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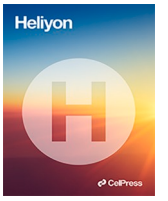

Research article

Commodity prices and economic growth: Empirical evidence from countries with different income groups

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ABSTRACT

The purpose of this paper is to examine the effect of global commodity prices such as beverage, energy, fertilizer, food, metal and mineral, precious metal and agricultural raw material on GDP per capita of countries with different income levels which are low, lower-middle, upper-middle, and high. The results of the study using panel system GMM method over the period 2007–2021 showed that for all income group countries, the impact of energy and fertilizer prices on GDP per capita is negative, while the impact of food and metal and mineral prices is positive on GDP per capita. The study also found that rising prices of agricultural raw materials reduces GDP per capita of all income group countries except lower-middle income countries. Moreover, according to the results of the study, rising beverage prices increased the GDP per capita only of high-income countries, while rising precious metal prices decreased the GDP per capita of lower-middle and high-income countries. The study revealed that price changes in all commodity groups have an impact on the GDP per capita of high-income countries. It is demonstrated that price changes in all commodity groups have an impact in both directions on the GDP per capita of all income groups, depending on whether they are net producers or net consumers. The results of the study showed that, contrary to the literature, the countries most affected by commodity prices are high-income countries. Based on the empirical findings, this study point to the need for international cooperation to minimize the adverse effects of commodity price changes.

1. Introduction

Commodity prices, which do not follow a straight line, often fluctuate more than the prices of manufactured goods or services [1]. In commodity markets notorious for their volatility, it's common for prices to fluctuate by more than thirty percent in a year or two [2]. However, the roller coaster trend in commodity prices, which occurred rarely in the past, has recently been a recurring feature of global commodity markets [3,4]. Since the mid-1990s, prices in commodity markets have followed a more volatile course because of the financialization of commodity markets, increases in demand from the global manufacturing industry, fluctuations in factor input costs, unfavorable weather conditions, and intensifying geopolitical tensions [5,6]. Especially due to the disruptions in supply chains following the COVID-19 pandemic and Russia's invasion of Ukraine since the beginning of 2022, the prices of many commodities climbed rapidly and reached their highest levels in history since the 1990s (Fig. 1).

Recently, changing commodity prices has made an unambiguous effect on the income levels of all countries, no matter how

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different their development levels are. Theoretically, commodity prices affect a country's income through two channels, "income" and "cost" [8]. Commodity prices determine the value of the commodity and affects the demand for commodities used in agricultural and manufacturing industrial production. According to Deaton's [9] net benefit approach, the effect of the price of a commodity on income depends on whether the country is a net producer or net consumer of the commodity in question. Net producers and exporters benefit from higher commodity prices, while net consumers and importers suffer. The reverse is true when commodity prices decline [10–14].

The dependence of export revenues of many developing countries, especially low-income ones, on a few commodities has been of interest for both academics and policy makers. Until the 1980s, abundance of natural resources was considered to be an important advantage for developing countries attempting to achieve a rapid economic growth. Since the 1980s, a sizable literature, challenging the view that an abundance of natural resources is a blessing for these countries whose exports are dependent on a small number of commodities, has emerged [15–20]. These studies have suggested that countries with abundant natural resources tend to grow slower than countries with scarce resources, and that natural resource endowment could turn into a "curse". However, many studies have also claimed that the abundance of natural resources is a blessing and positively affects economic growth [21–23]. Besides, in recent years, many studies have focused on the effect of commodity price volatility on economic growth. The overwhelming majority of those studies found that commodity price volatility negatively affects economic growth [22,24–26]. A few studies have pointed out the existence of a positive relationship between commodity price volatility and economic growth [27,28]. Empirical results of some studies have also revealed that there is no relationship between commodity price volatility and growth [29,30].

However, these studies have focused mostly on low-income countries whose income depends on the export of a small number of commodities [22,27,31]. It is difficult to argue that commodity price movements are only a problem for the low-income countries. In a globalizing world, no country, whatever its income level, is immune from the effects of commodity price movements [13]. In the past, commodities were viewed as plentiful and cheap for the growth of high-income countries. Today, those countries cannot easily access them due to increasing drought, wars, bottlenecks in production, and more autarkic anti-globalization policies implemented in the post-pandemic period [4]. Although high-income countries still account for the majority of global commodity consumption, especially emerging market countries, which have a strong growth performance, have also started to take a larger share of the commodity market since the early 2000s [32,33]. Therefore, the burning question is to reveal the impact of commodity price changes on the income of countries in all income groups. This study attempts to fill this gap in the literature.

The primary objective of this study is to investigate the impacts of commodity prices like energy, fertilizer, food, raw materials, metals/minerals, and precious metals on GDP per capita of countries with different income levels. Compared to studies in the existing literature, the study covers changes in prices of a wide range of commodities. Moreover, the study focuses on the impact of change in prices not only on the economic growth of low-income countries whose export incomes are dependent on a few commodities, but also on the economic growth of high-income countries, which are the largest consumers of the global commodity market. In the current literature, this is the only study, at least to the authers' knowledge, that examines countries together by considering all income groups separately. To this end, based on the world bank's country classification, we choose 168 countries from 4 different income groups, namely: low, lower-middle, upper-middle, and high.

