1015	0.037
DGHE	-0.0029***	-2.9264	0.004	-0.0044***	-3.9769	0.000
DGEE	-0.0021**	-2.0125	0.046	-0.0007	-0.0011	0.476
Wald chi2(3)	98.47***			24.25***		
Prob. > chi2	0.000			0.000		

Note: ***$p < 0.01$, **$p < 0.05$, and *$p < 0.10$ indicate the statistical significance of the estimated coefficients.

Based on the panel-wide coefficient results from the PFMOLS and PDOLS tests, the coefficient for the EPE variable is positive and statistically significant at the 10% and 5% significance levels, respectively. In other words, a 1% increase in EPE

in the long run provides a 0.012% and 0.017% increase in the HDI across the panel[3]. In other words, it re-establishes equilibrium in the long run. This finding is consistent with the results of the studies by Young et al. (2012), Edeme (2023), Fadly and Edward (2023) and Tomić et al. (2025), all of which report positive and statistically significant effects of EPE on the HDI. The economic magnitude of this effect is limited, which can be attributed to three main reasons: (i) The effects of EPE on the HDI generally occur through indirect channels and with a delay; (ii) There are differences among OECD countries in terms of institutional capacity, implementation effectiveness and policy implementation; (iii) The relatively small share of the EPE in the public budget, combined with a ceiling effect due to the sample consisting of high-HDI countries, naturally leads to limited marginal improvements.

The negative and statistically significant coefficients obtained for the GHE and GEE variables are consistent with studies reporting similar results in the literature, particularly for health expenditures. Indeed, Wiratmoko and Purwanti (2023), Pahlevi (2017), and Rahimi et al. (2022) (Asian subsample) found a negative and significant effect of health expenditures on the HDI. Conversely, some studies have found no statistically significant effect for health expenditures (Lantion et al., 2023; Prasetyo & Zuhdi, 2013) and education expenditures (Prasetyo & Zuhdi, 2013). Possible reasons for this negative relationship include the long-term effects of these expenditures (lagged effects), inefficiency and targeting issues in resource allocation, the differential impact of expenditure components on the sub-dimensions of the HDI, and measurement limitations in the data set. The efficiency of education expenditures may be limited by a focus on current administrative expenses rather than on infrastructure investments or direct improvements in educational quality. Furthermore, since the returns on human capital from education investments are generally long-term, they have limited short-term impact on HDI indicators. Furthermore, the quantity-oriented nature of the education components of the HDI (average and expected

[3] The EPE data used in this study covers only a limited number of countries and a relatively short period; moreover, the EPE cannot be decomposed into its subcomponents. This may lead to relatively low coefficients. The findings should be evaluated within the context of the current data coverage and time period. Future studies with longer time series and a broader country coverage will be able to provide clearer and more comprehensive results regarding the magnitude of the effects.

years of schooling) may not fully reflect quality differences, leading to low or negative, and sometimes even insignificant, coefficients. The validity of PFMOLS and PDOLS test results was confirmed using the Wald statistic. Accordingly, the test results were found to be statistically significant. There is a cointegration relationship between the variables, and any departure from equilibrium leads to a return to equilibrium in the long run.

Table 7: Panel causality test results

Null Hypothesis – H_0		*F*_statistic	Prob.	Conclusion
DEPE does not Granger-cause DHDI		0.08071	0.7767	H_0 -Accepted
DHDI does not Granger-cause DEPE		3.43057*	0.0660	H_0 -Rejected
DGHE does not Granger-cause DHDI		0.57776	0.4484	H_0 - Accepted
DHDI does not Granger-cause DGHE		1.12866	0.2898	H_0 - Accepted
DGEE does not Granger-cause DHDI		0.13388	0.7150	H_0 - Accepted
DHDI does not Granger-cause DGEE		3.66082**	0.0500	H_0 -Rejected
DGHE does not Granger-cause DEPE		0.16870	0.6819	H_0 - Accepted
DEPE does not Granger-cause DGHE		0.17285	0.6782	H_0 - Accepted
DGEE does not Granger-cause DEPE		0.37820	0.5395	H_0 - Accepted
DEPE does not Granger-cause DGEE		8.22665***	0.0047	H_0 -Rejected
DGEE does not Granger-cause DGHE		1.66639	0.1988	H_0 - Accepted
DGHE does not Granger-cause DGEE		11.8275***	0.0008	H_0 -Rejected
Wald test	*F*-statistic (prob)	37.61081***	*(0.0000)*	
	Chi-square (prob)	112.8324***	*(0.0000)*	

Note: ***$p < 0.01$, **$p < 0.05$, and *$p < 0.10$ indicate the statistical significance of the estimated coefficients.

Table 7 presents the results of causality analyses that examine the relationships between the series without distinguishing between dependent and independent variables. This allows for discussion of the direction of variables. The findings show a unidirectional causal relationship from the HDI to EPE (HDI → EPE). This indicates that the HDI has a statistically significant explanatory effect on the EPE. Within the scope of the HDI components, the existence of this causal relationship is expected: developments in knowledge, healthy living, good standard of living, and similar, inherently affect environmental awareness and consciousness. Similarly, a unidirectional causality relationship was found from the HDI to GEE (HDI → GEE). Increasing standards within the framework of the HDI naturally lead to an increased emphasis on education, with parents with a

high level of education expected to prioritise good education and future opportunities for their children. Unidirectional causality from EPE to GEE (EPE → GEE) was observed, suggesting that increases in expenditures on environmental protection may lead to greater education expenditures, likely driven by rising living standards. Finally, a unidirectional causality relationship was found from GHE to GEE (GHE → GEE). These findings are consistent with the results of many studies in the literature, including those by Edeme (2023), Fadly and Edward (2023), Wiratmoko and Purwanti (2023), and Pahlevi (2017). The Wald test, which was used to test the causality relationship, also yielded statistically significant results (Urfalıoğlu, 2022).

EPE has been shown to have a significant influence on both the HDI and economic growth in the long run (Fendoğlu & Konat, 2023; Krajewski, 2016; Ladaru & Dracea, 2017; Yildirim et al., 2023). Rational implementation of EPE could improve health outcomes by providing clean water, food, and air, which directly and favourably impact the life expectancy component of the HDI (Cervantes et al., 2021; Ketenci & Murthy, 2018). Furthermore, sustainable environmental management can strengthen the quality of education and, thus, the educational component of the HDI by improving access to educational materials (Biggeri & Mauro, 2018). Moreover, spending on environmental protection can increase the GDP per capita by creating new jobs in sectors such as renewable energy and waste management. These associations demonstrate that environmental protection activities yield both ecological and socioeconomic benefits.

5. POLICY IMPLICATIONS

The findings of this study offer important insights into assessing the impact of EPE on human development from both fiscal policy and development economics perspectives. First, the positive and statistically significant long-run impact of EPE on the HDI demonstrates its strategic importance as a preventive public investment. Although environmental investments may not generate direct short-term revenue, they can enhance welfare through indirect channels such as reducing externalities, increasing labour productivity, and ensuring continuity in education. However, the findings also reveal that the economic magnitude of this effect is limited. This can be explained by the relatively small share of EPE in the

public budget, the long-term nature of the returns on these investments, and the subordination of such expenditures to political priorities.

Second, the negative coefficients of GEE and GHE in relation to the HDI suggest that simply increasing their quantity is not enough; instead, these expenditures need to be restructured for better effectiveness, targeting, and quality. This result supports the frequently discussed notion in the literature that "a quantitative increase does not translate into a qualitative improvement" and points to structural problems such as a lack of institutional capacity, corruption, incompetent hiring, or misplaced priorities. The fact that panel causality analyses do not show a direct and strong causal link between these expenditures and the HDI suggests that their current composition is reactive and insufficiently aligned with development goals.

Third, the obtained causal relationships – HDI → EPE, EPE → GEE, and GHE → GEE – are consistent with public choice and social investment chain theories. Increased welfare strengthens public demand for environmental protection, while environmental investments can contribute directly or indirectly to educational infrastructure and content. The impact of health expenditures on education expenditures can be explained by the capacity of healthy populations to benefit from higher-quality education systems. These multifaceted causalities suggest that integrated, rather than single-sector, approaches should be adopted in policy design. In conclusion, this study offers three key messages for policymakers: (i) Increase the share of EPE in the budget, but support this with effective institutional mechanisms and performance-oriented monitoring; (ii) Restructure education and health expenditures based on criteria of quality, targeting, and effectiveness rather than quantitative increases; and (iii) Implement integrated fiscal policies that consider the interplay of budget allocations across the environment, education, and health sectors. This approach will ensure that environmental sustainability and human development goals are aligned in the long term.

6. CONCLUSION

This study used panel data analysis to examine the impact of EPE on the HDI in 15 selected OECD countries from 2010 to 2021. The primary goal was to investigate the long-term relationship between environmental expenditures and

human development, as well as the direction of causality. Second-generation panel unit root, cointegration, and causality tests revealed a statistically significant and positive long-term relationship between EPE and the HDI, but a limited long-term relationship in terms of economic size. In contrast, the negative long-term coefficients for government education and health expenditures suggest that these spending categories did not support human development performance as expected during the study period.

This study makes several contributions to the existing literature by examining the EPE–HDI relationship within a holistic framework, specifically for OECD countries. It is one of the few studies to include both health and education expenditures in its model. In addition, the application of second-generation panel unit root tests (Pesaran CADF) and cointegration tests (Westerlund), taking into account cross-section dependence, along with the combined use of FMOLS and PDOLS methods for long-term coefficient estimation, and a Dumitrescu–Hurlin panel causality analysis, increased the reliability of the method and the robustness of the findings. The findings demonstrate that EPEs can be a strategic tool in the form of preventive public investment, but that time and institutional effectiveness are required for the full effects of these investments to become apparent.

This study has several limitations. First of all, the data set for the EPE variable is restricted to a limited number of countries, and the time period for all the countries included in the study is also short. Due to the limited number of countries and short time period, a large sample size was not feasible; therefore, the analyses were conducted with the available sample, and the results should be evaluated with these limitations in mind. Increasing the number of countries and the time period in the future will increase the sample size and increase the statistical power and generalisability of the analysis results. Furthermore, the EPE data cover total environmental expenditures and cannot be disaggregated at the sub-component level. This constrains the ability to examine the differential impact of specific types of expenditures on the HDI. Finally, the variables included in the model are macro-level, and additional factors such as institutional quality, income distribution, or regional differences are not included. The limited economic magnitude of the coefficients suggests that caution should be exercised when assessing the direct policy implications of the results.

Future research could yield more detailed results by incorporating subcomponents of EPE (such as waste management, air pollution prevention, and biodiversity protection) into the model. In addition, including factors such as institutional quality indicators and income distribution measures could provide a more comprehensive understanding in this regard. Furthermore, comparative analyses for different country groups or development levels would also offer more targeted implications for policy design.

Although the study's findings confirm the potential of EPE to support human development, the results should be interpreted cautiously due to the limited economic magnitude of the effects and the dependence of implementation success on institutional capacity. Accordingly, it is crucial for policymakers to gradually increase the share of EPEs within the budget while also implementing performance-oriented spending programmes and fiscal discipline mechanisms in the allocation of these resources. Moreover, they should restructure education and health expenditures based on quality, targeting, and efficiency rather than quantity. This approach would ensure that fiscal policy supports both environmental sustainability and human development goals.

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ACHIEVING SDG 3 IN AFRICA: THE ROLE OF INSTITUTIONS, THE ENVIRONMENT, AND SOCIOECONOMIC FACTORS

ABSTRACT: *With the year 2030 rapidly approaching, most African nations are facing difficulties meeting their sustainable development goal (SDG) commitments. "Good health and well-being", as outlined in SDG 3, continue to be high on the agenda of nations around the world. A number of factors, including weak institutions, deteriorating environmental conditions, and socioeconomic challenges, among others, have contributed to the difficulties that many sub-Saharan African (SSA) countries face in reaching SDG 3. This study therefore analyses the role of institutions and environmental and socioeconomic factors in achieving good health and well-being of 45 SSA nations from 1996 to 2018. Three estimators, pooled OLS, fixed effects, and system GMM, form the basis of our empirical findings. Our finding shows that human outcomes were negatively impacted by the deteriorating environmental quality. Furthermore, weak institutional frameworks explain the region's poor health outcomes. Concerning the socioeconomic factors, there is substantial statistical evidence linking rising income to better health outcomes. The region's health status improves once literacy and basic school enrolment increases. Furthermore, investing in infrastructure improves health outcomes through better energy and sanitation. Macroeconomic stability measured by low inflation and net official development assistance improves health outcomes. However, population growth and urbanisation contribute to SSA's poor health outcomes. The findings provide input into formulating sound health policies for attaining SDG 3.*

KEY WORDS: *income, governance, pollution, amenities, health outcome index*

JEL CLASSIFICATION: E02, E31, F43, I15, I25, O44

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1. INTRODUCTION

The United Nations approved the 17 Sustainable Development Goals (SDGs) in 2015 as part of its 2030 Agenda for Sustainable Development to promote peace and prosperity for people and the planet. Hence, the SDGs encourage sustainable development and address a variety of social, economic, and environmental issues facing countries worldwide. These goals are all essential to advancing human development in Africa, as they address poverty (SDG 1), improve health outcomes (SDG 3), boost education (SDG 4), decrease inequality (SDG 10), protect the environment (SDG 13), etc. The target of Goal 3 shares a close relationship with the targets of the other SDGs, much like the other goals. A case in point: targets 2.2 (stop all kinds of hunger and malnutrition) 4.1 (universal, free, and high-quality secondary education for everyone); 4.2 (high-quality child development in the early years); 4.7 (knowledge and skills for long-term growth and development); 5.2 (get rid of all kinds of public and private violence against women and girls); 5.3 (eliminate all harmful practices, including female genital mutilation), 5.6 (access to sexual and reproductive health and rights for everyone), 6.1 (access to drinking water), 6.2 (access to sanitation), 7.1 (access to cutting-edge energy services), 9.5 (improve scientific research/hire more people in R&D), 11.6 (air quality and waste control of cities), 13.1 (ability to withstand natural disaster), and 16.1 (curtail rate of violence and related deaths) (High-Level Political Forum, 2017). These interlinkages illustrate that advancements in health outcomes are contingent on social, economic, environmental, and institutional factors that are capable of advancing SDG 3 targets and indicators. Thus, SDG 3 is to ensure healthy lifestyles and promote well-being for people of all ages. With high rates of child and maternal deaths, communicable ailments, and non-communicable diseases (Ajide & Alimi, 2020; Alimi & Ajide, 2021; Alimi et al., 2022), this objective is especially important for Africa.

Over the past years, countries in sub-Saharan Africa (SSA) have had some of the worst health statistics in the world. In spite of progress toward the Millennium Development Goals (MDGs) in many SSA nations, health outcomes remain much worse than in the rest of the world (Otim et al., 2020). As reported by the World Health Organization (2015), the probability of a woman dying during pregnancy or childbirth is 1 in 3700 in the industrialised world, while it remains high in SSA nations at 1 in 38. Nonetheless, the global under-5 mortality rate decreased by 47% between 2000 and 2016, falling from 78 to 41 deaths per 1,000

live births (United Nations Children's Fund, 2018). Despite intervention from international agencies, progress toward the goal of lowering infant and maternal mortality and increasing life expectancy has been unimpressive. The World Health Organisation's statistics indicate that despite progress towards the MDGs, the region still faces significant challenges in combating communicable diseases such as HIV/AIDS, syphilis, tuberculosis, malaria, and hepatitis, and in reducing the mortality rates of mothers, babies, and young children (High-Level Political Forum, 2017). In light of the latest statistics, at an estimated 64 per 1,000 live births in 2020, SSA had the highest child mortality rate in the world in 2020, well above the rates in the Middle East and North Africa (MENA, 21 per 1,000), North America (18 per 1,000), East Asia and the Pacific (8.3 per 1,000), and the Organisation for Economic Co-operation and Development (OECD, 3.1 per 1,000) (United Nations Children's Fund, 2023). Likewise, in 2020, the region had the highest maternal mortality rate in the world, with 545 deaths per 100,000 live births, compared to 52 deaths in the MENA region, 29 deaths in East Asia and the Pacific, 17 deaths in North America, and 8 deaths in the OECD (United Nations Children's Fund, 2021). As well, life expectancy in SSA was 61.2 years in 2020, the lowest of any region, compared to that in the OECD at 80.7 years, North America at 78.7 years, East Asia and the Pacific at 74.3 years, and the Middle East and North Africa at 71.2 years (World Bank, 2022a). In addition, regional health spending per capita differs greatly. Statistically, SSA spends the least on health per capita (US$91), much lower than North America (US$11,982), the OECD (US$5,229), Asia (US$453), MENA (US$428), and the world average (US$1,276) in the year 2020 (World Bank, 2022b).

The above statistics suggest that environmental degradation, weak institutional frameworks, declining female child education, social inequality, and low income in SSA countries may hinder the 2030 Agenda's efforts to ensure quality health and well-being for all. Hence, the socioeconomic restrictions and the ever-changing health landscape in Africa provide substantial barriers to progressing towards SDG 3. At the same time, quality institutions, resilient socioeconomic elements, and a liveable environment are all crucial to making headway towards achieving the SDGs. All these factors have lasting consequences for the ability of individuals and the economy to ensure healthy living, such as a low child mortality rates and high life expectancy. This study, then, looks at how institutions, the environment, and socioeconomic factors affect human health in

forty-five SSA countries between 1996 and 2018. Moreover, the outcomes of this study will provide a deeper understanding of the health effects of institutions, environment, and socioeconomic factors not just for the region under study but also for other emerging economies with similar socioeconomic, institutional, and environmental features.