This study contributes to the existing literature in four ways. Firstly, this study investigates the impact of changing commodity prices on the GDP per capita of countries with different income levels. The extensive literature has focused more on low-income countries that are dependent on a few commodities and other income group countries that import commodities. To the best of our knowledge, this study is novel in contributing to the literature analyzing countries from all income groups, both commodity exporters and commodity importers together. Secondly, this study has a very comprehensive sample of 168 countries. Although there are studies examining many countries in the literature [34–36]. This study is unique in the literature in terms of country sample size. Thirdly, in

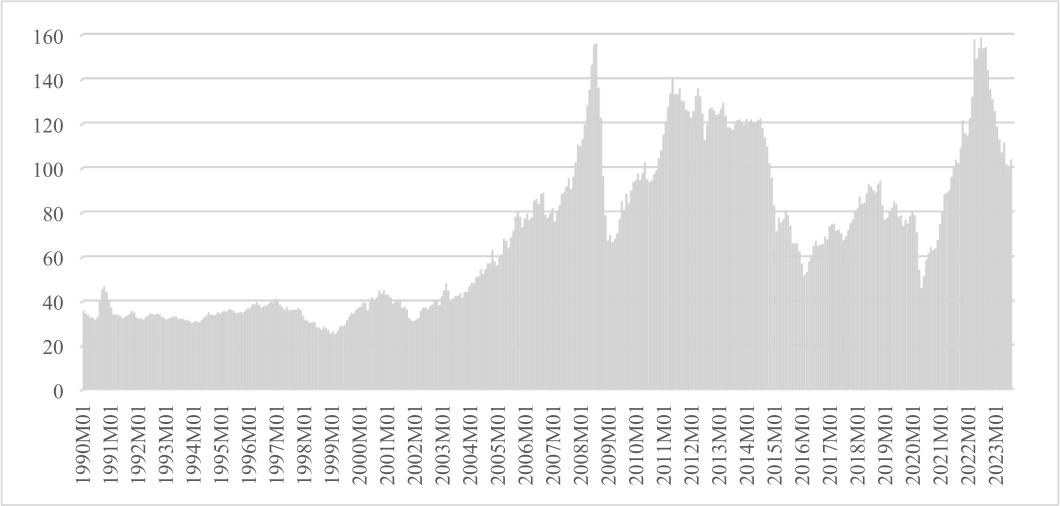

Fig. 1. Commodity price index (1990–2023), source [7].

this study, all commodity types as seven main groups were used to investigate the effect of each commodity price on GDP per capita. Although there are studies that analyze the effect of commodity price volatility on growth, these studies include a limited number of commodities [30,37–39]. Lastly, although there are many studies in the literature examining the effects of commodity price volatility on economic growth, this study attempts to examine the impact of commodity prices levels on GDP per capita.

The rest of the study is organized as follows: Section 2 reviews the relevant literature. Section 3 presents the empirical methodology and data. Section 4 presents a discussion about the emprical results. Section 5 provides the conclusion and policy implications.

2. Literature review

One of the burning problems of recent times in the literature is related to the effects of commodity prices. Commodity prices affect both the production of the commodity and related goods and the consumption of commodity [37]. The relationship between commodity prices and economic growth has a significant place in the literature. The results of these studies vary depending on the type of commodity, country or region.

Beverage consisting of coffee, cocoa and tea is produced mostly by low-income countries in South America, Africa and South Asia. Therefore, the ups and downs in the prices of these products have the potential to affect the macroeconomic aggregates of the countries in question, such as growth, employment, poverty, exports and government revenue. There are many studies in the literature focusing on the impact of beverage exports on economic growth [40–45]. Additionally, some studies have examined the impact of beverage taxes on beverage prices [46–49]. However, there are few studies in the literature examining the impact of beverage prices on economic growth. In this regard [50], investigated whether commodity prices affect the real exchange rate and manufacturing industry production in Colombia, which is dependent on two different products, oil and coffee. They applied a vector error correction model using annual data from 1972 to 2013. According to the results, there is a positive relationship between commodity prices and real exchange rate, and therefore commodity price increases harm Colombia's competitiveness. In contrast, Bussolo et al. [51], using household survey data for Uganda, found that the increase in coffee prices was accompanied by a significant reduction in poverty. Similarly, by using regression model with time series from 1961 to 2012, Ankrah et al. [52] inveatigated whether world cocoa prices have an impact on cocoa production in Ghana. The findings of their study showed that the world cocoa price has a positive relationship with the production of cocoa in Ghana. Again, the study by Ref. [53] also showed that higher coffee prices lead higher household income and lower rates of poverty. However, Ofori-Abebrese et al. [54] reached very different results from previous three studies. Using autoregressive distributed lag model, they studied relationship between cocoa prices, exchange rate and economic growth for Cote d'Ivoire and Ghana over the period 1980–2011. According to the estimated results, the increase in cocoa prices negatively affects economic growth in Ghana only in the long term, but no significant relationship was found between the two variables in the short term. On the other hand, the study did not reach significant results for Cote d'Ivoire, both in the short and long term.

Fertilizer, one of the most important agricultural inputs, has a crucial role in increasing agricultural productivity. Fertilizer prices alone correspond to 15–20 % of the total costs in agricultural production [55]. Some studies in the literature have focused on analyzing the effects of fertilizer policies, such as pricing and subsidies [56–59]. On the other hand, most studies have examined more on the effects of fertilizer use on agricultural production. In this respect, a study by Ref. [60] tested the relationship between agronomic inputs such as fertilizer and cereal yields per hectare. The results of the study confirmed that the use of fertilizer increases cereal yield. They furher found that the increase in agricultural yields also promotes GDP per capita. Consistent with [60,61] showed that the use of fertilizer is effective in increasing agricultural production in the China. Similarly [62], also demonsrated that fertilizer use stimulates land productivity and increases agricultural income. On the other hand, the study of [63] employed a simulation model to examine the impact of fertilizer prices on different indicators such as income of households in Malawi. The results revealed the existence of a negative relationship between fertilizer prices and income and other indicators [64]. found that rising fertilizer prices reduced the yields of most crops for 10 Asian countries over the period 1966–2005. Again, the study by Ref. [65] built different fertilizer price scenarios based on an econometric relationship with oil and gas prices from 2005 to 2050. According to the findings of their studies, rising fertilizer prices reduce crop yields.

Energy, which comprises coal, crude oil and natural gas, is one of the most fundamental inputs used in the production of different goods and services. Non-renewable energy sources still have a substential share in the total. Thus, rising energy prices will result in higher costs at all production stages throughout the country's economy. However, rising energy prices are to the benefit of net producer and exporting countries and to the detriment of net consumer and importing countries. A study by Arshad et al. [66] investigated whether energy prices affect economic growth in Pakistan. They used quarterly data for the period 1991–2011 and applied the Generalized Method of Moments (GMM). The estimated results revealed the negative impact of energy prices on growth. Similarly, Ferdaus et al. [67] investigated how energy consumption and energy prices affected economic growth for the Next 11 countries over 1990–2013. According to the results of panel Autoregressive Distributed Lag approach, energy prices negatively affect economic growth both in the long-run and short-run. Contrary to Arshad et al. [66] and Ferdaus et al. [67], Shahbaz et al. [20] examined the link between oil prices and economic growth by applying the VECM Granger causality approach for the case of USA. The estimation results demonsrated that oil prices positively affect economic growth in the long run. Consistent with Shahbaz et al. [20], Prabheesh and Laila [68], by applying the NARDL approach, examined the impact of crude oil and palm oil prices on GDP in Indonesia over the 2000–2019 period. The findings of the study confirmed the existence of a significant and positive relationship between both oil and palm oil prices and the country's output. In the same vein, in case of Azerbaijan, Mukhtarov et al. [69], using the Johansen cointegration and vector error correction model approach, analyzed the influence of oil prices on economic growth and other macroeconomic variables from 2005 to 2019.

Precious metals consisting of gold, silver and platinum are considered "safe havens" to protect against negative economic

conditions, especially where fluctuations in asset prices occur [70,71]. Especially gold is in high demand due to its value storage role. Annual gold demand reached 4741 tons in 2022, almost the same level as in 2011, when extraordinary investment demand was experienced [72]. However, the increase in demand for precious metals will be met by imports unless there is domestic production. There have been studies in the literature examining the relationship between gold production and gold prices and other macroeconomic aggregates such as growth. In this regard, a study was presented by Bildirici and Sonustun [73] examined whether gold and oil prices have an impact on the growth of some oil exporting countries. By using MS-VAR method for the period from 1979 to 2018, they noted the importance of gold and oil price volatility on economic growth. Other study by Bildirici and Gokmenoglu [74] investigated whether precious metal production had an impact on the growth of Australia, Canada, Mexico, the Philippines, Peru, South Africa and the USA. By using Markov-Switching-Vector Error Correcting model, they found that in the long run precious metal production affects growth, but the effect of precious metal production on growth varies from country to country. Li [37] tested the price volatility of commodities such as livestock, agriculture, coal, crude oil, and precious metal on the growth of China from 1981 to 2019. According to results of, there does exist a positive relationship between growth and commodity prices. Guan et al. [75] studied how volatility in oil and gold prices affects the growth in the top 10 oil-producing and 10 gold producing countries. The study, by employing the panel autoregressive distributed lag model, used the 2000–2020 period data of oil and gold producing countries. They concluded that volatility in both oil and gold prices has adverse effects on growth in the long run. Raza et al. [76], who used monthly data for the period 2000–2015, examined the impact of gold and oil prices and their related volatilities on stock markets in China, India, Brazil, Russia, South Africa, Mexico, Malaysia, Thailand, Chile and Indonesia. According to the results of the nonlinear ARDL approach, gold prices affected the stock markets of BRICS positively and others negatively. Oil prices have negatively affected the stock markets of all countries. On the other hand, oil and gold price volatility had a negative impact on stock markets of all countries.

The prices of metals and minerals, including aluminum, copper, iron ore, lead, nickel, tin and zinc, are important not only for consumers who use them widely in various sectors, but also for the producing countries [77]. Therefore, rising metal and mineral prices lead to an income-increasing effect for net producer and exporter countries and an income-decreasing effect for net consumer and importer countries. Although there is a large literature examining the impact of metal and mineral imports and exports on economic growth [78–81], the number of studies examining the effects of prices of different metal and mineral types is more limited. In this regard, a study of [36] used a panel-VAR approach and constructed a commodity price index that includes the prices of oil and gas and the prices of nine minerals. According to estimated results, rising prices promote the level of national income per capita. Similarly [82], also examined the impact of metal-mining prices on poverty in Chile utilizing 1998–2013 household data. They found that rising metal prices increased employment while reducing poverty. In addition [83], claimed in their studies that mineral resources contribute to the economic and social development of countries. On the other hand [84], used a dynamic computable general equilibrium model and showed that fluctuation in world iron ore prices has detrimental effects on growth and employment in China. A study by Ref. [85] using a dynamic stochastic general equilibrium (DSGE) model for Chile invesitigated the effect of rising copper prices on growth and the results proved the positive relationship between variables [86]. employing the Bayesian Model Averaging (BMA) approach over the period 1995–2015 for Zambia examined relationship between the copper price dynamics and economic growth. The study showed a positive and significant relationship between copper prices and economic growth [87]. analyzed the relationship between copper prices and economic growth in Chile from 1995 to 2018. The results of the causality, cointegration and impulse-response function revealed the existence of a strong and positive relationship between copper prices and economic growth. By imlementing a quantile regression approach [88], examined the impacts of changing aluminium price movements on manufacturing industry production during the COVID period in India. According to estimated results, aluminium prices have a statistically significant and positive effects on Indian manufaturing sector.