The following are ways in which this research adds to the current body of knowledge. First, primary school enrolment, literacy rate, fertility rate, access to clean water, better sanitation, access to reliable and modern electricity services, inflation rate, net official development assistance, urbanisation rate, and population growth are some of the important variables added to the empirical model in this study. We estimate these variables in a single model to assess their impact on health outcomes. Second, the study uses principal component analysis to create a single composite index for health outcomes that incorporates measures of life expectancy, child mortality, and healthcare expenditure together in a single metric. This would help validate the association between socioeconomic factors, institutional quality, environmental factors, and health outcomes, as well as allow us to calculate and identify the countries with the best aggregate health outcomes in the region (Alimi et al., 2022). Third, previous studies rarely consider the endogeneity problem in their empirical estimations. Thus, the dynamic system generalised method of moments (SGMM) is employed in this study to account for this widespread econometric concern. Finally, the results of this study will help policymakers in the SSA area fulfil the third target of the SDGs by forming effective institutional, environmental, and health regulatory frameworks that do not compromise the region's social values or current rate of economic growth.

Following the introduction, Section 2 reviews the literature. The third section outlines the methodology used to analyse the relationship between the variables of interest. The empirical findings are discussed in the fourth section, and the last part ends with some recommendations for public policy.

2. BRIEF LITERATURE REVIEW

Achieving SDG 3 in developing countries requires an understanding of the multifaceted factors of health outcomes. In spite of the gradual economic progress of SSA economies over the decades, the region still has the highest rates of child and maternal mortality and the lowest life expectancy in the world

(Birhanie et al., 2025). Studies reveal three broad categories of determinants of these health outcomes: institutional, environmental, and socioeconomic. This section reviews the theoretical and empirical literature on each sub-area to explain how these determinants affect indicators such as under-five mortality, life expectancy, and other related health metrics.

2.1 Socioeconomic factors and health outcomes

Socioeconomic factors such as income, poverty levels, education, and other developmental measures influence health outcomes in every economy. The theory of modernisation states that industrialisation leads to economic prosperity, which in turn leads to better health for people, such as lower child mortality and a higher life expectancy. It suggests that industrial progress enables access to better nutrition, housing, education, healthcare, and sanitation (Shen et al., 2008). Shen et al. (2008) noted that the idea resembles that of neoclassical growth theory, which similarly posits that learning and imitation in development reduce disparities in health outcomes between developed and developing countries. The authors stressed that the two theories view economic development as a force bringing developed and developing countries together through learning and imitation. Existing country-specific, cross-sectional, and panel studies show a strong and positive relationship between economic development and several forms of human health improvement, including low child mortality and increased life expectancy (Babones, 2008; Frey & Cui, 2016; Fuse & Crenshaw, 2006; Jorgenson & Rice, 2010; Moore et al., 2006; O'Hare et al., 2013; Pamuk et al., 2011; Shandra et al., 2011; Shen et al., 2008; Wang, 2014).

The class stratification theory further argues that social class differences are crucial: individuals in lower socioeconomic classes tend to have poorer health outcomes due to constrained access to healthcare and lower income (Dutta, 2002; Shen et al., 2008). Dutta (2002) observed that several studies show that socioeconomic class affects health in different countries. People from lower-class backgrounds typically experience higher mortality rates and shorter lifespans. Yet, society's socioeconomic class-health status association remains unclear. Shen et al. (2008) emphasise that the low incomes of impoverished individuals make them more susceptible to diseases and cause them to die earlier than their wealthier counterparts. However, it remains unclear if the income disparity between the rich and the poor at the national level directly affects their health.

Income inequality has become a contentious issue in health research. The association has been studied inconclusively. Rodgers (1979), Kaplan et al. (1996), Kennedy et al. (1996), Kawachi (2000), and Shen et al. (2008) supported the hypothesis; however, Daly et al. (1998), Gerdtham and Johannesson (2004), Jones et al. (2004), and Beckfield (2004) did not. These studies suggest that social class, financial capacity, social cohesion, and social democratic policies may improve the income inequality-health association (Subramanian & Kawachi, 2004).

Numerous studies identify low socioeconomic status as a major determinant of poor health, especially for maternal and child health outcomes. Avelino et al. (2025) conducted a systematic review of under-five mortality across Africa and found that poverty and low maternal education are consistently among the key drivers of high child mortality rates. They discovered that children born to poor families or to mothers with little or no education are more likely to die due to preventable diseases. These circumstances are most likely to manifest as a poor diet, inappropriate health-seeking behaviour, and the denial of access to healthcare, all of which, taken together, account for high rates of mortality. On the other hand, Fuchs et al. (2021) reported a positive impact on children's survival through improvements in mothers' education. This is because better-educated mothers are more likely to adopt healthy habits, seek necessary care, and receive immunisations, resulting in fewer child deaths. Avelino et al. (2025) confirmed that socioeconomic determinants, especially maternal education and income, are essential determinants of SSA child health inequalities. Using child malnutrition as an outcome variable, Meshach (2025) looked at health inequality in 15 SSA countries and found that higher rates of child malnutrition are linked to higher rates of poverty. On the other hand, higher GDP per capita and health spending are linked to lower rates of malnutrition.

Achana et al. (2024) tested the widely held assumption that women's autonomy always improves child survival by examining the links between women's level of autonomy and mortality in the Upper East Region of Ghana. With the application of bivariate and multivariate logistic regression on a database of more than 3,000 women participating in the Ghana Essential Health Intervention Programme, they established that secondary level of education was significantly related to infant mortality as well as under-five mortality. Maternal age was strongly related to neonatal, infant, and under-five mortality, and rural environment was strongly

related to decreased risk of neonatal and under-five mortality. However, the authors discovered that in comparison to mothers with least autonomy, infants of those who had moderate autonomy and high autonomy were significantly more likely to have died. The research concludes that women's autonomy was not an indicator of children's death. Odejimi et al. (2022) used the Physician-Coded Verbal Autopsy (PCVA) and Expert Algorithm Verbal Autopsy (EAVA) to estimate at national and zonal levels the causes of under-five mortality in Nigeria for the 2013–2018 period. Using data from the 2018 Nigeria Demographic and Health Survey (NDHS), the study indicated that 56% of neonatal deaths and 51.5% of deaths among children aged 1–59 months were boys. Approximately one-quarter of under-five deaths were neonatal, and 50% of these were within 48 hours of birth. Furthermore, 84% of under-five deaths occurred in the northern states, with neonatal infections such as sepsis and pneumonia accounting for nearly half of the neonatal deaths. Among older children (aged 1–59 months), malaria, diarrhoea, and pneumonia were the main causes of death.

Osborne et al. (2025) analysed socioeconomic and geographic disparity in infant mortality in Sierra Leone based on the 2008, 2013, and 2019 Sierra Leone demographic and health surveys. Longitudinal analysis revealed national decreases in Sierra Leone infant mortality rates from 111 to 77 deaths per 1,000 live births. The study, however, reveals persistent as well as widening inequalities along economic, educational, and geographic strata. Furthermore, they found that although inequalities based on maternal income and education have narrowed, rural-urban and provincial inequalities widened. Nwanze et al. (2023) conducted a meta-analysis of 48 studies with 8,139 references to estimate the factor determinants of infant mortality in Nigeria. The study showed how factors at the individual level (e.g. the mother's age and education), the interpersonal level (e.g. household income and cultural practices), the organisational level (e.g. health workforce and access to care), the community level (e.g. the environment), and the policy level (e.g. governance and national programmes) all affect infant mortality. It also shows that Nigeria has a very high infant mortality rate, regardless of its economic growth and health sector initiatives.

Furthermore, socioeconomic factors also affect life expectancy. In general, economic growth leads to better living conditions and healthcare, thereby extending people's lives. Ajide and Alimi (2020) found that health inputs and

income per capita significantly enhance life expectancy, whereas inadequate access to good-quality water and power diminishes it. Miladinov (2020) found that increased per capita income and decreased infant mortality rates contributed significantly to higher life expectancy at birth in five EU accession candidate nations (Macedonia, Serbia, Bosnia & Herzegovina, Montenegro, and Albania) from 1990 to 2017. Delavari et al. (2016) identified that food availability, the number of physicians per 10,000 individuals, GDP per capita, and the literacy rate statistically amplify life expectancy at birth in Iran. The link between total fertility rate and life expectancy was negative and statistically significant. However, the influence of urbanisation, CO_2 emissions, and the inflation rate on life expectancy was not significant. Wirayuda and Chan (2021) conducted a systematic empirical review of 46 studies published between 2004 and 2019 to investigate the influence of sociodemographic, macroeconomic, and health resource factors on life expectancy. Among the sociodemographic parameters, the infant mortality rate, the literacy rate, education level, socioeconomic status, population growth, and gender disparity significantly influence life expectancy. The principal macroeconomic indicators that exhibit a substantial relationship with life expectancy include gross domestic product, the Gini coefficient, income level, the unemployment rate, and the inflation rate. Health care resources, including facilities, the healthcare workforce, public health expenditure, mortality rates, smoking prevalence, pollution levels, and immunisation rates, also show a substantial association with life expectancy.

2.2 Environmental determinants of health outcomes

Past studies have questioned the link between economic development and health outcomes (Anand & Ravallion, 1993; Frey & Field, 2000). This is due to the fact that economic development, while enhancing human well-being, also carries negative externalities, such as a decline in environmental quality. While modernisation brings environmental improvement through technological progress, critics argue that it ignores negative externalities, such as pollution, which can counteract health gains (Ajide & Alimi, 2020; Alimi & Ajide, 2021; Alimi et al., 2022). As such, environmental degradation is a blind spot in classic economic development models. These criticisms align with dependency theory, which suggests that resource exploitation by core (developed) countries leaves peripheral (developing) nations with environmental harm and a weakened ability to invest in health and infrastructure. The theory examines how the dependence

of semi-peripheral and peripheral economies on core nations, which is prevalent among developing countries, impacts human well-being. Modernisation theory ignores this explanation. This theory states that core countries exploit the resources of peripheral and semi-periphery resources, thereby limiting their resources. Consequently, poor investment in education, sanitation, food, healthcare services and programmes, and other aspects of human welfare tends to exacerbate health burdens such as high child mortality and low life expectancy in dependent countries. Previous research used debt dependence and structural adjustment, a heavy concentration on inelastic export commodities, trade reliance, and foreign investment to measure dependency, with conflicting results (Frey & Cui, 2016; Frey & Field, 2000; Jorgenson & Burns, 2004; Jorgenson & Rice, 2010; Moore et al., 2006; York & Ergas, 2011).

Previous studies have found that both developed and developing countries suffer from environmental pollution-related health problems, but developing nations suffer more. For instance, the World Bank (2014) found that air pollution caused about 1 in 8 fatalities in developing countries. Neidell (2004) reported that carbon emissions significantly affect people with asthma in California, United States. Currie et al. (2009) revealed that carbon pollution negatively impacts the prenatal and postnatal health of infants in New Jersey, United States. Hansen & Selte (2000) determined that industries' small particulate matter (PM_{10}) emissions increase sick leave, which harms commerce and industrial performance in Oslo, Norway. Asiskovitch (2010) found that nitrogen dioxide emission indirectly affected life expectancy at birth and 65 years for men and women in 19 OECD nations from 1995 to 2005. Remoundou & Koundouri (2009) confirmed that environmental hazard exposure increases health risk. Sinha (2014) established a bi-causal link between child mortality and carbon emissions in India between 1973 and 2000. Ajide & Alimi (2020), Alimi & Ajide (2021), and Alimi et al. (2022) found that poor environmental quality causes low life expectancy and high infant mortality in SSA nations. However, Fayissa & Gutema (2005) discovered that the carbon emissions reduction that improved life expectancy in 31 SSA nations was insignificant.

Recent studies highlight that SSA bears a disproportionate burden of environment-related health problems. For instance, ambient and household air pollution have emerged as major killers of young children. Mlambo et al. (2023)

found that SSA suffers a high burden of disease and premature death attributable to environmental pollution, with children under five being especially at risk. They contended that the region's overall life expectancy decreases by 4–5 years on average due to chronic exposure to high levels of air pollution in early life. This aligns with global health assessments identifying pollution as a leading environmental cause of death. This means that without active intervention to curb air pollution (through cleaner energy and transport policies), rising pollution will continue to fuel excess child illness and mortality, which will undermine progress toward SDG 3.

Indoor air pollution is a particular concern in SSA due to widespread reliance on solid fuels for cooking. A recent systematic review by Lake et al. (2025) confirms that household use of solid biomass fuels significantly increases the risk of under-five mortality. Their meta-analysis of studies across African settings found that children living in homes cooking with wood, charcoal, or dung have about 30% higher probability of dying before age five compared to those in cleaner-fuel households. Additionally, evidence of ambient fine particulate matter ($PM_{2.5}$) exposure, though limited in Africa, suggests it is also associated with higher child mortality and respiratory infections. Okirie & Adesete (2024) show a negative relationship between rising greenhouse gas emissions (as a proxy for climate change) and life expectancy in SSA, indicating that climate change has begun to erode health gains. Other environmental determinants include water, sanitation, and hygiene conditions, which remain poor in many SSA communities. Inadequate access to clean water and safe sanitation leads to diarrheal diseases and other infections that drive up child mortality. Birhanie et al. (2025) confirmed that children from households with unimproved sanitation have a higher risk of dying before age five due to greater exposure to environmental pathogens.

2.3 Institutional determinants of health outcomes

The social democratic theory challenges the laissez-faire approach of modernisation theory. It emphasises state responsibility by promoting equitable access to healthcare, education, and social protection. This theory contends that government intervention, rather than pure market forces, is necessary to address health inequities (Palme, 1999; Shen et al., 2008). Modernisation theorists believe that the free-market economy creates social inequities that worsen the physical condition of the poor. Social-democratic philosophy encourages government

intervention in resource allocation to improve health in every economy. Research on developed countries cites such countries as Sweden, Finland, and Denmark as examples of well-established social protection plans, which combine community services and benefits based on residence with social insurance programmes (Shen et al., 2008). Palme (1999) argued that the strategy reduced social inequality and poverty, created jobs, and increased women's economic engagement. Past studies have measured state commitment using government spending on healthcare, education, infrastructure, social services and amenities, legal procedures, rule of law enforcement, and institutional quality. Moon & Dixon (1985) stated that a government's political will can enhance living standards, especially for low-income workers, by implementing strong social redistributive policies and increasing its budget for infrastructure development and social welfare programs.

Azfar & Gurgur (2008) also described how inadequate hospital institutional settings lower the quality of care delivered by healthcare providers. Giedion et al. (2001) divided poor actors' connections into three layers: doctor-patient, hospital-payers, and hospital-supplier. Health practitioners, patients, vendors, and hospitals mismanaged funds and engaged in corrupt practices. The first relationship involves a doctor neglecting patients or exploiting public property for private gain. In the second connection, the hospital falsifies fees, a common practice in underdeveloped countries transitioning to insurance and payment systems. The third, the hospital-supplier connection, explored how open bribery or hidden gifts might taint contract awards (Azfar, 2004). These dysfunctional relationships make healthcare services more expensive for the poor, leading to increased healthcare spending and child mortality and reducing life expectancy. Furthermore, Azfar & Gurgur (2008) reported instances in which the poor are unable to access healthcare. Patients may resort to bribery in order to receive healthcare services more quickly. This will raise end-user costs, reducing demand and worsening health outcomes. Theft of highly subsidised public pharmaceuticals, which are then sold at higher prices on private markets, leads to government income leakages. Most stolen medications deter households from using public health facilities. Sometimes doctors overcharge people for medications. The researchers also observed macro-level fraudulent acts, such as suppliers inflating commodity prices during procurements or public officials favouring huge investment projects to obtain kickbacks from participating private parties. Finally, health sector fraud encompasses absenteeism and the sale

of public positions for a fee. In rural locations, high absenteeism degrades service quality and health outcomes. The sale of positions also lowers performance, as it discourages health professionals from giving their utmost effort. Ultimately, these practices negatively impact health outcomes by raising healthcare costs and child mortality and reducing life expectancy.

Kaufmann et al. (1999) found that strong governance decreased infant mortality per 1000 births, increased income per capita, and improved literacy in 150 countries in the period 1997–1998. Gupta et al. (1999) observed that corrupt nations have high infant and child mortality rates. Gupta et al. (2000) found that 128 advanced and developing nations with higher levels of corruption experienced higher child and under-five mortality rates from 1985 to 1997. A study by Rajkumar and Swaroop (2008) showed that governance quality affected the efficacy of public health expenditure in reducing under-five child mortality in 91 nations in 1990, 1997, and 2003. Olafsdottir et al. (2011) established a strong correlation between governance and the under-five mortality rate, but only a marginal relationship with the quartile ratio, in 46 SSA nations. Farag et al. (2012) demonstrated that governance synergised with public health investment to reduce newborn and child mortality in 133 low- and middle-income countries between 1995 and 2006. Hu and Mendoza (2013) found, for 136 countries from 1960 to 2005, that public healthcare spending and governance affected child mortality. Ajide & Alimi (2020) discovered that institutional dysfunctions negatively impact SSA health outcomes. Furthermore, the findings of Alimi et al. (2022) indicate that good institutional frameworks are required to counteract the health consequences of poor environmental quality in SSA.