Agriculturel raw materials, which comprise timber and other raw materials such as cotton, natural rubber and tobacco, are the primary source of many sectors, from textiles to housing and transportation. Most studies have focused on the impact of agricultural raw material production, imports and exports on economic growth [89–94]. But the current article has examined the impact of prices of aggricultural raw materials GDP per capita. Rising agricultural raw materials prices are a gain for the producer and exporter and a cost for the consumer and importer. There are few studies in the literature discussing the effects of agricultural raw material prices on economic growth. By using panel data model, GARCH model and impulse response function [95], investigated the interactions between prices and productions of natural rubber. The findings of the study emphasized that there is a positive relationship between price increases and economic growth for developing countries that export agricultural raw materials. Similarly [96], found that the rise in cotton prices would result in an increase in cotton production and farmers' income. On the other hand [97], analyzed whether the volatility in prices of agricultural raw materials affects the growth of developed countries. By based on the generalized autoregressive conditional heteroskedasticity (GARCH) model from 1980 to 2020, they found that agricultural raw material prices harm the economic growth of developed countries that import these raw materials. A study by Ref. [98] employed the two-step least-squares method to analyze the impact of volatility and the level of raw material prices on GDP and industrial production for groups of three different developed countries. According to the results, rising raw material prices improved income dynamics, while high price volatility worsened them.

Food, which consists of three different sub-groups such as creals, oils and meals, and other foods, are primary needs of humans and other living beings. If food prices rise, food producers and exporters earn higher incomes. Otherwise, food consumers and importers will have to bear higher costs [3]. In this regard, Ivanic and Martin [99] and Ivanic et al. [100] argued that rising in staple food prices in recent years increases the real incomes of food producers in many poor countries but have a detrimental impact on the incomes of net food consumers. They found that the impact of rising food prices on poverty varies by country and by commodity, and that the poverty-increasing effect was much more frequent and greater than the poverty-reducing effect. Wodon and Zaman [101] also reached similar results with those of the previous two studies and emphasized that higher food prices generally increase poverty in Sub-Saharan

Africa. On the other hand, Parabheesh and Laila [68] obtained different results. Using linear, and non-linear autoregressive distributed lag (ARDL) model for Indonesia in 2000–2019, they found that rising oil and palm oil prices posively affects on GDP. In line with Parabheesh and Laila [68], a study of Headey [102], using simulation models, tested the relationship between real food prices and change in poverty. Estimatied results revealed the existence of a relationship between food price increase and poverty reduction. The study also reported that agricultural production responded positively to food price increases. In other study by Headey and Hirnoven [103], who applied panel regressions and used annual data for 33 middle-income countries from 2000 to 2019, found that the increase in real food prices reduces the number of poor people and also encourages agricultural production, except countries with larger urban or non-agricultural populations.

3. Data and methodology

This study analyzes the impact of commodity prices on economic growth for the four different country groups over the period 2007–2021 using panel system GMM method. We take GDP per capita as a proxy to represent economic growth. We use seven different commodity prices which are the prices of beverages, energy, fertilizers, food, metals and minerals, precious metals and raw materials. In addition, we use four control variables to control for the effects of these variables. The control variables are the ratio of gross fixed capital formation to GDP, the ratio of international trade to GDP that is the ratio of sum of imports and exports to GDP, the ratio government expenditures to GDP and the population growth rate of each country. We take the natural logarithms of GDP per capita and commodity prices to obtain elasticity coefficients while we take level values of the control variables. The underlying reason for using variables in this way is that per capita GDP and commodity prices are expressed quantitatively, and control variables are expressed proportionally. To control for the effects of the Covid-19 pandemic, we use a dummy variable that takes a value of 1 for the years 2020 and 2021, and 0 for the other years. As is known, the Covid-19 pandemic manifested itself in the form of production declines, disruption of the supply chain, supply constraints and subsequently rising inflation in the majority of world economies. If these effects of Covid-19 are not controlled for by using a dummy variable, they may be misinterpreted as the effect of commodity prices and other control variables, which are explanatory variables, on national income per capita, the dependent variable of our analysis. Therefore, by using a dummy variable for Covid-19, it is aimed to control these effects and see the net effects of other explanatory variables.

Table 1 shows the descriptive statistics for the explanatory variables. The reason for removing the letter L from the names of the variables is that the actual values of the variables are used, not their logarithmic values.

Panel A in Table 1 shows the descriptive statistics of commodity prices. Since these prices are global, they are valid for all countries for each year. Mean, median and maximum values of FERT is the highest as compared with the other commodity prices. Looking at skewness, all the values of commodity prices are positively skewed. In other words, mean values of the commodity prices are more than the corresponding mode values and the data are skewed left. Kurtosis values indicate that only RAW, FERT an BEV have a leptokurtic distribution since their kurtosis values are 4.724, 3.667, 3.249 and they are greater than 3 while the other commodity prices are platykurtic since their values are lower than 3. This can be interpreted that while RAW, FERT and BEV have a relatively high probability of extreme events, whereas the opposite is true for the other commodity prices which have platykurtic distributions. In other words, RAW, FERT and BEV have many outliers while the other commodity prices have fewer outliers.

Looking at panel B showing the descriptive statistics of GDPC for each country group, the highest standard deviation is of high-income country group while the lowest one is of upper-middle income group. In other words, the most heterogenous group in terms of income per capita is high-income country group while the most homogeneous one is upper-middle income group. As for skewness, all the country groups have a positively skewed distribution This shows that the data all income groups have a skewness to

Table 1
Descriptive statistics.

Panel A: Descriptive Statistics of Commodity Prices

	BEV	ENERGY	FERT	FOOD	METMIN	PREC	RAW
Mean	88.64131	95.42059	107.1733	101.1170	88.56996	104.2237	88.41558
Median	86.09782	94.36915	100.0000	93.12163	84.79044	100.0000	82.94613
Maximum	115.9746	135.2151	190.0851	124.1511	116.4445	140.1723	122.0384
Minimum	68.71736	52.68381	73.19746	83.86603	62.96807	59.49352	75.79315
Std. Dev.	11.33417	27.90660	31.52155	13.89191	16.41600	23.81169	11.82132
Skewness	0.583151	0.094141	1.081523	0.488755	0.161532	0.017099	1.474400
Kurtosis	3.248816	1.676597	3.666632	1.663571	1.870587	2.149437	4.724461

Panel B:Descriptive Statistics for GDPC of Different Country Groups

	Low Income	Lower-Middle Income	Upper-Middle Income	High Income
Mean	702.6514	2360.931	6897.185	40120.67
Median	640.6767	1998.738	6238.110	32169.50
Maximum	3188.750	9225.845	19849.72	234315.5
Minimum	170.7069	321.8283	1531.222	6205.822
Std. Dev.	380.1949	1398.693	2864.519	29271.33
Skewness	2.565324	1.554616	1.075931	2.375717
Kurtosis	12.92032	6.787731	4.452530	11.40031

the left and the mean values are more than the corresponding mode values. Kurtosis values demonstrate that all the country groups have a leptokurtic distribution since their kurtosis values are higher than 3 and 12.920, 6.788, 4.452 and 11.400 for low-income, lower-middle income, upper-middle income and high income groups, respectively. This can be interpreted that the data of all country groups have a relatively high probability of extreme events. Moreover, all the country groups have many outliers.

3.1. Panel system GMM regression model

3.1.1. Dynamic panel data analysis and panel system GMM technique

Panel data analysis is key in identifying relationships that are difficult to detect with a particular cross-section or time series. In addition, panel data analysis emerges as a method with a wide range of uses, as it has more degrees of freedom, is based on more data, and eliminates multicollinearity problems to a large extent compared to time series models. However, the behavior patterns of economic actors can be affected by the behavior of the previous period(s) due to many reasons such as permanence or habit persistence. For this reason, dynamic modeling is needed in many panel data analysis. Many economic activities appear to be inherently dynamic. For this reason, dynamic modeling in panel data analysis provides researchers to comprehend the adjustment dynamics more clearly [104]. Balestra and Nerlove [105] suggested the first panel data model. Since then, panel data models have become very popular in the literature [106].

A general panel data model is given by:

$$y_{it} = \delta y_{i,t-1} + x_{it}^{'}\beta + u_{it}\ i = 1, \ldots\ldots N; t = 1, \ldots\ldots T \tag{1}$$

In equation (1), y_{it} is dependent variable and y_{it-1} is the lagged dependent variable, respectively. x_{it} represents a vector of regressors while u_{it} symbolizes the disturbance term. The error term takes the form of a one-way error component model and can be represented as:

$$u_{it} = \mu_i + \nu_{it} \tag{2}$$

where the μ_i and ν_{it} have a form of normal distribution in equation (2). On the other hand, several issues arise due to the use of the lagged dependent variable as a regressor. Due to the fact that y_{it} is a function of μ_i, its lagged value is also a function of μ_i. For this reason, y_{it-1} becomes associated with the error term. Since the lagged value of the dependent variable is associated with the error term, it makes the OLS estimator biased and inconsistent, even if ν_{it} is not serially correlated. The fixed effects estimator is consistent only in the case that the time dimension is too large as compared with the number of cross-sections. A method is suggested by Anderson and Hsiao [107] that provides individual effects to be removed via the first difference transformation. The argument that instrumental variables can be used for the estimation of the difference equation is suggested by Anderson and Hsiao [107]. On the other hand, this method results in inefficient estimates, even if they are consistent, as they do not satisfy all the appropriate moment conditions [104]. The fact that not using all possible instrumental variables is a reason for this situation is stated by Arellano and Bond [108]. Therefore, they suggested the generalized method of moments (GMM). The employment of all acceptable previous values of variables as instruments is an effective technique is suggested by Arellano and Bond [108]. They suggested a similar way with Anderson and Hsiao [107] to remove the effects that are idiosyncratic to each cross-section. On the other hand, they showed the use of the difference equation technique to get rid of idiosyncratic effects leads to a new bias because the new disturbance term $(\nu_{it} - \nu_{it-1})$ of the difference equation is associated with $\left(Y_{i,t-1} - Y_{i,t-2}\right)$. If the error term does not have serial correlation and the regressors are weak, it is supposed that the following moment conditions hold:

$$\begin{aligned} E\left[Y_{i,t} - s\left(\nu_{it} - \nu_{i,t-1}\right)\right] &= 0 for\ s \geq 2; t = 3, \ldots, T \\ E\left[X_{i,t} - s\left(\nu_{it} - \nu_{i,t-1}\right)\right] &= 0 for\ s \geq 2; t = 3, \ldots, T \end{aligned} \tag{3}$$

where X's represent the independent variables $(\nu_{it} - \nu_{it-1})$ and denotes the new disturbance term in equation (3).

Since they are commonly used in dynamic panel data analysis, Soto [109] emphasized that both the difference GMM and the system GMM were developed within the context of labor and industrial studies which the number of individuals (N) is very large. Nevertheless, the large number of dynamic panel studies involve less not more than 100 cross-sections and probably less than half that. In addition, not all instrumental variables may be employed because of the small sample size, which may reduce the effectiveness of the various GMM estimators used in the research. Therefore, Soto [109] examined the efficiency of the several estimators involving applying Monte Carlo simulations to small samples. The fact that system GMM estimator has the lowest bias relative to the other estimators (i.e the difference GMM estimator) is the key finding of the study [109]. In addition, Blundell and Bond [110] put emphasize on that the conventionally used difference GMM estimator acquired by first-differencing transformation was determined to have large finite sample bias and poor precision characteristic in simulation studies in the case that the coefficient of the lagged dependent variable is large and the number of time series observations is small. Blundell and Bond [110] showed that the system GMM estimator that is proposed by the authors provides more effective results as compared with the difference GMM estimator under the condition that the additional moments conditions required for the system GMM are valid [111]. Therefore, the system GMM estimator is preferred to use in this study.