Ouedraogo et al. (2020), using a panel study of 45 SSA countries, found that the most relevant institutional dimensions for improving health outcomes are (in order of importance) rule of law, control of corruption, government effectiveness, voice and accountability, and political stability. These governance attributes promote stability and accountability in the health sector, enabling more effective delivery of health services and resources. However, the empirical analysis of Glynn (2022) observed that high levels of corruption are associated with worse health indicators, such as higher infant and child mortality and lower life expectancy. Corruption diverts resources from public health services and undermines trust in the system, exacerbating health inequities. Using data from

46 SSA countries, Sibanda et al. (2024) show that institutional quality significantly mediates the impact of health spending on child health. According to their analysis, robust governance and effective management of public funds translate higher healthcare expenditures into greater reductions in under-five mortality. Robust institutions allocate external health aid and public spending more efficiently, resulting in significant improvements in child survival. In contrast, where institutions are weak, even increased spending yields only marginal gains, and households often resort to out-of-pocket spending as a coping mechanism, with a limited overall impact on mortality. Using data from 15 West African countries, Kouadio & Njong Mom (2025) discovered that good governance increases the returns on health spending. They found that when governance scores rise, life expectancy goes up and infant and maternal mortality rates go down. The findings underscore that accountable institutions and good governance are critical drivers of better population health. Therefore, these studies demonstrate that attaining SDG 3 in Africa requires not only increased health spending but also the reinforcement of institutional frameworks to ensure transparent and effective resource utilisation.

The reviewed literature reveals a deep interrelated influence of institutions, environment, and socioeconomic factors on health outcomes in SSA, yet their findings remain inconclusive. Several studies have shown, for example, that socioeconomic and environmental policy and institutional setups are more robust in developed countries than in developing countries, which makes the detrimental impact of these factors on human health in the latter more pronounced. Evidence of the influence of socioeconomic, institutional, and environmental factors is necessary to improve health outcomes in developing nations such as those in SSA. The purpose of this research is to fill this gap in the existing literature. The literature reveals a dearth of African studies and the exclusion of most variables from the modelling framework. Few studies reflect the dynamic aspect of human health, and almost all ignore the high persistence of health outcomes. Hence, such sophisticated estimators as the difference generalised method of moments (GMM) or system GMM for dynamic studies, which are effective for a dependent variable with strong persistence, have not been frequently used. This study models SSA health outcomes using the system-GMM estimating approach and additional variables to gain a deeper understanding of health, socioeconomic, institutional, and environmental policy

frameworks. Lastly, new empirical contributions since 2020 have reinforced the need for a holistic approach, as they emphasise that improving health outcomes in SSA requires simultaneous progress in governance, environmental protection, and social development. It has therefore become empirically clear that achieving SDG 3 in Africa will depend on strengthening institutions (control of corruption, government effectiveness, and regulatory quality), safeguarding the environment (to reduce carbon pollution, ecological footprint, and climate-related health risks), and improving socioeconomic conditions (to tackle the root causes of ill-health).

3. DATA AND METHODOLOGY

The scope of the study spans the years from 1996 to 2018. Additionally, it selects at least 85% of 47 SSA nations based on the availability of data on important variables of interest. The necessary data were obtained from the World Bank's World Development Indicators (World Bank, 2022b) and Worldwide Governance Indicators (WGI) (World Bank, 2022c).

3.1 Data

Outcome variables

Health outcomes refer to the changes in an individual's or a group's health within an economy that result from a planned set of intervention programmes, regardless of their intended purpose. Intervention programmes may involve central authority or government agency laws, rules, and regulations; health services and policies; environmental policies to reduce environmental health-related disorders; and others. We measure health outcomes using health indicators. Health outcomes are commonly measured by mortality (length of life) and morbidity (burden of disease), with quality of life assessed separately or as influenced by morbidity and other factors (World Health Report, 2000). The length of life is a measurement of how long people live, with death before the age of 75 indicating an untimely demise. Life expectancy captures the length of life based on birth year, age, and other demographic parameters. Quality of life refers to people's subjective assessment of their physical, social and emotional wellbeing. Of particular importance here is how these relate to pregnant women and children under five years old. Infant mortality rates are employed. A country's under-five mortality rate indicates the likelihood of a child dying before

five. Intervention programmes that impact health outcomes also encompass healthcare expenditures. They serve as a catalyst for enhancing the health status of the population within an economy. Poullier et al. (2002a, b) separated healthcare expenditures into two categories: public and private. These expenditures on healthcare facilities and services contribute to an increase in life expectancy and a decrease in infant and child mortality rates.

Table 1: Principal component analysis (PCA) for health outcomes

Principal components	Component matrix			Proportion	Cumulative proportion	Eigen-value
	lep	*minf*	*hep*			
1st PC (*hout*)	0.5628	0.7512	0.3449	0.8680	0.8680	2.6041
2nd PC	0.5973	-0.0812	-0.7979	0.0958	0.9638	0.2874
3rd PC	0.5714	-0.6551	0.4944	0.0362	1.0000	0.1086

Note: PC– Principal component; *lep* –life expectancy; minf – infant mortality; *hep* – health expenditure; and *hout* (measure of health outcomes) – first PC of *lep*, *minf* & *hep*. Infant mortality is rescaled to follow the positive direction of life expectancy by subtracting its values from 1,000 to reflect infant survival rate.

We calculated health outcomes using principal component analysis. Infant mortality, life expectancy, and health spending compose the composite value. Sricharoen & Buchenrieder (2005:2) defined principal component analysis as "an indicator reduction procedure to analyse observed variables that would result in a relatively small number of interpretable components (groups of variables), which account for most of the variance in a set of observed variables". The method lowers series with highly correlated values into discrete principal components while retaining dataset information. This strategy also reduces the likelihood of a strong connection between the indices. To keep the common primary factors, Kaiser (1974) and Jolliffe (2002) employed the decisive criterion to estimate the eigenvalues. An eigenvalue greater than one indicates that the component should retain the principal component's fluctuation. Table 1 shows the PCA results, with the cumulative proportion of the three health indicators explaining 86.8% (eigenvalue 2.6041) of the total shocks in the main data. The summary statistics of health outcomes are reported in Table 2, with an average value of 0.0013, which indicates low health outcomes.

Table 2: Summary statistics of socioeconomic, environmental, institutions and health outcomes

Variables	Measurements	Mean	Std. Dev.	Max.	Min.	Obs.
Outcome variables						
hout	Health outcomes (index from PCA of *lep*, *minf*, & *hep*)	0.0013	1.479	5.061	-3.869	939
Environmental factors						
co2	Carbon emissions (kt per capita)	0.895	1.749	9.837	0.017	945
ecft	Ecological footprint (gha per person)	1.412	0.652	3.865	0.501	903
Institutional quality variables						
ccn	Control of corruption: estimate	-0.585	0.626	1.217	-1.813	945
ge	Government effectiveness: estimate	-0.707	0.605	1.049	-1.885	943
rqv	Regulatory quality: estimate	-0.647	0.602	1.127	-2.298	945
insq	Institutional quality	-0.645	0.569	0.912	-1.966	945
Socioeconomic factors						
incp	GDP per capita, PPP (current international $)	3985.5	5538.8	38790.9	348.85	931
pse	School enrolment, primary (% gross)	96.82	23.51	149.31	28.85	918
lr	Literacy rate, adult total (% of people ages 15 and above)	58.61	21.52	95	9.434	869
fr	Fertility rate, total (births per woman)	5.089	1.268	7.716	1.36	944

agws	People using at least basic drinking water services (% of population)	59.62	17.77	99.87	16.73	720
ais	People using at least basic sanitation services (% of population)	31.82	21.85	100	3.150	720
aelc	Access to electricity (% of population)	34.59	25.45	100	0.413	838
cpi	Inflation, consumer prices (annual %)	45.62	831.03	24411.0	-9.616	890
oda	Net ODA received per capita (current US$)	67.08	76.62	691.93	-11.97	940
urbr	Urban population (% of total population)	38.02	15.93	88.56	7.412	945
ppg	Population growth (annual %)	2.505	1.018	8.118	-2.629	940

Note: GDP – Gross Domestic Product; ODA – official development assistance; Max. – maximum; Min. – minimum; Std. Dev. – standard deviation; PCA – principal component analysis; and Obs. – observations. Control of corruption, government effectiveness, and regulatory quality are the governance indicators from the WGI project and are standardised on a scale from approximately -2.5 to +2.5, with 0 representing the global average. Negative values indicate governance quality below the global average. The average of the three governance series is taken to be the institutional quality.

Explanatory variables

Socioeconomic factors

A person's socioeconomic status is a combined economic and sociological measure of their work history, their personal or family's financial resources, and their social standing in comparison to others (Oakes & Rossi, 2003; Palta et al., 2015). Socioeconomic factors, such as money, education, work, neighbourhood safety, and social supports, can have a substantial impact on health and lifespan. These characteristics influence a person's capacity to make healthy decisions, afford medical treatment and housing, and manage stress, among other things. The following socioeconomic characteristics are considered in this study: income per capita, primary school enrolment, literacy rate, fertility rate, access to good water source, access to improved sanitation, access to electricity, inflation rate, net official development assistance, urbanisation rate, and population growth. Table 2 shows the mean values of GDP per capita, primary school enrolment, literacy rate, fertility rate, access to good water sources, access to improved sanitation, access to electricity, inflation rate, net official development assistance per capita, urbanisation rate, and population growth: US$3,985.5, 96.82%, 58.6%, 5.09, 59.62%, 31.82%, 34.59%, 45.62%, US$67.08, 38.02%, and 2.51%, respectively. Except for the fertility rate and the inflation rate, all the sampled socioeconomic factors are presumed to have a positive influence on health outcomes.

Environmental quality

Environmental quality is defined as the varied characteristics of maintaining a pollutant-free and healthy environment. These features involve steps or policy programmes that are formulated and put into practice to reduce or eradicate environmental pollution or degradation in a society. This is measured by carbon emissions (i.e., the total volume of emissions in the form of carbon dioxide per individual in a country) and the ecological footprint (i.e., the total amount of nature on earth consumed and the remaining amount of nature available). In Table 2, carbon emissions per capita averaged 0.895 kt, with the maximum and minimum values of 9.837 kt per capita (South Africa in 2009) and 0.017 kt per capita (Chad in 1996), respectively. According to Hafner et al. (2018), South Africa's energy use per capita exceeds the world average. Because of its heavy reliance on coal and its high energy use per capita, it has the highest rate of carbon emissions in Africa. The largest ecological footprint value is 3.865 gha per person

(South Africa in 2008), and the minimum is 0.501 gha per person (Eritrea in 2018). This highlights the close relationship between energy sources, carbon intensity, and ecological impact in the South African economy. Health outcomes are predicted to improve as a result of enhancements to environmental quality, as measured by the mitigation of factors contributing to poor air quality. People's increased energy consumption, especially from fossil fuels, leads to a deterioration in air quality, resulting in adverse health effects.

Institutional quality

Institutional quality refers to law, individual rights, and high-quality government regulation and services of an economy. North acknowledged that the imposition of "formal rules" or "informal constraints" on executive power enhances the institutional quality of an economy (as cited in Bruinshoofd, 2016). This evaluates a nation's laws to ensure that no individual violates another person's rights. The indicators are regulatory quality, government effectiveness, and control of corruption. Table 2 shows that government effectiveness (-0.707) had the lowest average values, followed by regulatory quality (-0.647), and corruption control (-0.585). The mean value of institutional quality is -0.645, indicating a declining African institutional environment. Better health outcomes directly correlate with robust institutions. If a country's institutions are robust, its citizens can expect a more equitable allocation of its wealth, which in turn means more money for health care. Similarly, it is hypothesised that a country's poor institutional frameworks contribute to wide income gaps, thereby limiting the government's capacity to provide universally high-quality healthcare for its population.

Table 3 displays the correlation matrix of the variables under study and demonstrates a direct relationship between health outcomes and environmental quality indicators. It reveals a positive correlation between health outcomes and institutional quality indices, income per capita, educational attainment, infrastructure, and urbanisation rate, in contrast to the negative correlations observed with fertility rate, inflation rate, and population growth. It is important to note that the correlation matrix also shows associations between the explanatory variables that have a role in determining health outcomes, albeit to varying degrees and magnitudes. Overall, the low correlation coefficients obtained indicate the lack of a multicollinearity problem. Furthermore, the results provide preliminary evaluations that will be confirmed in Section 4.

Table 3: Correlation matrix

	co₂	*ecft*	*ccn*	*ge*	*rqv*	*insq*	*incp*	*pse*	*lr*	*fr*	*agws*	*ais*	*aelc*	*cpi*	*oda*	*urbr*	*ppg*
hout	0.517	0.514	0.574	0.587	0.458	0.581	0.576	0.411	0.605	-0.781	0.601	0.613	0.753	-0.040	0.416	0.441	-0.334
co₂	1	0.726	0.325	0.438	0.322	0.387	0.754	0.154	0.516	-0.575	0.439	0.689	0.645	-0.007	0.068	0.488	-0.250
ecft		1	0.450	0.562	0.537	0.553	0.635	0.080	0.373	-0.569	0.528	0.567	0.528	-0.020	0.062	0.412	-0.303
ccn			1	0.828	0.710	0.911	0.220	0.189	0.352	-0.622	0.455	0.402	0.394	-0.059	0.416	0.119	-0.484
ge				1	0.861	0.962	0.298	0.246	0.374	-0.599	0.461	0.465	0.431	-0.042	0.226	0.151	-0.405
rqv					1	0.918	0.230	0.238	0.224	-0.431	0.414	0.341	0.284	-0.110	0.109	0.112	-0.291
insq						1	0.267	0.241	0.340	-0.593	0.475	0.431	0.399	-0.076	0.275	0.138	-0.424
incp							1	0.154	0.552	-0.531	0.409	0.709	0.713	-0.020	0.122	0.564	-0.129
pse								1	0.508	-0.446	0.335	0.227	0.187	-0.003	0.181	0.201	-0.163
lr									1	-0.689	0.372	0.595	0.519	0.044	0.211	0.352	-0.401
fr										1	-0.681	-0.634	-0.72	-0.017	-0.341	-0.417	0.620
agws											1	0.625	0.714	0.017	0.331	0.513	-0.523
ais												1	0.665	0.014	0.247	0.345	-0.388
aelc													1	-0.001	0.299	0.681	-0.401
cpi														1	-0.020	-0.008	-0.058
oda															1	0.258	-0.178
urbr																1	-0.044

Note: *hout* – health outcomes; *co₂* – carbon emissions; e*cft* – ecological footprint; *ccn* – control of corruption; *ge* – government effectiveness; *rqv* – regulatory quality; *insq* – institutional quality; *incp* – income per capita; *pse* – primary school enrolment; *lr* – literacy rate; *fr* – fertility rate; *agws* – access to good water source; *ais* – access to improved sanitation; *aelc* – access to electricity; *cpi* – annual growth of consumer price index; *oda* – net official development assistance; and *urbr* – urbanisation rate.

3.2 Model specification

Drawing on the empirical work of Azfar & Gurgur (2008), Currie et al. (2009), Asiskovitch (2010), Farag et al. (2012), Hu & Mendoza (2013), Wang (2014), Frey & Cui (2016), Ajide & Alimi (2020), and Alimi et al. (2022), among others, this study proposes the following empirical model that establishes the relationship among institutions, environment, socioeconomic factors, and health outcomes:

$$hout_{i,t} = \theta_0 + \Phi_i scf_{i,t} + \Pi_i envf_{i,t} + \Theta_i istf_{i,t} + e_{i,t}, \quad (1)$$

where *hout* denotes health outcomes; *scf* represents a vector of socioeconomic factors which consists of real per capita income (*inpc*), primary school enrolment (*pse*), literacy rate (*lr*), fertility rate (*fr*), access to good water sources (*agws*), access to improved sanitation facilities (*ais*), access to electricity (*aelc*), annual growth of consumer price index (*cpi*), net official development assistance (*oda*), urbanisation rate (*urbr*) and population growth (*ppg*); *envf* denotes environmental degradation which is a vector of carbon dioxide emissions (co_2) and human ecological demand on Earth measured by ecological footprint (*ecft*); and *istf* signifies institutional quality measured by three of the six WGI: government effectiveness, regulatory quality, control of corruption, and a composite institutional quality index (World Bank, 2021b) – the values of these indices range between -2.5 (weakest) and 2.5 (strongest). In line with established practices in institutional economics, this study unbundles institutional quality indicators rather than including them simultaneously in a single model. We justify this decision both theoretically and econometrically. In theory, each measure shows a different aspect of governance that may have various effects on health outcomes. Our correlation analysis shows strong pairwise correlations of over 0.7 between these indicators (see Table 3). Including them all would create multicollinearity, which would increase standard errors and make it harder to determine how each affects the outcome. This method is in line with earlier empirical research such as that of Kaufmann & Kraay (2002), Acemoglu & Robinson (2012), and Asongu & Nwachukwu (2016), which look at governance metrics separately to find out what each one does. The disturbance term is represented by e_i, while θ_0 is constant; Φ_i, Π_i, Θ_i are vector of parameters of socioeconomic, environmental, and institutional factors; and *i* and *t* denote country and time, respectively.

3.3 Estimation approach

This study uses pooled least squares, panel fixed effects, and panel system GMM developed by Arellano & Bond (1991) and Blundell & Bond (1998) to estimate the parameters in the model. To meet the given goals, we developed an empirical model that uses *t* (time series subscript) and *i* (country units) to represent the attributes of time series and cross-sectional data, respectively.