A forward orthogonal deviation transformation method in order to remove country-specific effects as compared to first-differencing transformation is developed by Arellano and Bover [108] due to the fact that difference transformation enlarge the gaps in the data. In the case of missing of one period of data, two differences are missing in transformed data. The forward orthogonal deviation

transformation method makes changes to the data by subtracting each observation value from the mean of all future observation values, thus avoiding data loss no matter how many gaps there are. Owing to the fact that lagged observations are not included in the formula, they are considered as acceptable instrumental variables [112]. In addition, Hayakawa [113], using the Monte Carlo simulations method, showed that the GMM estimator of the model transformed with forward orthogonal deviation performs more efficiently than the first difference transformation. Hence, the forward orthogonal deviation transformation is selected to remove the effect that are idiosyncratic to each cross-section owing to its superiorities.

The econometric model adopted in this study is as follows:

$$LGDPC_{i,t} = \beta 0 + \beta_1 LGDPC_{i,t}(-1) + \beta_2 LBEV_t + \beta_3 LENERGY_t + \beta_4 LFERT_t + \beta_5 LFOOD_t + \beta_6 LMETMIN_t + \beta_7 LPREC_t + \beta_8 LRAW_t + \beta_9 GFCF_{i,t} + \beta_{10} TRADE_{i,t} + \beta_{11} GOV_{i,t} + \beta_{12} POP_{i,t} \quad (4)$$

where LGPDC and LGPDC (-1) natural logarithms of national income per capita and its lagged value respectively. LBEV, LENERGY, LFERT, LFOOD, LMETMIN, LPEC and LRAW are the independent variables of interest which are the prices of beverages, energy, fertilizers, food, metals and minerals, precious metals and raw materials, respectively. GFCF, TRADE, GOV and POP are the control variables which are the ratio gross fixed capital formation to GDP, the ratio of foreign trade volume (exports plus imports) to GDP, the ratio of government expenditures to GDP and population growth rate, respectively. Since the commodity prices subject to the research are global prices, they do not differ from country to country. On the other hand, the control variables are those that differ from country to country.

Table 2 presents sufficient information about the variables used in the research. However, it should also be noted that commodity prices are arranged as indices. While making this arrangement, the price of each commodity for 2010 was determined as 100. Prices before and after this date have been adjusted for current values in US dollars.

Since the panel GMM method is intrinsically suitable for short time intervals (T) and large cross-sections (N), unit root tests are generally not used as a preliminary test in panel GMM studies [114,115]. The main reason for this is that unit root tests can not give reliable results for short-term panel data. For this reason, we prefer not to use panel unit root tests as a preliminary. The following sub-section uses the data of the series in level rather than the differenced data.

3.1.2. Econometric results

Table 3 shows panel system GMM regression results. The first column shows the results of the low-income countries, while the other columns show the results of lower-middle, upper-middle and high-income countries.

Looking at the lagged dependent variable (LGDPC(-1)), it is positive and statistically significant for all country groups. It is seen that the autoregressive coefficient is 0.97 and 0.962 for the low-income and the lower-middle income country groups which are the highest ones. This shows that 1 % increase in the lagged income per capita leads to a 0.97 % and 0.962 % increase in the current income per capita for these country groups. On the other hand, the autoregressive coefficient (LGDPC(-1)) is 0.865 and 0.836 for the high-income and the upper-middle income country groups. In other words, a1% increase in the one-period lagged income per capita associates with a 0.865 and 0.836 increase current income per capita. These results show that the transition effect from the previous period to the current period per capita income is highest in low-income and lower-middle income countries, while it is lower in high-income and upper-middle income countries.

The coefficient of LBEV variable is statistically significant only for high-income country groups while it is not statistically significant for the other country groups. Looking at the coefficient, it is 0.10 for high-income country group. Accordingly, a 1 % increase in beverage prices is associated with a 0.10 % increase in per capita income in the high-income country group.

The coefficient of the LENERGY variable is negative and significant for all country groups. The coefficient of this variable is −0.181, −0.193, −0.249 and −0.190, respectively. That is, a 1 % increase in energy prices causes a decrease of 0.181 %, 0.193 %, 0.249 % and 0.190 %, respectively, in these country groups. These results clearly show that the increase in energy prices has a reducing effect on income in all country groups. In addition, the country group with the highest reducing effect is the middle-upper country group. In other country groups, the income-reducing effect is close to each other.

The coefficient of the LFERT variable is also negative for all country groups, similar to the coefficient of the LENERGY variable. The

Table 2
Description of variables.

Symbol	Variable	Tranformation	Source
LGDPC	GDP per capita (Current US$)	Natural Logarithmic	Worldbank-World Development Indicators
LBEV	Prices of Beverages	Natural Logarithmic	World Bank Commodity Price Data
LENERGY	Prices of Energy	Natural Logarithmic	World Bank Commodity Price Data
LFERT	Prices of Fertilizers	Natural Logarithmic	World Bank Commodity Price Data
LFOOD	Prices of Food	Natural Logarithmic	World Bank Commodity Price Data
LMETMIN	Prices of Metals and Minerals	Natural Logarithmic	World Bank Commodity Price Data
LPREC	Prices of Precious Metals	Natural Logarithmic	World Bank Commodity Price Data
LRAW	Prices of Raw Materials	Natural Logarithmic	World Bank Commodity Price Data
GFCF	Ratio of Gross Fixed Capital Formation to GDP	–	Worldbank-World Development Indicators
TRADE	Ratio of Trade to GDP	–	Worldbank-World Development Indicators
GOV	Ratio of Government Expenditures to GDP	–	Worldbank-World Development Indicators
POP	Population Growth Rate	–	Worldbank-World Development Indicators

Table-3
Panel system GMM regression results.

Explanatory Variables	*Low-Income Countries*	*Lower-Middle Income Countries*	*Upper-Middle Income Countries*	*High-Income Countries*
LGDPC(-1)	0.971** (0.470)	0.962*** (0.078)	0.836*** (0.129)	0.865*** (0.049)
LBEV	0.220 (0.185)	−0.017 (0.078)	0.078 (0.079)	0.10** (0.040)
LENERGY	−0.181** (0.086)	−0.193*** (0.065)	−0.249*** (0.071)	−0.190*** (0.026)
LFERT	−0.255)** (0.119)	−0.099** (0.038)	−0.216*** (0.032)	−0.253*** (0.028)
LFOOD	0.716** (0.285)	0.507*** (0.155)	0.854*** (0.122)	0.828*** (0.085)
LMETMIN	0.467*** (0.154)	0.511*** (0.089)	0.780*** (0.078)	0.632*** (0.042)
LPREC	0.020 (0.127)	−0.182** (0.087)	−0.139 (0.129)	−0.170*** (0.044)
LRAW	−0.399* (0.216)	−0.066 (0.139)	−0.556*** (0.208)	−0.517*** (0.081)
GFCF	0.043 (2.24)	0.0085 (0.0061)	−0.046 (0.177)	−0.239 (0.162)
TRADE	0.056 (0.039)	0.0052 (0.0035)	−0.041 (0.084)	−0.025 (0.030)
GOV	−0.127 (0.981)	−0.01** (0.005)	−1.092*** (0.199)	−1.646*** (0.386)
POP	−2.757 (6.22)	−2.178** (1.069)	−1.08** (0.541)	−0.931*** (0.238)
Covid-19 Dummy	−0.206*** (0.072)	−0.126*** (0.034)	−0.260*** (0.032)	−0.161*** (0.023)
Constant	−2.41 (3.65)	−1.69** (0.84)	−0.754 (1.52)	−0.116 (0.683)
AR(1)(p-value)	0.012	0.019	0.000	0.000
AR(2)(p-value)	0.740	0.132	0.989	0.254
Hansen J-test (p- value)	0.699	0.268	0.153	0.102
Number of Instruments	16	45	26	55
Number of Groups	19	51	43	55
Number of Observations	217	714	589	739

- Robust standard errors are reported in parentheses of estimated coefficients. The regression coefficients are estimated using the Arellano and Bover [116] and Blundell and Bond [110] system GMM approach.
- ***,*** and * represent statistically significance at 1 %, 5 % and 10 % significance level, respectively.
-Syntax used to obtain estimates of GMM is xtabond2 in Stata [117].
-The values reported for the Hansen J-test is the p-values for the null hypothesis of instrument validity. The values reported for AR(1) and AR(2) are the p-values for first-and second-order auto-correlated disturbances in the first differences equations.

coefficient of the LFERT variable is −0.255, −0.099, −0.216 and −0.253 for country groups, respectively. The coefficient of the LFERT variable is −0.255, −0.099, −0.216 and −0.253 for country groups, respectively. That is, a 1 % increase in fertilizer prices is associated with a −0.253 %, −0.099 %, −0.216 % and −0.253 % decrease in per capita income for these country groups, respectively. The income-reducing effect of fertilizer prices is evident in the low-income and high-income income groups, and this effect is very close to each other. On the other hand, while this reducing effect is slightly lower in the upper-middle income group, it is the least in the lower-middle income group.

As for LFOOD, the coefficient of this variable is 0.716, 0.507, 0.854 and 0.828, respectively, by country group. In other words, a 1 % increase in food prices causes an increase of 0.716 %, 0.507 %, 0.854 % and 0.828 % in these country groups, respectively. Income-increasing effect of food prices is highest in upper-middle income and high-income country groups. While this effect is slightly lower in the low-income country group, this effect is the lowest in the lower-middle income country group.

The LMETMIN variable has a positive coefficient for all country groups, similar to the LFOOD variable. The coefficient of LMETMIN is 0.467, 0.511, 0.780 and 0.632, respectively, by country group. This shows that a 1 % increase in metal and mineral prices causes an increase of is %0.467, %0.511,% 0.780 and %0.632 in these country groups, respectively. Similar to food prices, income-increasing effect of metal and mineral prices is highest in upper-middle income and high-income country groups while this effect is lower in low-income and lower-middle groups, respectively.

LPREC variable has statistically significant coefficients in the lower-middle and the high-income country groups while the other country groups do not have a statistically significant sign. The coefficient of lower-middle income and high-income group is −0.182 and −0.170, showing that a 1 % increase in the precious metals leads to a −0.182 % and-0.170 % decrease in the income per capita for these country groups, respectively.

As for LRAW, the coefficients of all the country groups are negative. The coefficients of the upper-middle-income and high-income country groups have a statistically significant sign at the 1 % significance level, and these coefficients are −0.556 and −0.517, respectively. On the other hand, the coefficient of low-income group is −0.399 and significant at 10 % significance level while the coefficient of lower-middle income group is statistically insignificant. According to these results, a 1 % increase in the raw material prices associates with a −0.556 %, −0.517 % and −0.399 % decrease in the income per capita for the upper-middle income, high-income and low-income country groups, respectively.