The empirical models are based on the following equation:

$$y_{i,t} = \alpha + Z_{i,t}^{'}\beta + \mu_{i,t}, \text{ where } i = 1,...,N;\ t = 1,...,T. \quad (2)$$

While β is a row vector $K \times 1$, the scalar is represented by α. The *i*th observation of the *K*- explanatory variables at distinct time *t* periods is represented by $Z_{i,t}^{'}$. The stochastic term is denoted by μ. Furthermore, the stochastic factors include two components: the unobserved country-specific impact (v_i), which accounts for individual effects that are not included in the regression model, and the idiosyncratic disturbance ($u_{i,t}$), which varies across countries and over time. Equation (2), rewritten, is as follows:

$$y_{i,t} = \alpha + Z_{i,t}^{'}\beta + v_i + u_{i,t}, \text{ where } i = 1,...,N;\ t = 1,...,T. \quad (3)$$

Panel fixed effects or random effects can be used to estimate the equation depending on (a) the distribution of the unobserved components and the error term and (b) the idiosyncratic disturbance process of the time series across nations. For the baseline model, we prefer the fixed effects strategy, as we did not randomly choose the data. The technique presumes that v_i is static, whereas the error term $u_{i,t}$ is assumed to be independent and identically distributed [IID($0, \sigma_v^2$)]. Furthermore, the explanatory variables do not depend on the stochastic terms for all countries (*i*) and times (*t*). The cross-weights are used to adjust for individual heteroscedasticity and serial correlation of error components, resulting in more efficient and consistent parameters.

In addition to its ability to mitigate endogeneity bias, panel system GMM was chosen for this investigation for five reasons: (a) The estimator solves problems with high persistence in dependent variables. The correlation coefficient between

the value and its initial lag must exceed 0.800 to identify persistent variables. In our case, the correlation coefficient of health outcomes and its first lag is 0.9974. (b) The estimation procedure is suitable for studies with more cross-sections (N) than time periods (T), such as $N(45) > T(23)$. (c) The method effectively manages the effects of regressor endogeneity. (d) The estimation does not eliminate cross-country variability. (e) The fourth benefit makes the system GMM of Arellano & Bover (1995) and Blundell & Bond (1998) fit better than the difference estimator of Arellano & Bond (1991) (Bond et al., 2001). The first two criteria are requirements for using the strategy, whereas the latter three are benefits (Tchamyou, 2020).

Since the panel dimension of the data is rather extensive, with 45 SSA countries covered for the period 1996–2018, there could be doubts about the need for unit root and cointegration tests. However, since the study uses the panel system-GMM estimator, these tests are not required. System GMM is specifically designed for dynamic panel models and performs well even with non-stationary variables by differencing the data and using internal instruments to handle endogeneity and bias. Moreover, the focus of this study is on estimating short- to medium-run dynamics and policy effects rather than long-run equilibrium relationships, which are usually the domain of cointegration-based approaches. Even though GMM is conventionally advised for short time panels ($T < 10$), we avoided complications from longer time dimensions by curbing instrument proliferation and enforcing rigorous diagnostic testing, such as the Hansen test for instrument validity and the Arellano-Bond test for serial correlation. In addition, we did not aggregate the data into non-overlapping intervals in order to preserve annual variation, which is crucial for identifying year-to-year changes in socioeconomic, institutional, and environmental factors relevant to SDG 3. This strategy ensured that our results are both methodologically sound and useful for making policy.

The method also solves the serious problem of weak instruments in difference-GMM when the dependent variable is highly persistent. The difference-GMM estimate's weak instrument makes point estimates and hypothesis testing inaccurate (Che et al., 2013; Stock & Wright, 2000; Stock et al., 2002;). Bond (2002) argued that system-GMM estimation always outperformed difference-GMM estimation. Heid et al. (2012) and Che et al. (2013) supported this claim.

Roodman's (2009) suggestion led to the validation of system GMM, as the number of instruments did not exceed the number of cross-sections. The study uses the two-step strategy because it controls heteroscedasticity in errors, unlike the one-step approach, which is homoscedastic. Equation (4) in levels and Equation (5) at first difference outline the system-GMM estimation procedure, following the baseline model:

$$y_{i,t} = \theta_0 + \theta_1 y_{i,t-\tau} + \sum_{h=1}^{n} \pi_h Z'_{h,i,t-\tau} + \lambda_i + \xi_t + \mu_{i,t} \quad (4)$$

$$y_{i,t} - y_{i,t-\tau} = \theta_0 + \theta_1 (y_{i,t-\tau} - y_{i,t-2\tau}) + \sum_{h=1}^{n} \pi_h (Z'_{h,i,t-\tau} - Z'_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + \mu_{i,t-\tau} \quad (5)$$

The series remains as stated earlier, where τ represents lag length in the dynamic specifications; $\theta_0, \theta_1, \pi_h$ are parameters, λ_i represents the country-specific effects, ξ_t is the time specific constant, and $\mu_{i,t}$ denotes the stochastic term.

Diagnostic tests

The study performed post-estimation tests to verify the parameters of the system-GMM estimation model. The study uses the AR(2) value to test for the presence of second-order serial correlation. If we do not reject the probability value of AR(2), we assume the existence of second-order autocorrelation. We also explored Sargan and Hansen's over-identification restriction (OIR) null hypothesis. Rejecting the null hypothesis implies the instruments used are invalid. The Sargan test provides results that are non-robust but less sensitive to instrument proliferation, whereas the Hansen test is robust, but its reliability diminishes when the number of instruments is excessively large. To resolve the incompatibility, the Hansen test is prioritised while ensuring that the number of instruments in each specification is smaller than the number of countries involved, as per the rule of thumb criterion in order to prevent the proliferation of instruments. Additionally, Wald statistical values confirm the joint validity of parameter estimates.

4. RESULTS AND DISCUSSION

4.1 Baseline regression results

This section summarises the baseline regression results using both panel ordinary least squares (OLS) and panel fixed effects techniques. The fixed effects model adjusts for unobserved individual-specific variables, allowing us to examine the role of socioeconomic, carbon emissions, and institutional factors in SSA health outcomes. Table 4 details the findings of the two estimating approaches. Our Hausman test statistic indicates that the panel fixed effects method is preferable to the random effects method. In terms of the signs and significance of our parameters, the findings obtained from the two baseline estimators are comparable. Our pooled OLS results indicated that, on average: (a) rising carbon emissions are responsible for poor health outcomes; (b) income per capita, institutional quality, educational attainment, access to electricity, net official development assistance, and population growth had positive and significant effects on health outcomes; and (c) urbanisation rate and fertility rate have negative effects on health outcomes. We also computed the panel fixed effect parameter estimates, due to the inherent shortcomings of the pooled OLS technique. Consequently, the panel effects estimates revealed that (a) carbon emissions and fertility rate influenced health outcomes indirectly and significantly, and (b) per capita income, educational attainment, access to electricity, urbanisation rate, and net official development assistance have a positive and significant impact on health outcomes. However, this study depended on the empirical findings of the parameters produced from the panel system of the GMM due to the fundamental concerns of the panel fixed effects estimator, which are similar to those of pooled OLS.

4.2 Discussion of the panel system-GMM results

The panel system of the GMM is used to address the potential endogeneity bias and high persistence of the regressands by (a) addressing omitted variables with unchanged periods by accounting for cross-section dependence and unobserved heterogeneity, and (b) reversing causality via instrumentation. Table 4 also shows our system-GMM results for the regression. In addition, the outcomes of the diagnostic tests verified the reliability of the system-GMM models. Given that the cross-sections are larger than the periods, the probability value of AR(2) indicated that the issue of second-order serial correlation was absent. The fact that the

regressand coefficients at lag one were statistically significant ($p < 0.05$) further corroborated their persistence rates. The following findings are discussed in reference to the impact of socioeconomic, carbon emissions, and institutional factors on health outcomes in SSA countries.

First, the coefficients for carbon emissions were negative at the 5% level of significance. Simply put, this indicates that deteriorating environmental conditions can have a negative impact on human health. Intuitively, unhygienic environments are detrimental to people's health. Table 4 shows that carbon emissions negatively impact health outcomes by up to -0.056%. The result is in line with the conclusions reached by authors such as Hansen & Selte (2000), Neidell (2004), Currie et al. (2009), Remoundou & Koundouri (2009), Asiskovitch (2010), Ajide & Alimi (2020), Alimi & Ajide (2021), and Alimi et al. (2022). Thus, the region's poor health outcomes can be attributed to poor environmental quality. Environmental hazards in SSA disproportionately affect vulnerable people, such as children and the elderly. Intuitively, co-pollutants released during the combustion of fossil fuels, such as particulate matter, nitrogen oxides, and sulfur dioxide, a major environmental threat in SSA, exacerbate asthma, bronchitis, and other lung problems. Premature death resulting from carbon emissions from combustion of fossil fuels is a serious problem, especially for children and the elderly.

Second, the statistical significance at the 5% level indicates that all institutional factors, including regulatory quality, government effectiveness, corruption control, and the broad institutional index, are negative. Low health outcomes in the region are likely due to the region's inadequate institutions, as indicated by the negative and statistically significant coefficients of institutional quality. In terms of statistical size, an increase in corruption control, government effectiveness, regulatory quality, and the broad institution index leads to a decrease in health outcomes of -0.047, -0.049, -0.035, and -0.043, respectively. This indicates that institutions are not effectively reducing socioeconomic disparity, which in turn leads to poor health outcomes. The implication is obvious: the region's current institutional structures are inadequate to ensure the health of its inhabitants. This is consistent with the argument put forth by Azfar & Gurgur (2008), who contend that weak institutional frameworks lower the quality of healthcare services. Mismanagement of health care budgets, insufficient

staffing, and outdated facilities are only a few examples of the many ways in which deficient institutions contribute to poor health outcomes for SSA residents. All these factors impede the provision of healthcare services, leading to outbreaks of diseases and sometimes untimely death. Mooketsane & Phirinyane (2015) assert that corruption, lack of transparency, and inadequate resource allocation in healthcare exacerbate health inequities and limit access to excellent healthcare for marginalised populations.

Third, the positive and statistically significant coefficients of income per capita at the 5% level highlight the relevance of income growth in ensuring improved health outcomes. The results of the study corroborate the hypothesis that rising income is associated with better health. Furthermore, a 10% increase in income per capita in SSA results in a 0.103–0.155% improvement in human health. Therefore, an improvement in the region's economy guarantees better human health. This lends credence to the modernisation theory, which states that economic expansion brought about by the industrial revolution had a positive effect on human health by increasing longevity, healthcare spending, and overall mortality rates. Previous studies that support this stance are Fuse & Crenshaw (2006); Babones (2008); Shen et al. (2008); Jorgenson & Rice (2010); O'Hare et al. (2013); Pamuk et al. (2011); Shandra et al. (2011); Wang (2014); and Frey & Cui (2016). The conclusion is that in SSA, income and health outcomes are tightly associated, lending credence to the claim that lowering inequality and improving economic conditions will improve people's health.

Fourth, the health outcomes in SSA improved significantly once the literacy rate and primary school enrolment increased. A high literacy rate is the most important factor in improving health outcomes in SSA, as it gives people the tools they need to make positive changes in their own lives. Studies such as Gakidou et al. (2010), Al Sayah et al. (2013), and Raru et al. (2022) have demonstrated a close association between the literacy rate and health outcomes in SSA. This finding suggests that raising the level of education in the region will improve health conditions. In order to increase health literacy, which empowers individuals and communities to make educated decisions about their health (including illness prevention, treatment, and management), people are required to have a better level of education. Healthcare services and health insurance become more financially feasible in a society where more people have completed higher levels of education.

Table 4: Regression outcomes of socioeconomic, carbon emissions, and institutional factors of health outcomes

Variables	**Dependent variable:** Health Outcomes											
	Pooled ordinary least square				**Panel fixed effect**				**Panel system GMM**			
	Control of corruption	Govt. effective	Regulatory quality	Quality of institutions	Control of corruption	Govt. effective	Regulatory quality	Quality of institutions	Control of corruption	Govt. effective	Regulatory quality	Quality of institutions
	1	2	3	4	5	6	7	8	9	10	11	12
Health outcomes(-1)	-	-	-	-	-	-	-	-	**0.940*** **	**0.948*** **	**0.936*** **	**0.941*** **
									(0.012)	**(0.013)**	**(0.010)**	**(0.014)**
Carbon emissions	**-0.187*** **	**-0.210*** **	**-0.166*** **	**-0.193*** **	**-0.297*** **	**-0.285*** **	**-0.297*** **	**-0.295*** **	**-0.053*** **	**-0.044** **	**-0.052*** **	**-0.056*** **
	(0.049)	**(0.050)**	**(0.050)**	**(0.049)**	**(0.063)**	**(0.063)**	**(0.063)**	**(0.063)**	**(0.016)**	**(0.017)**	**(0.009)**	**(0.015)**
Institutional factors	**0.335*** **	**0.328*** **	**0.199*** **	**0.339*** **	-0.013	**0.117***	-0.006	0.048	**-0.047*** **	**-0.049*** **	**-0.035*** **	**-0.043*** **
	(0.054)	**(0.054)**	**(0.051)**	**(0.058)**	(0.064)	**(0.064)**	(0.062)	(0.078)	**(0.012)**	**(0.015)**	**(0.009)**	**(0.011)**
Income per capita	**0.361*** **	**0.363*** **	**0.327*** **	**0.346*** **	**1.439*** **	**1.392*** **	**1.435*** **	**1.411*** **	**0.120*** **	**0.155*** **	**0.103*** **	**0.119*** **
	(0.075)	**(0.075)**	**(0.076)**	**(0.075)**	**(0.115)**	**(0.113)**	**(0.116)**	**(0.116)**	**(0.030)**	**(0.023)**	**(0.023)**	**(0.021)**
Primary school enrolment	**0.006*** **	**0.005*** **	**0.005*** **	**0.005*** **	**0.006*** **	**0.006*** **	**0.006*** **	**0.006*** **	0.001	-0.0003	**0.001** **	0.0003
	(0.001)	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**	(0.001)	(0.0004)	**(0.0004)**	(0.0004)
Literacy rate	**0.005*** **	**0.006*** **	**0.006*** **	**0.006*** **	**0.007*** **	**0.007*** **	**0.007*** **	**0.007*** **	**0.002*** **	**0.002*** **	**0.003*** **	**0.003*** **
	(0.002)	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**
Access to good water source	0.001	0.001	-0.000	0.001	0.005	0.006	0.005	0.005	**-0.005*** **	**-0.007*** **	**-0.006*** **	**-0.007*** **
	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)	(0.005)	(0.005)	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**
Access to improved sanitation	-0.001	-0.002	-0.001	-0.002	-0.003	-0.002	-0.003	-0.003	0.0005	-0.0001	**0.001*** **	**0.001*** **
	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.004)	(0.004)	(0.001)	(0.0001)	**(0.0004)**	**(0.0004)**
Access to electricity	**0.019*** **	**0.018*** **	**0.018*** **	**0.019*** **	**0.006** **	**0.006** **	**0.006** **	**0.006** **	**0.002*** **	**0.002*** **	**0.002*** **	**0.002*** **
	(0.002)	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.0005)**	**(0.0003)**	**(0.0004)**	**(0.001)**
Inflation rate	-0.000	**-0.000*** **	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	**-0.0001** **	**-0.0001**	**-0.0002*** **	**-0.0001*** **
	(0.000)	**(0.000)**	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	**(0.00001)**	**(0.00004)**	**(0.00004)**	**(0.00004)**
Net official dev. assistance	**0.257*** **	**0.301*** **	**0.326*** **	**0.295*** **	**0.047** **	**0.046** **	**0.047** **	**0.046** **	**0.047*** **	**0.051*** **	**0.043*** **	**0.050*** **
	(0.035)	**(0.033)**	**(0.033)**	**(0.033)**	**(0.023)**	**(0.023)**	**(0.023)**	**(0.023)**	**(0.009)**	**(0.006)**	**(0.004)**	**(0.008)**
Fertility rate	**-2.550*** **	**-2.603*** **	**-2.815*** **	**-2.597*** **	**-2.539*** **	**-2.500*** **	**-2.543*** **	**-2.548*** **	-0.105	-0.045	-0.063	-0.052
	(0.266)	**(0.271)**	**(0.271)**	**(0.272)**	**(0.302)**	**(0.301)**	**(0.301)**	**(0.301)**	(0.099)	(0.109)	(0.091)	(0.114)

Urbanisation rate	**-0.007*** **	**-0.006** **	**-0.007*** **	**-0.006** **	**0.023*** **	**0.027*** **	**0.023*** **	**0.025*** **	-0.002	**-0.002*** **	-0.0003	-0.001
	(0.003)	**(0.003)**	**(0.003)**	**(0.003)**	**(0.008)**	**(0.008)**	**(0.008)**	**(0.008)**	(0.001)	**(0.001)**	(0.001)	(0.001)
Population growth	**0.544*** **	**0.517*** **	**0.531*** **	**0.523*** **	0.040	0.037	0.040	0.040	**-0.015** **	0.003	**-0.017** **	0.006
	(0.079)	**(0.077)**	**(0.079)**	**(0.078)**	(0.026)	(0.026)	(0.026)	(0.026)	**(0.006)**	(0.004)	**(0.007)**	(0.006)
Constant	**-2.307*** **	**-2.321*** **	**-1.747** **	**-2.156*** **	**-9.981*** **	**-9.768*** **	**-9.954*** **	**-9.808*** **	**-0.856*** **	**-0.993*** **	**-0.840*** **	**-0.914*** **
	(0.764)	**(0.769)**	**(0.761)**	**(0.764)**	**(1.074)**	**(1.051)**	**(1.068)**	**(1.071)**	**(0.254)**	**(0.209)**	**(0.252)**	**(0.255)**
Adj. R^2	0.829	0.829	0.824	0.828	-	-	-	-	-	-	-	-
Within R^2	-	-	-	-	0.836	0.837	0.836	0.836	-	-	-	-
Hausman test	-	-	-	-	**144.6*** **	**149.5*** **	**139.5*** **	**144.6*** **	-	-	-	-
AR(1)	-	-	-	-	-	-	-	-	(0.039)	(0.042)	(0.043)	(0.042)
AR(2)	-	-	-	-	-	-	-	-	**(0.304)**	**(0.279)**	**(0.303)**	**(0.291)**
Sargan OIR	-	-	-	-	-	-	-	-	**(0.192)**	**(0.183)**	**(0.061)**	**(0.201)**
Hansen OIR	-	-	-	-	-	-	-	-	**(0.833)**	**(0.825)**	**(0.901)**	**(0.674)**
DHT for instruments												
(a) Instruments in levels												
H Excluding group	-	-	-	-	-	-	-	-	**(0.079)**	**(0.203)**	**(0.089)**	**(0.160)**
Diff(null, H=exogenous)	-	-	-	-	-	-	-	-	**(0.998)**	**(0.977)**	**(1.000)**	**(0.923)**
(b) IV(years, eq (diff))												
H Excluding group	-	-	-	-	-	-	-	-	**(0.796)**	**(0.733)**	**(0.646)**	**(0.570)**
Diff(null, H=exogenous)	-	-	-	-	-	-	-	-	**(1.000)**	**(1.000)**	**(1.000)**	**(1.000)**
F-test	**338.1*** **	**348.0*** **	**336.4*** **	**338.2*** **	**231.3*** **	**232.8*** **	**231.3*** **	**231.4*** **	**8855.6*** **	**2759.5*** **	**5633.3*** **	**4428.4*** **
Instruments	-	-	-	-	-	-	-	-	42	42	42	42
Country(s)	45	45	45	45	45	45	45	45	45	45	45	45
Observation	647	647	647	647	647	647	647	647	646	646	646	646

Note: Standard errors in parentheses; *, **, & *** signify significance level at 10%, 5%, & 1% respectively. The bold values signify significance of (a) estimated parameters and the F-test; (b) Fisher statistics and the Hausman test are in bold forms; (c) failure to reject the null hypotheses of: (i) no autocorrelation in the AR(1) & AR(2) tests; and (ii) the validity of instruments in the Sargan OIR test.

Fifth, infrastructure development promotes health outcomes by providing access to improved sanitation and electricity, while poor access to clean water negatively impacts health outcomes. This indicates that people in SSA are much healthier when they have better access to modern conveniences like power and a clean environment. It stands to reason that having adequate sanitary facilities in an economy can assist in reducing the incidence of contagious diseases and respiratory disorders. In addition, having reliable electricity will allow for the refrigeration and storage of vaccines and pharmaceuticals, both of which are essential for the prevention and treatment of disease. This is consistent with the position taken by the World Health Organization (2021) and the International Energy Agency (2021) on the significance of a healthy environment and reliable energy. However, a lack of access to clean water exacerbates the prevalence of water-borne diseases such as cholera, typhoid, and diarrhoea, thereby worsening health outcomes in SSA. Pickering et al. (2015) found, however, that even in areas where piped water was available, there was no change in the prevalence of diarrhoea in rural Mali.

Sixth, the declining health outcomes in SSA can be attributed in part to the increasing population and the resulting urbanisation as reported in Table 4. Statistically, a drop from -0.015% to -0.017% in health outcomes is the result of a 1% increase in population growth. Moreover, human health in the SSA declined by 0.02% for each 10% increase in the urbanisation rate. Although it is not statistically significant, a high fertility rate is also associated with poor health outcomes. Urban congestion, lack of access to clean water, and air pollution are only a few of the ways in which urbanisation severely impacts health. Rapid population expansion strains the region's healthcare infrastructure and resources, leading to poorer health outcomes. Barton et al. (2021) argue that urbanisation can exacerbate health disparities by disproportionately affecting poor and minority populations, who may have less access to healthcare and are more vulnerable to environmental hazards.

Finally, at the 5% significance level, macroeconomic stability positively influences health outcomes, as evidenced by the annual increase in the consumer price index and net official development assistance, ODA. When inflation is low and a country receives net ODA, health outcomes improve. In other words, low inflation in the region suggests that the economy is stable and people's healthcare

bills are manageable. As a result, healthcare and other necessities are within reach of more people and cost less for their families. The direct link between net ODA and health outcomes confirms the findings of Alimi et al. (2020) that overseas donors contribute critical resources and support for healthcare infrastructure, public health programmes, and disease prevention and treatment measures of the Economic Community of West African States (ECOWAS). Statistically, a 0.01% to 0.02% improvement in health outcomes results from a 100% decrease in inflation. In addition, human health in SSA improved by 0.47–0.51% for every 10% increase in net ODA.

Using the ecological footprint as a proxy for environmental deterioration, we re-estimated the models in Table 4 to ensure the consistency of our findings. Appendix 1 displays the results obtained. The pooled OLS, panel fixed, and system-GMM results in Table 4 are generally consistent with the findings in Appendix I. The statistical significance of the coefficients of environmental degradation shows only subtle variations. All the negative coefficients of the ecological footprint, except for that in column 9, indicate a correlation between greater environmental degradation and poorer health outcomes. Therefore, the panel fixed effects and system-GMM findings suggest that the ecological footprint bears equal responsibility for poor health outcomes. According to panel GMM results, all other variables have the same signs. Finally, the coefficients of lagged values for health outcomes are close to one, indicating that these variables have a strong tendency to persist over time.

5. CONCLUSION

This study examined the impact of institutions, environment, and socioeconomic factors on human health in 45 sub-Saharan African countries from 1996 to 2018. The study used a system of GMM to derive its empirical estimates. Here is a brief summary of the most important results: (a) the deteriorating environmental quality significantly impacted health outcomes; (b) weak institutions are to blame for the poor health of people in the region; (c) the importance of income growth in ensuring improved health outcomes is confirmed statistically; (d) the health of people in SSA improved once literacy and basic school enrolment improved; (e) infrastructure development promotes health outcomes through quality sanitation and energy, while poor drinking water negatively impacts health outcomes; (f) population growth and urbanisation contribute to SSA's poor health outcomes;

and (g) macroeconomic stability, as measured by low inflation and higher net ODA, enhances health outcomes.

What policy implications do these findings have for the creation of programmes to enhance health outcomes in SSA nations? The findings indicating that environmental degradation contributes to poor health have significant implications for SSA countries. For people to lead a healthy life, the region must switch from fossil fuels to clean energy, such as wind, solar, and hydropower. Feed-in tariffs and tax incentives for clean energy investments can help governments encourage sustainable energy. Governments need to impose a fee on carbon emissions to discourage carbon-intensive fuels and production methods. The region can use the tax revenues to fund renewable energy and low-carbon technologies. Governments should compel industries that use fossil fuel-powered machines, such as oil drilling, cement, and steel manufacture, to adopt carbon capture technology to capture and store industrial carbon dioxide underground. This finding also suggests that weak institutions contribute to the region's poor health outcomes. It means governments should promote transparency, accountability, and public participation in decision-making to strengthen governance. They should ensure that public officials do not mismanage funds for healthcare facilities such as clinics, hospitals, and healthcare worker training.

Furthermore, the study found that macroeconomic stability, per capita income growth, and education attainment improve health outcomes. This implies that the government should continue to implement policies aimed at maintaining economic stability, increasing citizen incomes, and ensuring they receive quality education. A way of boosting the rural poor's income is by transforming the region's agriculture sector. Rural poor mainly work in agriculture. Therefore, the subsistence practice of rural agriculture explains low income in the sector. Hence, peasant farmers need basic agricultural inputs such as fertilizers, seeds, and tools to increase their income. In accordance with the Monterrey and Gleneagles agreements of 2002 and 2005, respectively, the international community and G8 nations, in particular, must fulfil their promise to increase aid to African nations, as reaffirmed in later forums (U.S. Department of State, 2002; Government of Canada, 2005). It is equally important to untie and streamline aid procedures and abolish conditionalities (Akinlo & Sulola, 2019). Health outcomes are dependent

on increasing access to and quality of basic education. Eradicating gender stereotypes, improving school infrastructure, and providing gender-sensitive curriculum are all necessary to achieve education advancement in SSA. The findings reveal that governments in the SSA must support existing programmes, such as the African Development Bank's New Deal on Energy for Africa and the Power Africa Initiative, among others, to ensure systemic access to electricity in Africa by 2025 via renewable energy and infrastructure investments. As population growth and urbanisation are negatively related to health, provision of universal family planning services and instituting responsive urbanisation policies that prioritise inexpensive housing and such basic amenities as sanitation and potable water would greatly improve health outcomes.

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Appendix I: Robustness check – regression outcomes of socioeconomic, ecological footprint, institutional factors of health outcomes

Variables	**Dependent variable:** Health outcomes											
	Pooled ordinary least square				**Panel fixed effect**				**Panel system GMM**			
	Control of corruption	Govt. effective	Regulatory quality	Quality of institutions	Control of corruption	Govt. effective	Regulatory quality	Quality of institutions	Control of corruption	Govt. effective	Regulatory quality	Quality of institutions
	1	2	3	4	5	6	7	8	9	10	11	12
Health outcomes(-1)	-	-	-	-	-	-	-	-	**0.934*****	**0.962*****	**0.963*****	**0.942*****
									(0.011)	**(0.007)**	**(0.007)**	**(0.012)**
Ecological footprint	0.027	0.0002	0.006	-0.008	**-0.299*****	**-0.311*****	**-0.299*****	**-0.305*****	**-0.039*****	0.004	-0.017	-0.008
	(0.058)	(0.059)	(0.058)	(0.058)	**(0.063)**	**(0.063)**	**(0.063)**	**(0.063)**	**(0.010)**	(0.015)	(0.012)	(0.013)
Institutional factors	**0.284*****	**0.233*****	**0.176*****	**0.279*****	0.027	**0.129****	0.013	0.083	**-0.038*****	**-0.050*****	**-0.025*****	**-0.050*****
	(0.053)	**(0.053)**	**(0.054)**	**(0.056)**	(0.065)	**(0.065)**	(0.065)	(0.080)	**(0.010)**	**(0.012)**	**(0.009)**	**(0.014)**
Income per capita	**0.227*****	**0.217*****	**0.220*****	**0.219*****	**1.278*****	**1.264*****	**1.284*****	**1.259*****	**0.128*****	**0.110*****	**0.087*****	**0.099*****
	(0.072)	**(0.073)**	**(0.073)**	**(0.072)**	**(0.120)**	**(0.117)**	**(0.120)**	**(0.120)**	**(0.018)**	**(0.016)**	**(0.017)**	**(0.017)**
Primary school enrolment	**0.006*****	**0.005*****	**0.005*****	**0.005*****	**0.006*****	**0.006*****	**0.006*****	**0.006*****	0.001	0.0002	0.0003	**0.0009***
	(0.001)	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**	(0.0004)	(0.0004)	(0.0004)	**(0.0005)**
Literacy rate	**0.006*****	**0.006*****	**0.006*****	**0.006*****	**0.008*****	**0.008*****	**0.008*****	**0.008*****	0.001	**0.001****	0.0002	0.001
	(0.002)	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	(0.001)	**(0.0004)**	(0.0005)	(0.001)
Access to good water source	0.001	0.002	0.0001	0.001	0.002	0.003	0.002	0.002	**-0.006*****	**-0.008*****	**-0.006*****	**-0.007*****
	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)	(0.005)	(0.005)	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**
Access to improved sanitation	-0.002	-0.002	-0.002	-0.002	-0.002	-0.001	-0.002	-0.002	**0.002****	**0.002****	**0.003*****	**0.003*****
	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.004)	(0.004)	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**
Access to electricity	**0.017*****	**0.016*****	**0.017*****	**0.017*****	0.001	0.002	0.001	0.001	**0.003*****	**0.003*****	**0.001****	**0.002****
	(0.002)	**(0.002)**	**(0.002)**	**(0.002)**	(0.003)	(0.003)	(0.003)	(0.003)	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**
Inflation rate	**-0.000*****	**-0.000*****	**-0.000*****	**-0.000*****	-0.000	-0.000	-0.000	-0.000	**-0.0003*****	**-0.0002*****	**-0.0002*****	**-0.0003*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	(0.000)	(0.000)	(0.000)	(0.000)	**(0.0001)**	**(0.00004)**	**(0.0001)**	**(0.0001)**
Net official dev. Assistance	**0.297*****	**0.337*****	**0.350*****	**0.325*****	**0.070*****	**0.069*****	**0.071*****	**0.070*****	**0.052*****	**0.052*****	**0.040*****	**0.051*****
	(0.035)	**(0.033)**	**(0.032)**	**(0.033)**	**(0.023)**	**(0.023)**	**(0.023)**	**(0.023)**	**(0.006)**	**(0.007)**	**(0.006)**	**(0.006)**
Fertility rate	**-2.562*****	**-2.718*****	**-2.811*****	**-2.665*****	**-2.543*****	**-2.450*****	**-2.533*****	**-2.528*****	-0.010	0.072	0.035	-0.015

	(0.311)	**(0.313)**	**(0.312)**	**(0.314)**	**(0.348)**	**(0.348)**	**(0.347)**	**(0.346)**	(0.081)	(0.079)	(0.086)	(0.092)
Urbanization rate	**-0.013*****	**-0.012*****	**-0.012*****	**-0.012*****	**0.033*****	**0.035*****	**0.032*****	**0.035*****	**-0.004*****	**-0.004*****	**-0.002****	-0.002
	(0.002)	**(0.002)**	**(0.002)**	**(0.002)**	**(0.008)**	**(0.008)**	**(0.008)**	**(0.008)**	**(0.001)**	**(0.001)**	**(0.001)**	(0.001)
Population growth	**0.639*****	**0.635*****	**0.622*****	**0.628*****	**0.066****	**0.061***	**0.066****	**0.065****	0.004	**-0.015***	-0.004	-0.001
	(0.087)	**(0.087)**	**(0.085)**	**(0.086)**	**(0.032)**	**(0.032)**	**(0.032)**	**(0.032)**	(0.011)	**(0.008)**	(0.008)	(0.010)
Constant	-1.201	-0.937	-0.816	-0.943	**-8.099*****	**-8.196*****	**-8.155*****	**-8.023*****	**-0.787*****	**-0.635*****	**-0.469***	**-0.608****
	(0.768)	(0.776)	(0.764)	(0.768)	**(1.209)**	**(1.185)**	**(1.201)**	**(1.198)**	**(0.208)**	**(0.222)**	**(0.241)**	**(0.234)**
Adj. R^2	0.807	0.804	0.802	0.805	-	-	-	-	-	-	-	-
Within R^2	-	-	-	-	0.837	0.838	0.837	0.838	-	-	-	-
Hausman test	-	-	-	-	**167.4*****	**171.1*****	**160.3*****	**166.9*****	-	-	-	-
AR(1)	-	-	-	-	-	-	-	-	(0.037)	(0.035)	(0.037)	(0.037)
AR(2)	-	-	-	-	-	-	-	-	**(0.674)**	**(0.637)**	**(0.661)**	**(0.642)**
Sargan OIR	-	-	-	-	-	-	-	-	**(0.071)**	**(0.194)**	**(0.083)**	**(0.108)**
Hansen OIR	-	-	-	-	-	-	-	-	**(0.881)**	**(0.735)**	**(0.849)**	**(0.787)**
DHT for instruments												
(a) Instruments in levels												
H Excluding group	-	-	-	-	-	-	-	-	**(0.243)**	**(0.147)**	**(0.238)**	**(0.219)**
Diff(null, H=exogenous)	-	-	-	-	-	-	-	-	**(0.999)**	**(0.962)**	**(0.998)**	**(1.000)**
(b) IV(years, eq (diff))												
H Excluding group	-	-	-	-	-	-	-	-	**(0.847)**	**(0.629)**	**(0.904)**	**(0.702)**
Diff(null, H=exogenous)	-	-	-	-	-	-	-	-	**(1.000)**	**(1.000)**	**(1.000)**	**(1.000)**
F-test	**315.9*****	**314.8*****	**322.3*****	**326.3*****	**221.7*****	**223.5*****	**221.7*****	**222.2*****	**9758.9*****	**9457.2*****	**1907.5*****	**9317.9*****
Instruments	-	-	-	-	-	-	-	-	42	42	42	42
Country(s)	43	43	43	43	43	43	43	43	43	43	43	43
Observation	616	616	616	616	616	616	616	616	615	615	615	615

Note: Standard errors in parentheses; *, **, & *** signify significance level at 10%, 5%, & 1% respectively. The bold values signify significance of (a) estimated parameters and *F*-test; (b) Fisher statistics and Hausman test are in bold forms; (c)failure to reject the null hypotheses of: (i) no autocorrelation in the AR(1) & AR(2) tests; and (ii) the validity of instruments in the Sargan OIR test.

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THE INFLUENCE OF ONLINE REVIEWS ON CUSTOMER DECISIONS IN ALGERIAN E-MARKETPLACES

ABSTRACT: *This study examined how online review dimensions – quantity, consistency, reviewer expertise, and product ratings – influence purchasing decisions in Algeria's emerging e-marketplace. While electronic word-of-mouth (eWOM) is pivotal in global e-commerce, research remains skewed towards developed economies, leaving North African contexts under-studied. In countries such as Algeria, low digital literacy and limited customer trust may alter consumer behaviour. Using the partial least squares structural equation modelling method (PLS-SEM) on survey data from 61 Algerian online shoppers, the study found that product ratings exert a statistically significant effect on purchase decisions, whereas review quantity, consistency, and reviewer expertise lack statistical impact. This contrasts with established markets, suggesting that Algerian consumers prioritise simplified metrics, such as ratings, due to cognitive load and distrust of complex review systems. Methodologically, the research validated PLS-SEM's robustness for small-sample contexts, while theoretically challenging universal assumptions about eWOM efficacy. Practical insights highlight the need for platforms to enhance rating transparency and authenticity in nascent markets. Future studies should explore cultural and infrastructural moderators in similar regions and integrate mixed methods to uncover behavioural nuances.*

KEY WORDS: *review quantity, review consistency, reviewers' expertise, product rating, customer decision*

JEL CLASSIFICATION: M31, L81.

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1. INTRODUCTION

The advent of the web and data technologies has brought about profound adjustments to the marketing environment, especially after the onset of Web 2.0 technologies. To survive and compete in the marketplace, firms have all begun to build their own online commerce environments (Kang, 2012). Peer-consumer reviews act as indirect electronic word-of-mouth (eWOM) communications regarding products between consumers. Customer reviews have become a widely used tool in e-commerce. Concerns over the credibility of information found in e-marketplaces, such as the perceived promotional intent of customer reviews, perceived trustworthiness, and perceived usefulness, have also garnered much attention (Forouhandeh et al., 2022). In order to maintain their success, understanding how and when customer reviews and product consumer satisfaction influence the customer decision-making procedure becomes imperative (Sardar et al., 2021).

E-commerce (EC) has witnessed remarkable growth, and the COVID-19 outbreak has accelerated this growth. As a consequence, the development of advanced information technology has led to consumers increasingly encountering external environments of the EC marketplace (Gharib et al., 2019). In 2024, global EC revenues surpassed $4,116.6 billion, underscoring the sector's dominance in modern economies (p. 345, Statista, 2024). In addition to this phenomenal growth, EC channels have appeared in diverse forms of platforms, and consumers have more opportunities for market choice (Dwidienawati et al., 2020). The prosperity of an EC channel or platform bank largely depends on the vitality of the marketplace, especially eWOM, in which customers post information about the product and retailers, and recent developments in technology has enabled this kind of information transmission on the Internet. EC retailers strive to leverage eWOM in creating and spreading a buying experience, and the integration of eWOM, which is seized by a third party, into the shopping process on the EC site has been considered one of the key strategic assets in competing with rival retailers (Kato, 2022).

Consumers evaluate not only the content of reviews but also the agent producing the reviews. This notion is commonly examined in the context of eWOM communications from other consumers or experts. This study focuses on the agent producing the reviews, and the equivalence of the perceived influences on

purchase intention between reviews posted by customers and those posted by social media influencers. Customer review as one form of eWOM influences consumers' online shopping experiences by retrieving appropriate products and providing the associated information to assist in decision-making. This kind of information is easily accessed online since customers prefer sharing their experiences and recommendations on the product and retailer at an individual level (Jin et al., 2022). The synergistic effects of customer reviews on perceived risk and trustworthiness have been confirmed. Based on consumers' characteristics and situations, customer reviews may contribute to the creation of satisfaction and intention of repurchase in EC scenarios (Dwidienawati et al., 2020).

With virtually all product categories being sold in e-marketplaces, competition between vendors is increasingly strong. Consequently, several vendors have sought strategies to promote their products in the emerging e-marketplaces, resulting in stronger exogenous influences on consumer purchasing behaviour (Köcher, 2018). Complementary to vendors' promotional activities, consumer ratings and reviews on such products in e-marketplaces can be analysed as a source of endogenous influence that affects potential buyers' purchasing behaviours. Consumer ratings and reviews of such products positively influence viewer interest in the products and enhance product purchase intentions, even in the presence of vendor promotional activities. As information on the products is anticipated to be plentiful, ratings and reviews from other consumers who have either experienced or examined the same products can be considered more impartial and credible than vendor-provided information (Kim & Bang, 2021). Based on the aforementioned, a research problem arises: How does review quantity, consistency, reviewers' expertise, and a product's rating influence a customer's perception and decision in e-marketplaces?

The existing literature has extensively explored the role of online reviews in consumer decision-making, yet these studies remain disproportionately focused on developed economies and established e-commerce markets, such as the United States, Europe, China, and Southeast Asia. Critical gaps persist in understanding how these dynamics operate in developing regions, particularly in North Africa, where e-commerce penetration remains low (18.5% in Algeria as of 2024) and consumer trust in digital platforms is fragile (Global System for Mobile

Communications Association [GSMA], 2024). Moreover, prior studies often isolate individual review dimensions, neglecting their synergistic effects, and rely on covariance-based structural equation modelling (CB-SEM), which is ill-suited for small-sample exploratory research (Hair et al., 2019). These limitations obscure the contextual nuances of eWOM's impact in emerging markets, where infrastructural constraints, cultural preferences, and digital literacy disparities may reshape consumer behaviour.

This study addresses these gaps by examining the interplay of four review dimensions – quantity, consistency, reviewer expertise, and product ratings – in shaping customer decisions within Algeria's evolving e-marketplaces. Employing partial least squares structural equation modelling (PLS-SEM), a method robust to small samples and complex models (Hair et al., 2022), this research analyses survey data from 61 Algerian online shoppers to examine how these factors collectively influence purchasing behaviour. By situating the investigation in a region where e-commerce is still emerging, the study offers three key contributions. First, it challenges the universality of findings from developed markets, revealing that Algerian consumers prioritise straightforward metrics, such as product ratings, over nuanced attributes, such as review consistency or volume. Second, it advances methodological rigour in small-sample contexts by demonstrating PLS-SEM's efficacy in exploratory settings. Third, it provides actionable insights for businesses and policymakers aiming to foster trust and optimise user-generated content in underpenetrated markets. In doing so, this research not only enriches such theoretical frameworks as the heuristic-systematic model (Zhang et al., 2014) but also equips stakeholders with culturally tailored strategies to navigate the complexities of global e-commerce.

This paper begins by establishing the contextual framework and conducting a critical review of the relevant literature. Building upon this foundation, the study's hypotheses are developed. The research methodology is then detailed, followed by a presentation of the empirical findings. The discussion section examines the relationship between online review dimensions and consumer decision-making, while also situating the study's contributions within the broader academic discourse. Finally, the conclusion synthesises key theoretical and practical implications, acknowledges the study's limitations, and proposes avenues for future research.

2. LITERATURE REVIEW

2.1 Customer decision-making

Customer decision-making in e-commerce has been extensively studied through diverse theoretical lenses, reflecting its multidimensional nature. Early foundational work by Helander (2000) established the interplay between store environment, web technology, and consumer behaviour, emphasising the role of information flow in shaping online purchasing choices. This framework was expanded by Louvieris and Oppewal (2004), who introduced the Channel Benefits Portfolio (CBP) model to optimise managerial investments in multi-channel retailing, underscoring how consumer channel selection behaviour drives decision-making efficiency. Subsequent research shifted towards longitudinal consumer engagement, with Lemon and Mark (2006) pioneering the Customer Lifetime Value (CLV) model to segment consumers based on profitability, thereby linking decision-making patterns to long-term business outcomes.

The literature further explores psychological and structural factors influencing retention and choice. Colgate et al. (2007) identified switching costs and relational investments as critical determinants of customer retention, challenging the assumption that satisfaction alone drives loyalty. This aligns with Wang's (2010) findings, which demonstrated that switching costs mediate the relationship between perceived value and retention, particularly in competitive markets. Meanwhile, Chen (2009) applied rough set (RS) theory to decode nonlinear relationships in consumer satisfaction surveys, offering a novel methodological approach to predict behavioural trends.

Technological advancements have introduced new dimensions to decision-making research. Nilashi et al. (2015) highlighted the role of security, design, and content (iContent) in building trust in mobile commerce, while Ruiz Díaz (2017) emphasised post-purchase satisfaction and loyalty in the mobile phone industry. The rise of social commerce has further complicated decision pathways, as evidenced by Zhang et al. (2018), who found that the quality of online product recommendations (OPRs) – encompassing both positive and negative attributes – directly impacts purchasing decisions and loyalty in social shopping environments.

Despite these advancements, critical gaps persist. First, the existing literature disproportionately focuses on developed markets (e.g., the U.S., Europe, and East Asia), neglecting the unique socio-economic and technological contexts of emerging economies, particularly in North Africa. For instance, while such studies as Chevalier and Mayzlin (2006) and Mudambi and Schuff (2010) established the global relevance of review quantity and quality, their applicability to regions with lower digital literacy and nascent e-commerce adoption, such as Algeria, has not yet been examined. Second, prior work often examines decision-making factors in isolation (e.g., trust, switching costs, or OPRs), overlooking their synergistic effects in dynamic, multi-platform e-marketplaces. For example, the interplay between review consistency (Zhang et al., 2014) and reviewer expertise (Vermeulen & Seegers, 2009) has yet to be contextualised in environments where consumers may prioritise heuristic cues such as product ratings over detailed analyses.

Additionally, methodological limitations abound. While Chen (2009) and Zhang et al. (2018) advanced predictive modelling, their reliance on CB-SEM restricts applicability to small-sample exploratory studies common in under-researched markets. Furthermore, the literature lacks culturally adapted frameworks to account for regional variations in trust-building mechanisms. For instance, Algerian consumers' reliance on social proof versus institutional credibility – a factor critical in collectivist societies – remains unexamined, despite its implications for review credibility and platform design (Sirdeshmukh et al., 2002).

2.2 Review quantity and customer decisions

Online consumer reviews exert a significant impact on purchasing decisions. Review quantity influences customer decisions by affecting product preference, conversion rates, trust, and purchase intentions. Numerous studies have concluded that the volume of reviews positively correlates with buying intentions, with a greater number of reviews generally leading to increased purchase activity (Chevalier & Mayzlin, 2006; Iqbal et al., 2024; Mudambi & Schuff, 2010; Park et al., 2007; Simanjuntak et al., 2024; Tran, 2020; Vrânceanu, 2017; You et al., 2015; Zhang et al., 2014). In one study, consumer preference rose with the number of reviews even when average ratings remained constant (Viglia et al., 2014). In another investigation of e-commerce products, cumulative reviews boosted conversion rates by as much as 270%, with the first few reviews driving most of

that increase (Askalidis & Malthouse, 2016). Reviews that combine high quantity with positive valence tend to enhance sales. However, in experiments with hypothetical products, a shift occurs whereby consumers may favour a lower-rated option even if it exhibits a larger number of reviews (Kordrostami et al., 2021; Watson et al., 2018).

Review quality also plays a crucial role, particularly for highly involved consumers. Keller and Staelin (1987) explore the influences of data quantity on decision effectiveness, hypothesising that while information quality improves decision effectiveness, information quantity can decrease it. This suggests that an overload of reviews might hinder consumers' ability to make effective decisions, potentially leading to confusion or decision fatigue. Wansink et al. (1998) and Chintagunta (1993), however, do not directly address the impact of review quantity on customer decisions. Wansink et al. (1998) focus on the anchoring and adjustment model in purchase quantity decisions, while Chintagunta (1993) investigates the influences of marketing variables on buying incidence, brand selection, and purchase quantity preference, emphasising the role of reservation prices and intrinsic brand preferences. The impact of reviews is moderated by factors such as product price and consumers' exposure to reviews, with the effect of review valence being strongest for higher-priced products when customers read many reviews (Maslowska et al., 2017). Notably, the order in which consumers make decisions can affect purchase quantities, with decisions about less replaceable attributes (e.g., flavour) made earlier, leading to greater overall purchases and variety (Nowlis et al., 2010). Ardianti & Widiartanto (2019) examine the influence of online consumer ratings on purchasing decisions in the context of the Shopee marketplace. Their study discovers that online consumer reviews have a substantial, positive impact on buying decisions, contributing 16.1% to the decision-making process. This indicates that the presence of reviews, regardless of their quantity, performs a crucial task in shaping consumer behaviour. However, the study does not explicitly differentiate the impact of the quantity of reviews from their presence. The results indicate that consumers view supplies with a larger number of reviews as being more dependable and credible, leading to a positive influence on their decision-making in online marketplaces. Therefore, this study puts forward the hypothesis that

H1: The review quantity has a positive impact on customer decisions in e-marketplaces.

2.3 Review consistency and customer decisions

Consistent online product reviews significantly influence customer decision-making in the digital economy, as they shape consumer purchase intentions across diverse e-commerce settings. Review consistency, both globally and sequentially, positively affects perceived quality, confirmation of expectations, and trust in sellers, ultimately impacting purchase intentions. Studies such as Furner et al. (2021), Jiménez and Mendoza (2013), Li et al. (2024), Park et al. (2007), Rachmiani et al. (2024) and Thomas et al. (2019) indicate that reviews with high credibility, quality, and alignment with consumer expectations increase purchase intention. For instance, Campos and Campos (2024) report that consistent and credible reviews boost purchase intention, and Iqbal et al. (2024) note that consistent product ratings enhance review credibility, which in turn raises purchase intention. The consistency of reviews, based on volume, length, and content, plays crucial roles in determining review quality and influencing purchase decisions (Kargozari et al., 2023). Rating consistency can enhance recommendation performance by selecting representative consumers as neighbours in collaborative filtering algorithms (Park et al., 2023). The heuristic-systematic model explains how both systematic factors, 'argument quality' and 'heuristic factors' (source credibility and perceived quantity) of online reviews directly influence purchase intentions, with heuristic factors also positively influencing argument strength (Zhang et al., 2014). In contrast, several studies report that inconsistent or deceptive reviews reduce purchase intention. Wang et al. (2023), Peng et al. (2016), and Wang et al. (2021) observe that review inconsistency correlates with a decline in purchase intention. These findings underscore the importance of review consistency in fostering a perception of authenticity, as clear and consistent reviews build trust and encourage purchases, whereas inconsistency diminishes consumer willingness to buy; hence, the second hypothesis is suggested:

H2: Review consistency positively impacts customer decisions in e-marketplaces.

2.4 Reviewers' expertise and customer decisions

The correlation between different levels of reviewer experience and customer trust in e-commerce platforms is significant. Factors such as years of product use and professional background contribute to the perceived credibility of reviews, which in turn affects consumer trust and purchasing behaviour and decisions. Several studies indicate that reviews written by experts and experienced reviewers have a greater impact on consumer opinions and beliefs (Iqbal et al., 2024; Su et al., 2017; Xu, 2014). Reviewers with extensive experience are often perceived as more credible, as their insights are seen as informed and reliable; this credibility enhances consumer trust in the reviews (Sani Sneha, 2024). In addition, reviewers with relevant professional expertise can provide detailed and technical insights, which are particularly valued in specialised markets. Their opinions may significantly sway potential buyers' decisions (Salari, 2024).

Verified and experienced reviewers tend to produce reviews that are detailed and balanced, which are more likely to foster trust and influence purchasing decisions positively. As indicated by Septokasya (2024), consumers often rely on peer reviews to assess product quality, making the experience of the reviewer a critical factor in their decision-making process. Vermeulen and Seegers (2009) conducted a study to analyse the influence of online hotel ratings on consumer picks. The study examined variables such as the sentiment of reviews, the level of familiarity with the hotel, and the expertise of the reviewer. The findings indicated that reading online reviews increases the possibility of consumers considering a hotel, with reviewer expertise being one of the independent factors. Aditya and Alversia (2019) also explored the impact of online reviews on customer purchase intent. Their study focused on the impact of online ratings on a review website platform in the context of picking the first visited cafe. The research highlighted that customer decision-making is influenced by many aspects, including rating platforms, other customer reviews, and property features, alongside the consumer's profile as such. In the realm of online reviews, Ward (2016) discussed the rise of predatory publishing, where reviews publish articles with hardly any peer review. These journals generally exaggerate their editorial expertise and try to attract writers by promising quick editorial procedures. This highlights the importance of reviewer expertise in ensuring the credibility and reliability of online ratings. Overall, the expertise of reviewers carries a significant role in influencing consumers' decisions. Vermeulen and Seegers (2009) and Aditya and

Alversia (2019) emphasise the impact of reviewer expertise on consumer behaviour. Ensuring that reviewers are knowledgeable and credible can enhance the trust and reliability of online reviews, ultimately impacting customer decision-making processes.

Conversely, while reviewer experience can enhance customer trust, it is essential to recognise that not all consumers prioritise this aspect equally. Some may rely more on brand reputation or influencer endorsements, indicating a multifaceted approach to trust in e-commerce (Soleimani, 2022). Based on the above, this study puts forward the third hypothesis:

H3: Reviewer expertise has a positive impact on customer decisions in e-marketplaces.

2.5 The product rating and customer decisions

Product ratings and reviews have become integral components of consumer decision-making in e-marketplaces. The proliferation of online platforms has transformed how consumers evaluate products, with ratings and reviews serving as critical influencers of trust, perceived quality, and ultimate purchasing decisions. Generally speaking, product ratings are numerical evaluations provided by consumers based on their experiences with a product or service. These ratings, often displayed as stars or points, act as quick indicators of product quality. Multiple studies indicate that higher-rated products are more likely to attract consumer attention and trust, thereby influencing purchasing decisions (Mukarromah, 2023; Novela et al., 2023; Sari & Othman, 2024; Shazuli Ibrahim, 2023).

Trust is a fundamental factor in online purchasing decisions, particularly in the absence of physical interaction with products. Studies have shown that product ratings play a crucial role in building consumer trust. For instance, a study on e-commerce platforms such as Tokopedia, Shopee, and Bukalapak found that highly rated products increase consumer trust, which in turn influences purchase decisions (Rachmiani et al., 2024). Similarly, research on the Lazada marketplace highlighted that positive ratings enhance consumers' confidence in product quality, leading to a higher likelihood of purchase (Sugiarto & Hanif, 2023).

Online shopping inherently involves risk due to the inability to physically inspect products before purchase. Product ratings help mitigate this risk by providing insights into the experiences of other consumers. A study on the Shopee marketplace found that positive ratings reduce perceived risk, making consumers more confident in their purchasing decisions (Asari & Yulinda, 2024). This risk-reducing effect is particularly significant in the context of lesser-known brands, where consumers may lack prior experience with the product (Sung et al., 2023).

In other studies, Kim and Srivastava (2007) highlighted the importance of social effect in online commerce decision-making, emphasising the potential benefits for companies in leveraging social interactions to improve customer relationship management and increase sales. Agustina and Kurniawan (2018) discussed the role of online ratings in the decision-making process, emphasising their influence on buyers' decisions. Furthermore, Deshpande and Pendem (2020) focused on the relationship between logistics performance, ratings, and consumer purchasing behaviour in online commerce platforms, highlighting the importance of delivery performance and logistics ratings in influencing sales. Yoon et al. (2013) examined the moderating impact of customer product knowledge and online buying experience on customer loyalty when utilising recommendation agents, providing insights into the factors that influence customer decisions. Additionally, Hult et al. (2019) addressed the differences in antecedents and consequences of customer satisfaction across online and offline purchases, offering guidance to retailers on enhancing customer loyalty in both channels.

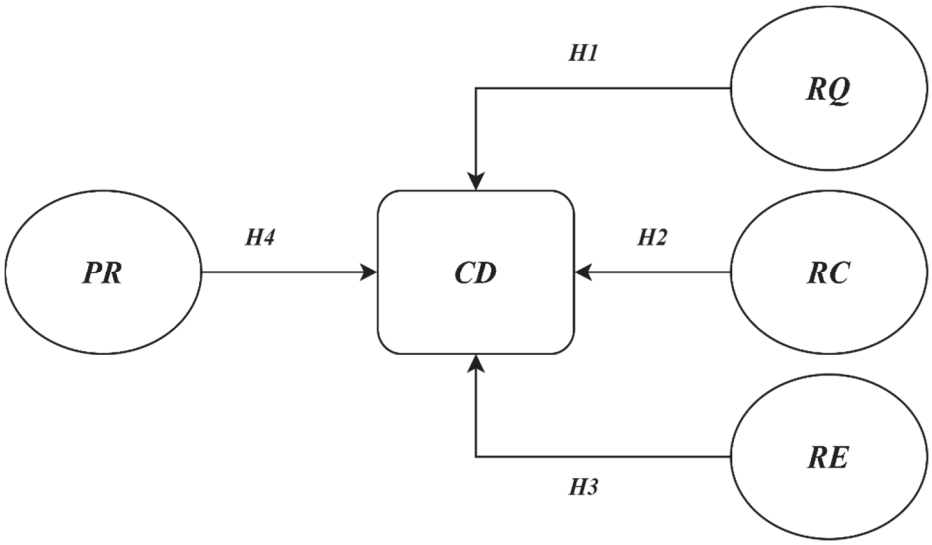
It is also important to note that ratings alone do not always have a significant effect; research has shown that the combination of ratings and reviews exerts a stronger influence on purchasing decisions than either factor alone. A study on the Tokopedia platform found that, while positive ratings influence purchasing decisions, these decisions are not solely dictated by ratings (Ikhsan et al., 2023). While product ratings provide a quantitative assessment, online reviews offer qualitative insights into product experiences. The interplay between ratings and reviews further enhances their influence on consumer perception and decision-making.

Overall, the literature suggests that product ratings play a major role in influencing customer decision-making in e-commerce and online platforms. Understanding the impact of social influence, online reviews, logistics performance, and customer knowledge can help companies improve customer relationship management, increase sales, and enhance the overall customer experience. Based on the discussed literature, this study proposes the fourth hypothesis as follows:

H4: The product rating positively impacts customer decisions in e-marketplaces.

The above literature review is summarised in the following research model:

Figure 1. Research model



Note: RQ=Review quantity, RC=Review consistency, RE=Reviewer's expertise, PR=Product rating, CD=Customer decision.
Source: Compiled by the authors

The research model posits four key dimensions of online reviews – Review Quantity (RQ), Review Consistency (RC), Reviewer Expertise (RE), and Product Rating (PR) – as independent variables hypothesised to positively influence Customer Decision (CD) in e-marketplaces (H1–H4). Grounded in heuristic-

systematic and trust-transfer theories, the model examines how these review attributes shape consumer perception and choices.

3. METHOD

3.1 Measures

This study utilised a structured questionnaire to gather data. Through an examination of the theoretical frameworks around the ideas of review quantity, review consistency, reviewer expertise, and product rating, as well as previous studies examining their relation with customer decision, the concepts mentioned were operationalised into five constructs, each assessed by multiple items on a five-point Likert scale (Likert, 1932), where (1) indicated strong disagreement and (5) indicated strong agreement with a given statement. Furthermore, demographic inquiries were incorporated to gather pertinent participant information, including age, gender, and online shopping patterns. These five constructs are presented in Table 1:

Table 1. Constructs and sources

Construct	Variables	Items	Sources
Review quantity	RQ1–RQ4	4	Ardianti and Widiartanto, 2019; Park et al., 2007; Vrânceanu, 2017
Review consistency	RC1–RC4	4	Kargozari et al., 2023; Li et al., 2024; Zhang et al., 2014
Reviewers' expertise	RE1–RE4	4	Aditya and Alversia, 2019; Vermeulen and Seegers, 2009; Ward, 2016
Product rating	PR1–PR4	4	Agustina and Kurniawan, 2018; Deshpande and Pendem, 2020; Yoon et al., 2013
Customer decision	CD1–CD4	4	Chen, 2009; Colgate et al., 2007; Zhang et al., 2018

Source: Compiled by the authors

To reduce the common issue of method variance, the scale was designed with anonymity in mind, the number of questions was limited, and respondents were allowed ample time for completion. Additionally, the scale was revised to clarify any confusing wording.

3.2 Data collection

The study was based on a questionnaire (see Appendix 1) to explore the influence of rating dimensions on customer decisions in Algerian e-marketplaces. The survey was distributed online through social media groups to collect data from a diverse array of respondents across various towns in Algeria to avoid geographical limitations to a single city or specific cities. A convenience sampling technique was utilised to recruit participants with diverse purchasing behaviours and levels of online experience. This approach was chosen to facilitate feasibility and efficiency (Etikan et al., 2016). The questionnaire was developed using Google Forms and included a filter question to exclude individuals who had not made online purchases in the preceding three months. To ensure comprehension, all survey questions were translated into Arabic by the researchers. 154 individuals participated in the survey and after a two-month period, 61 responses were considered eligible for analysis after the screening process (incomplete surveys, duplicates, and inconsistent responses, e.g., straight-lining or implausible answer patterns, were removed). In addition, the Arabic-translated questions included attention checks to ensure comprehension and engagement, further refining data reliability. The demographic information of the sample (e.g., gender, age, shopping habits) was evaluated to identify key respondents. The next table presents the descriptive statistics for the respondents:

Table 2. Sample description

Characteristics		Frequency (n)	Percentage (%)
Gender	Male	34	55.7
	Female	27	44.3
Age	<30	28	45.9
	30–50	22	36.1
	>50	11	18
Shopping frequency	Daily	2	3.3
	Weekly	15	24.6
	Monthly	33	54.1
	Rarely	11	18

Source: SPSS 27 output (IBM Corp, 2020)

3.3 Data analysis

Structural equation modelling based on partial least squares, a second generation multivariate data analysis technique, is applied to analyse the research model and explain the variance in dependent variables and verify the reliability and validity of the model's components and its items. This technique is commonly utilised in exploratory studies to generate new views (Hair et al., 2022), and is usually contrasted with CB-SEM, which is based on the common factor model, whereas PLS-SEM is based on the composite model, with this being a key distinction between the two approaches (Hair Jr. et al., 2014). Researchers can choose between variance-based partial least squares or covariance-based structural equation modelling. Selecting either method requires careful consideration of the distinctions between the two methodologies. The primary purpose of CB-SEM is to validate existing theories. PLS-SEM, on the other hand, is a prediction-oriented method that is primarily employed in exploratory research but is also suitable for confirmatory research (Sarstedt et al., 2019). In particular, PLS-SEM researchers want their model to have high predictive accuracy while also being rooted in well-developed causal explanations, bridging the apparent divide between confirmatory and predictive research (Sarstedt et al., 2019). Additionally, PLS-SEM is particularly well-suited for analysing survey data with small sample sizes due to its unique statistical properties and methodological flexibility, as it can handle samples as small as ten times the largest number of structural paths directed at any single construct in the model (Hair et al., 2011, 2019). Within this study, the survey responses will undergo meticulous data analysis using SmartPLS 4.1.0.6 (Ringle et al., 2024) to evaluate the reliability and validity of the measurement model, as well as to assess the proposed connections between constructs in the structural model.

4. RESULTS

4.1 Measurement model assessment

In assessing the measurement model, we took into account indicator reliability, construct reliability, convergent validity, and construct validity. Table 3 shows that all quality criteria were established for this model, as indicated by factor loadings, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) values all exceeding the advised cut-off of 0.7, 0.7, 0.7, and 0.5, respectively.

Note that the items marked with *, RC4, PR1, PR4, CD3, and CD4, have been kept even though they did not meet the quality criterion of 0.7 in terms of the factor loadings. The reason for this, as outlined by Hair et al. (2022), is that if a factor loading is between 0.5 and 0.7, the item should be considered for removal only if it enhances the overall quality criteria of the model. In this case, removing the mentioned items negatively affected the model's quality criteria; the items have therefore been kept for further analysis.

Table 3. Measurement model assessment

Items	SFL	Mean	SD	Cronbach's alpha	CR		AVE
					Rho_a	Rho_c	
RQ1	0.826	3.328	1.004	0.820	0.823	0.881	0.648
RQ2	0.803	3.492	0.986				
RQ3	0.786	2.852	1.038				
RQ4	0.805	3.016	1.016				
RC1	0.814	3.279	1.103	0.781	0.785	0.861	0.609
RC2	0.817	3.033	0.975				
RC3	0.837	3.197	1.099				
RC4*	0.638	2.492	1.096				
RE1	0.832	3.328	1.264	0.838	0.848	0.891	0.671
RE2	0.837	2.984	1.063				
RE3	0.817	3.475	1.080				
RE4	0.791	3.197	1.068				
PR1*	0.618	3.557	1.094	0.738	0.765	0.833	0.558
PR2	0.842	3.525	0.985				
PR3	0.808	2.902	1.067				
PR4*	0.698	2.967	0.940				
CD1	0.835	2.787	0.852	0.704	0.769	0.814	0.532
CD2	0.869	2.787	1.042				
CD3*	0.615	3.033	0.975				
CD4*	0.546	2.967	1.130				

Note: SFL=Standardised factor loading, SD=Standard deviation, CR=Composite reliability, AVE=Average variance extracted.
Source: SmartPLS 4 output (Ringle et al., 2024)

As indicated in Table 3, the factor loadings of standardised indicators are anticipated to exceed 0.7, which is considered acceptably reliable. The composite reliabilities surpass 0.7, thereby ensuring construct validity. Cronbach's alpha values meet the threshold of 0.7, signifying that construct reliability is established. The AVE values exceed 0.5, thereby fulfilling the model's convergent validity (Hair Jr. et al., 1998).

The evaluation of discriminant validity is now universally acknowledged as an essential measure in inspecting the interrelationships among reflectively measured constructs. Its purpose is to confirm that a reflective construct shows stronger associations with its own indicators than with those of any other construct in the PLS model (Hair et al., 2022). Common ways to assess a model's discriminant validity are the Fornell-Larcker criterion and the analysis of cross loadings. However, according to Henseler et al. (2015), the current approaches are not consistently effective in detecting issues with discriminant validity in typical research scenarios, as shown in their Monte Carlo simulation study. As a result, they suggest using an alternative method built on the multitrait-multimethod matrix called the heterotrait-monotrait ratio of correlations (HTMT+) (Ringle et al., 2023) to evaluate discriminant validity. Initially, employing the HTMT as a benchmark entails comparing it with a set threshold. Should the HTMT value exceed this threshold, it indicates a deficiency in discriminant validity. The precise threshold for HTMT is a topic of debate; some scholars advocate a threshold of 0.85 (Clark & Watson, 2016; Kline, 2016), while others recommend a threshold of 0.90 (Gold et al., 2001; Teo et al., 2008). The results in Table 4 indicate that the values of the HTMT matrix are lower than 0.85, suggesting that discriminant validity is established.

Table 4. HTMT matrix results

	Customer decision	Product rating	Review consistency	Review quantity	Reviewers' expertise
Customer decision					
Product rating	0.826				
Review consistency	0.693	0.823			
Review quality	0.640	0.744	0.815		
Reviewers' expertise	0.684	0.571	0.653	0.647	

Source: SmartPLS 4 output (Ringle et al., 2024)

4.2 Structural model assessment

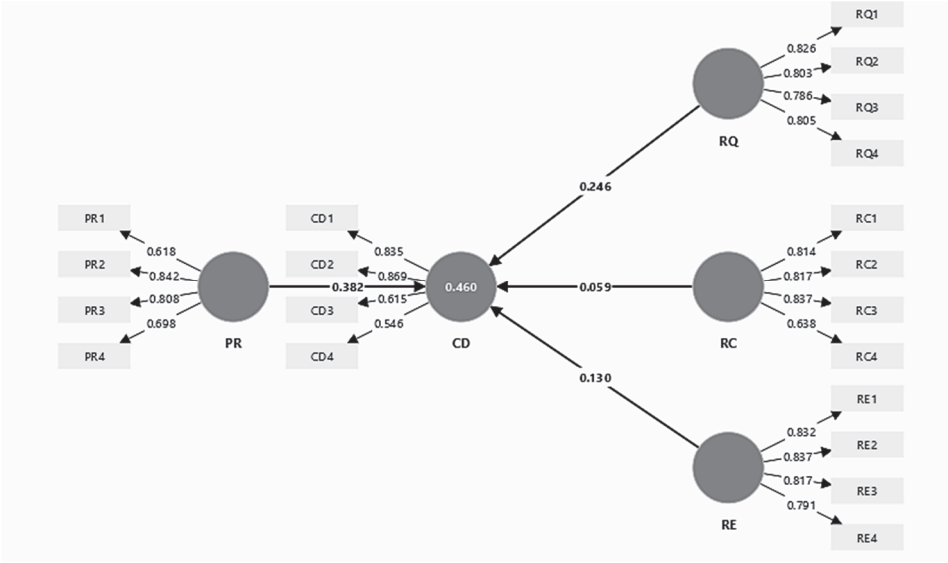
Once the measurement model was examined and met the fundamental quality criteria, the analysis of the structural model proceeded with a focus on collinearity diagnostics using variance inflation factors (VIF), which need to be smaller than 5 according to Hair et al. (2022), coefficients of determination (R^2), the effect size (f^2), and relevance and significance of the model paths (β values). The results and hypothesis testing are presented in Tables 5, 6, and Figure 2.

Table 5. Variance inflation factors (VIF)

Items	VIF values
CD1	2.008
CD2	2.096
CD3	1.315
CD4	1.259
PR1	1.383
PR2	1.888
PR3	1.568
PR4	1.234
RC1	1.683
RC2	2.128
RC3	2.152
RC4	1.224
RE1	1.800
RE2	1.879
RE3	2.001
RE4	1.665
RQ1	1.841
RQ2	1.624
RQ3	1.732
RQ4	1.669

Source: SmartPLS 4 output (Ringle et al., 2024)

Figure 2. PLS-SEM results



Source: SmartPLS 4 output (Ringle et al., 2024)

The R-squared (R^2) coefficient of the endogenous component was calculated to determine the predictive value of the structural model. As seen in Figure 2, all of the review independent variables (review quantity, review consistency, reviewer's expertise, product rating) were able to explain 46% of the variance in customer decision ($R^2_{CD} = 0.460$), which is considered a moderate value according to Hair et al. (2022). In terms of the effect size (f^2), according to Cohen (1988), values ≤ 0.02, ≤ 0.15, ≥ 0.35 indicate small, medium, and large effects, respectively. The results show a small impact of review consistency (RC) ($f^2 = 0.002$) on customer decision and a medium effect of product rating (PR) ($f^2 = 0.128$), review quantity (RQ) ($f^2 = 0.074$), and reviewer's expertise (RE) ($f^2 = 0.016$) on customer decision (CD).

Table 6. PLS coefficient path analysis

Hypothesis	Relationship	Std. beta	Std. error	*t*-value	*p*-value	Decision	Effect size (f^2)
H1	RQ -> CD	0.246	0.148	1.661	0.097	Not accepted	0.074
H2	RC -> CD	0.059	0.160	0.367	0.714	Not accepted	0.002
H3	RE -> CD	0.130	0.191	0.648	0.494	Not accepted	0.016
H4	PR -> CD	0.382	0.155	2.460*	0.014	Accepted*	0.128

*$p < 0.05$. RQ=Review quantity, RC=Review consistency, RE=Reviewer's expertise, PR=Product rating, CD=Customer decision.
Source: SmartPLS 4 output (Ringle et al., 2024)

As represented in Table 6, the relevance of all the direct impacts within the structural model was evaluated by examining path coefficients (*ß*), *t*-values, and *p*-values computed using a bootstrapping procedure (two-tailed, 5000 resamples). RQ had a direct positive effect on CD ($\beta = 0.246$), but this was not statistically significant ($p = 0.097$); thus, H1 must be rejected. RC had a small positive effect on CD ($\beta = 0.059$) but again, the result was not significant ($p = 0.714$), thus not supporting H2. A similar pattern was found in the relationship between RE and CD with $\beta = 0.130$ and $p = 0.494$; therefore, this result does not support the acceptance of H3. However, a different pattern was found in the relationship between PR and CD, with a positive direct effect ($\beta = 0.382$), which was statistically significant ($p = 0.014$); thus, these data support H4.

5. DISCUSSION

The current study investigated the influence of four critical dimensions of online reviews – quantity, consistency, reviewer expertise, and product rating – on the customer decision-making process in Algeria's emerging e-marketplaces. The findings revealed that product rating exerted a statistically significant positive effect on customer decisions ($\beta = 0.382$; $p = 0.014$), corroborating prior research that positions ratings as pivotal trust-building mechanisms (Asari & Yulinda, 2024; Mukarromah, 2023; Novela et al., 2023; Rachmiani et al., 2024; Sari & Othman, 2024; Shazuli Ibrahim, 2023; Sugiarto & Hanif, 2023). In contrast,

review quantity, consistency, and reviewer expertise did not demonstrate significant impacts ($p > 0.05$), diverging from the established literature in developed markets, where these factors are often decisive (Askalidis & Malthouse, 2016; Chevalier & Mayzlin, 2006; Iqbal et al., 2024; Li et al., 2024; Mudambi & Schuff, 2010; Salari, 2024; Sani Sneha, 2024). This discrepancy may stem from contextual differences in consumer behaviour within Algeria's nascent e-commerce ecosystem. Algerian customers, who are relatively new to digital platforms, may prioritise easily interpretable metrics, such as star ratings, over nuanced attributes, such as review depth or reviewer credentials. This aligns with the heuristic-systematic model (Zhang et al., 2014), where users in less mature markets rely on cognitive shortcuts (heuristics) rather than exhaustive information processing. Furthermore, the non-significance of review quantity contradicts studies showing that higher review volumes enhance perceived credibility (You et al., 2015), suggesting that Algerian consumers may distrust review systems due to concerns about authenticity or platform manipulation.

6. CONCLUSION AND IMPLICATIONS

Increasing use of digital platforms has transformed the retail trade, positioning online marketplaces as a primary venue for consumer purchases. In this environment, understanding how shoppers make decisions is essential. Electronic word-of-mouth manifested through customer reviews plays a pivotal role in shaping purchase behaviour, yet the bulk of existing studies examine mature e-commerce contexts. Exploring eWOM dynamics in Algeria is especially important because the country's online market is still developing and consumers often approach digital reviews with caution. Such a setting demands focused investigation into how review attributes drive buying choices.

This study evaluated how four dimensions of online reviews – review quantity, review consistency, reviewer expertise, and product rating – influence consumer purchasing decisions. Survey data were collected from 61 Algerian online shoppers, and the responses were analysed using the partial least squares structural equation modelling method. This approach allowed the simultaneous testing of each review attribute's effect on purchase decisions in the context of Algeria's nascent e-marketplaces.

The analysis revealed that product rating was the only review dimension with a statistically significant impact on consumers' purchase decisions, whereas review quantity, consistency, and reviewer expertise showed no meaningful effect. This result runs counter to patterns documented in developed e-markets, where review volume often influences choices. The findings suggest that Algerian consumers rely on a simple heuristic (prominently using visible star ratings) rather than processing detailed review information. This behaviour likely reflects lower digital trust and the need to minimise cognitive effort when shopping online, explaining why aggregate ratings dominated other review cues.

Theoretical and practical implications

Theoretically, the findings challenge the assumption that review quantity and consistency universally drive consumer behaviour. While studies in mature markets emphasise the role of voluminous or congruent reviews, this research suggests that in nascent e-commerce environments, consumers prioritise simplicity and immediacy. This supports the heuristic processing theory as explained by Zhang et al. (2014), where users under time constraints or cognitive load default to easily digestible cues (e.g., ratings) over detailed analyses. The results also align with the trust-transfer theory as demonstrated by Sirdeshmukh et al. (2002), where ratings act as proxies for platform credibility in regions with low institutional trust.

Practically, the study offers actionable insights for e-marketplace managers. First, optimising rating displays such as highlighting average ratings or using visual cues (e.g., gold stars) could enhance consumer trust in Algeria's sceptical market. Second, incentivising post-purchase reviews may boost rating volumes, indirectly reinforcing credibility. However, investments in reviewer expertise programmes (e.g., verified buyer badges) or AI-driven consistency algorithms may yield limited returns unless paired with consumer education initiatives to improve review literacy. For instance, tutorials on interpreting review depth or identifying fake reviews may shift reliance from ratings to more nuanced attributes. For new and established local and international businesses, the study offers valuable insights to better understand the Algerian consumer mindset, thereby improving their marketing strategies and optimising returns on investment. Policymakers could also advocate transparency regulations, requiring platforms to disclose review authenticity metrics, thereby mitigating distrust.

Limitations

While this study provides valuable insights, several limitations warrant acknowledgement. First, the sample size (n = 61) and geographic restriction to Algeria constrain the generalisability of the findings. Small samples, though accommodated by PLS-SEM according to Hair et al. (2019), reduce statistical power and increase the risk of Type II errors, potentially obscuring weak but meaningful relationships. Second, measurement challenges emerged, as items with suboptimal factor loadings (e.g., RC4: 0.638, PR1: 0.618) were retained to preserve model integrity, risking construct validity. While PLS-SEM tolerates lower loadings, this compromises precision in capturing latent variables. Third, although the use of convenience sampling is time and cost-efficient, it may introduce bias: recruiting participants through social media likely overrepresents younger, tech-savvy individuals while excluding older adults and rural populations with limited digital access. This demographic skew is reflected in the sample profile, in which 45.9% of the participants were under 30 and only 18% were over 50. Finally, the cross-sectional design limits causal inference. For instance, while product ratings correlate with decisions, longitudinal data are needed to determine whether higher ratings cause purchases or merely reflect pre-existing consumer preferences.

Despite these limitations, the study offers several contributions. Methodologically, the application of PLS-SEM addressed the challenges of small sample sizes and complex models, aligning with recommendations of Hair et al. (2019). This approach allowed simultaneous analysis of multiple relationships while maintaining statistical robustness, demonstrating its utility in exploratory and confirmatory contexts. Contextually, the focus on Algeria addresses a critical gap in eWOM research, which has predominantly centered on developed economies (e.g., the U.S., China, and Europe) or Southeast Asian markets. By examining a region where e-commerce is still emerging, characterised by lower digital literacy and infrastructural constraints, this study highlights the variability of eWOM efficacy across cultural and economic landscapes. Additionally, the multidimensional analysis of review attributes advances prior work that often isolates single dimensions (e.g., ratings or quantity). By integrating four factors, this research provides a holistic framework for understanding how diverse review elements interact in shaping decisions, offering a foundation for more nuanced models in future studies.

Future research directions

Future research should address this study's limitations while expanding its scope. Geographically, replicating the study in neighbouring North African countries (e.g., Tunisia, Morocco) or other emerging markets (e.g., Sub-Saharan Africa) could identify regional patterns or cultural moderators. Methodologically, integrating mixed-methods approaches, such as combining surveys with interviews, could uncover why Algerian consumers undervalue review consistency or expertise. Qualitative insights may reveal distrust in platform moderation or linguistic barriers in parsing detailed reviews.

Investigating moderating variables could further refine the model. For instance, does the impact of ratings vary between experience goods (e.g., hotels) and search goods (e.g., electronics)? Similarly, demographic factors such as age, gender, or digital literacy might moderate how reviews influence decisions. Longitudinal designs tracking purchasing behaviour over time could elucidate causal pathways, such as whether high ratings lead to sustained loyalty or short-term spikes in sales.

Finally, measurement refinement is critical. Developing culturally adapted scales for consistency and expertise, validated across diverse populations, would enhance construct validity. For example, reviewer expertise in Algeria might encompass local dialect proficiency or familiarity with regional product preferences, dimensions overlooked in Western-centric scales.

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APPENDICES

Appendix 1. The constructed survey

Axes	Items	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Customer Decision	I prefer to buy from e-platforms that have a user-friendly interface					
	Discounts and promotions heavily influence my purchasing decisions on e-platforms					
	Customer service quality of an e-platform affects my decision to shop there					
	I consider the shipping cost and delivery time before making a purchase					
Review Quantity	I prefer to buy products that have a large number of reviews.					
	I am less likely to purchase a product that has fewer than 10 reviews.					
	When comparing two similar products, the one with more reviews is more likely to be chosen.					
	If a product has a high number of reviews but mixed ratings, I will still consider purchasing it.					
Review Consistency	I prefer to buy products that have consistent reviews.					
	When comparing two similar products, the one with more consistent reviews is more likely to be chosen.					
	I am less likely to purchase a product that has highly inconsistent reviews (some very positive, some very negative).					
	If a product has a high number of reviews but mixed ratings, I will avoid purchasing it.					

Reviewer Expertise	I prefer to buy products that have reviews from experts or knowledgeable individuals.					
	The expertise of the reviewer is a critical factor in my purchasing decision.					
	When comparing two similar products, the one with reviews from more knowledgeable reviewers is more likely to be chosen					
	I would choose a product with fewer reviews from experts over a product with many reviews from general consumers					
Product Rating	I prefer to buy products that have a high overall rating (e.g., 4 stars and above)					
	The overall rating of a product is a critical factor in my purchasing decision					
	I am less likely to purchase a product with an overall rating below 3 stars					
	If a product has a high overall rating but mixed reviews, I will still consider purchasing it					

Source: Compiled by the authors

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BOOK REVIEW:
Power and Progress: Our Thousand-Year Struggle over Technology and Prosperity, by Daron Acemoglu and Simon Johnson, New York, NY, Public Affairs, 2023, 560 pp. ISBN-10: 1399804464, ISBN-13: 978-1399804462

The latest book by two Nobel laureates, Daron Acemoglu and Simon Johnson, offers a critical analysis of the ways in which society develops and deploys technology, and how these processes are reflected in productivity growth. Drawing on a millennium of historical examples, the authors challenge the widely accepted narrative that technological progress inherently drives economic growth and enhances living standards for all social groups. Departing from this narrative, they introduce a more nuanced perspective, emphasising that technological development is highly malleable and contingent on deliberate societal choices – choices that determine whether technology complements or substitutes human labour. Different developmental trajectories thus create distinct groups of winners and losers.

Through historical evidence and scientific literature, presented in an extensive bibliographic essay at the end of the book, the authors systematically dismantle the assumption of the positive link between technological advancement and broad-based prosperity. They critically examine how the direction of technological change shapes both productivity growth and quality of life, particularly in societies where breakthrough innovations are initially subsidised with significant public funds. The book is highly relevant for discussions on how to manage technological policy in the most advanced countries – the U.S., China, and Europe.

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The "productivity bandwagon," which, according to proponents of endogenous growth theory based on knowledge and innovation, should lift all boats like a rising tide, does not function as expected for various reasons. According to the authors, the two most important reasons are the following: (1) In cases where technologies that substitute labour are developed and commercialised, average labour productivity increases significantly, but marginal productivity either declines or increases much less. Automation is not the only form of technological progress; often, there is a choice between full automation and more worker-friendly applications of machines, such as creating new labour-intensive tasks that are important for the production process (as discussed by Acemoglu & Restrepo, 2018). (2) The second reason lies in the way rents are distributed. Neither average nor marginal increases in labour productivity necessarily translate into higher wages. If there is a coercive labour market, where workers have limited bargaining power and few outside options (as discussed in Acemoglu & Wolitzky, 2011), wages may remain stagnant or even decline in real terms despite higher productivity. The translation of productivity gains into wage increases depends on the type of rent-sharing arrangements and how new technologies impact workers' bargaining power. Periods when workers had a voice and participated in the decision-making process on the use of technology saw positive effects of the new technologies on wages and shared prosperity, which in turn supported further development.

In general, workers can benefit from technological progress even if it follows a path of high automation, provided that productivity growth is sufficiently large and rent sharing is fair. However, can we realistically expect this? Throughout the book, the authors present multiple arguments suggesting that this is unlikely. Firstly, the workers' bargaining position has weakened due to institutional changes. Major shifts in ideas about how business models should be organised (e.g., the prevalence of remote work, which weakens the workers' voice) and new technologies that allow for much greater surveillance and monitoring at workplaces have contributed to the diminishing bargaining position of workers. Even worse, productivity growth itself does not seem very rapid, particularly in Europe. The so-called "excessive automation" – termed "so-so automation" by the authors – fails to create new jobs, while the labour share in total value added continues to shrink due to specific technologies focused on labour savings.

Acemoglu and Johnson explain in their book that the development of new technologies is largely driven by a small group of influential individuals who, supported by a tax system that favours capital investment, tend to develop technologies that replace rather than complement labour, thereby advancing a

model of a "two-tier society." They propose a three-pronged strategy to redirect technological progress towards shared prosperity instead of merely maximising returns to capital, the prevailing paradigm of managers and owners in the past three decades. Their "three-pronged society" is based on: (1) changing narratives and norms to emphasise the role of technology in improving the lives of all people, not just the wealthy or tech elites; (2) building countervailing powers by strengthening institutions, civil society, and employee voice to balance the power of large tech firms and ensure technology serves broader societal interests; (3) implementing effective public policies to fairly distribute the benefits of technological progress, similar to concept of the entrepreneurial state (Mazzucato, 2018). Addressing global challenges requires carbon taxes, significant public subsidies for R&D in areas of missing markets, and regulations that steer innovation toward sustainable development and equitable benefit sharing.

Future research must focus more on machine usefulness rather than merely machine intelligence, as only usefulness complements human capabilities. Based on historical evidence and more than 50 pages of bibliographic references, the book convincingly argues that only through democratic participation can technology be developed in a way that fosters shared prosperity. Employee voice in technological choice processes must become a crucial component of future development. Historical periods when workers were involved in decisions about technological changes, trained for new tasks, and shared in the productivity gains corresponded with the highest improvements in quality of life.

Regarding economic policy measures, the authors suggest several concrete examples for promoting more beneficial technological progress: breaking up large tech firms (following early 20th-century U.S. precedents such as Standard Oil and U.S. Steel) to foster competition and innovation diversity; equalising tax rates on labour and capital to remove biases favouring automation; tightening regulations on personal data collection; introducing a digital advertising tax; and rejecting the idea of universal basic income, as individual prosperity should be based on societal contribution, not "charity" from tech elites. It is crucial to allocate sufficient private and public funds to education and workforce training.

In summary, their work highlights the importance of democratic participation and countervailing powers against the tech elite in designing and implementing new technology for the benefit of the community. The future societal narrative should be built on fostering countervailing forces and promoting technologies that enhance collective welfare. Their policy solutions align less with the neoliberal paradigm and more with alternative approaches that emphasise

greater involvement of the state (especially in addressing inequality, as argued by Blanchard & Rodrik, 2023), based on redefined values and new social contracts (Carney, 2021; Shafik, 2021). While some works portray dystopian scenarios in the face of such emerging technologies as generative AI, Acemoglu and Johnson implicitly suggest viable solutions. The major contribution of their work lies in tempering the overly optimistic belief that technology inherently generates prosperity and in contributing to a shift in the mainstream narrative on automation. *Power and Progress* makes a significant contribution to the formation of a movement for socially useful technology and it should be required reading for policymakers shaping the future of technology, work, and society.

Furthermore, the book offers critical insights for scholars across such disciplines as economics, political science, sociology, and science and technology studies. Its challenge to conventional growth models and nuanced perspective on the political economy of technology provide a robust foundation for analysing the complex interactions between technological change, labour markets, and social structures. With extensive historical evidence, supported by more than 50 pages of bibliographic references, it serves as a valuable resource for academics examining how technological choices shape economic inequality, institutional power, and social progress. In this sense, *Power and Progress* is not just a policy roadmap, but also a foundational text for anyone seeking to understand the broader societal implications of technological innovation.

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As a rule, submitted articles should not exceed 8,000 words. All pages apart from the first one should be numbered. Subtitles should be concise, clearly marked in bold, and numbered (up to two levels of numbering). No other entries should be bolded. Formulae should be numbered on the right-hand side of the page. In case of long proofs, these should be inserted in a separate Appendix, following the References. Tables and Figures must not use colour, and should be in a format easy to edit, for instance they should take half a page (or a full page) within the indicated margins. They should be clearly labelled at the top, with a legend at the bottom, and should be logically ordered, using Arabic numerals. Sources of the data should be given below tables and figures.

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