GFCF, GOV, TRADE and POP determined as control variables are among the most widely adopted control variables in the literature. The reason why these variables are among the most adopted variables is that they are considered to be among the factors that determine and affect the national income per capita. Even if the statistically significant effects of these variables could not be determined as a result of the study, it does not mean that these variables are incorrectly determined variables. The most important reason for including these variables in the study is to purify the effects of these control variables. GFCF and TRADE do not have a statistically significant sign for all country groups. As for GOV and POP, the coefficients of low-income country group are insignificant while they are negative and significant at 1 % significance level for the other country groups. As for POP, the significant coefficients are −2.178, −1.08 and −0.931 for the lower-middle, upper-middle and high-income country groups, respectively. The two interpretations

can be made in this case: First of all, the negative coefficients are compatible with the growth theory [118] showing that population growth rate negatively affects the economic growth. The coefficient of the POP variable is −2.178, −1.08 and −0.931 for the lower-middle, upper-middle and high-income country groups, respectively. According to these, when the population increases by 1 %, per capita income in these country groups decreases by 2.178 %, 1.08 % and 0.931 %, respectively. This result shows that the population growth rate has the highest income-reducing effect in the lower-middle income country group. This effect is less in the other country groups than in the low-income country group. GOV is a variable representing the ratio of public expenditures to national income, as described in Table 1. The coefficients of this variable are −0.01, −1.092 and −1.646 in the lower-middle income, upper-middle income and high-income country groups, respectively. This shows that a 1 point increase in the ratio of public expenditures to national income reduces the per capita income by 0.01 %, 1.092 % and 1.646 %, respectively, in these country groups. In other words, it is determined for these three country groups that the ratio of public expenditures to national income has a decreasing effect on per capita income. In addition, it is seen that this reducing effect is higher in the high-income country group, lower in the upper-middle country group, and very low in the lower-income country group.

4. Discussion

The study results revealed the existence of a positive relationship between beverage prices and GDP per capita only for high-income countries. However, for other income group countries, there is no significant relationship between the two variables. These results are consistent with [54] who analyzed relationship between cocoa prices, exchange rate and economic growth for Cote d'Ivoire and Ghana. They found a relationship between cocoa prices and economic growth in the long term only for Ghana, but did not find a significant relationship between the two variables for Cote d'Ivoire in both the short and long term. Even though low-income countries are leading producers of coffee and cocoa, they have been unable to turn these products into drivers of growth enhancement and poverty reduction due to unfavorable internal and external conditions. However, coffee and cocoa imported from Africa and South America are re-exported by European countries with very high mark-up [118]. Although the top 5 coffee producing countries are Brazil, Vietnam, Colombia, Indonesia and Honduras, the share of raw common coffee bean exports of Germany, Switzerland, Italy, the USA, France, the Netherlands and Canada in 2002 is close to 50 % of the total. Similarly, while Ivory Coast and Ghana produce more than 60 % of global cocoa production, approximately 70 % of world cocoa bean exports in 2022 are carried out by just two countries, the Netherlands and Belgium [119]. On the other hand, the results of our study contradict the findings of Bussolo et al. [51] and Moss et al. [53], who observed that increasing coffee prices reduce poverty.

According to the results of the study, fertilizer prices negatively affect GDP per capita for all income group countries. The increase in fertilizer prices will reduce the use of the said input in production, which will diminish agricultural production and GDP. Both the coefficient and the significance level are higher for high-income and upper-middle-income countries with higher fertilizer adoption and application rates. These results align with the study of [63] who revealed the existence of a negative relationship between fertilizer prices and income and other indicators. Additionally, the results of both [64,65] are consistent with those of our study. In contrast, our results are not consistent with the study by Ref. [60], who found that the rising in fertilizer prices increases GDP per capita.

The study results have also indicated a negative association between energy prices and GDP per capita for all income group countries. The fact that the majority of countries are net energy consumers and importers matches the empirical results of the study. The results show consistency with [66,67], who examined whether energy prices affect economic growth and showed the negative impact of energy prices on growth. However, these results contradict the studies by Refs. [20,68], who revealed that oil price increases have a positive impact on economic growth.

The study also showed a negative relationship between precious metal prices and GDP per capita only for lower middle income and high income countries. On the other hand, no significant relationship was found between precious metal prices and GDP per capita for other countries. Although the booming gold demand has increased the income of a small number of gold-exporting countries, it has had a decreasing effect on the income of gold-importing countries, the majority of which have high incomes. The fact that there is a strong and negative relationship for especially high-income countries confirms that precious metals are also an important alternative investment tool for them. A study by Raza et al. [76] reached findings that were both consistent and inconsistent with the results of our study. They found that gold prices positively affect the stock markets of BRICS but negatively affect the stock markets of Mexico, Malaysia, Thailand, Chile and Indonesia.

This study confirmed the existence of a strong and positive relationship between metal/mineral prices and GDP per capita for all country income groups. These results indicate that for all country groups, the income gain effect of rising metal and mineral prices outweighs their income loss effect. The results of the study are consistent with those of studies by Refs. [36,82] who showed that rising prices promote the level of national income per capita and employment while reducing poverty. Similarly, except for the results of [84], the results of [85–88] are consistent with the results of our study.

The results also showed the significant adverse impact of agricultural raw material prices on GDP per capita for all income group countries except lower-middle income ones. Especially there is a strong association between agricultural raw prices and GDP per capita for upper-middle and high income countries, most of which are importers of agricultural raw materials. These results agree with the study of [98], who investigated the impact of volatility and the level of raw material prices on GDP, and found that rising raw material prices improved income dynamics, while high price volatility worsened them. Although the results of [97] coincide with the results of our study [95,96], produced results that were not compatible with our study.

Another result of the study is that there is a positive relationship between food prices and GDP per capita for all country income groups. Deaton [9] argued the effect of food prices depends on whether households are net consumers or net producers of food. In this regard, our results are in line with literature. Our results showed that the benefit of a rise in food prices to net producers outweighs the

harm to net consumers. In this regard, the results of the study are in line with studies by Headey [102], Headey and Hirnoven [103] and Parabheesh and Laila [68], who found that rising food prices stimulates the growth. On the other hand, our results are in contrast with those of Ivanic and Martin [99], Ivanic et al. [100] and Wodon and Zaman [101], who found that rising food prices have a poverty-increasing effect.

The fact that a significant and positive relationship between beverage prices and GDP per capita was found only for high-income countries does not support whether resource abundance is a "curse or blessing". The empirical results of negative impact of energy and fertilizer prices on GDP per capita for all country income groups also mean an increase in costs for both agricultural and industrial sectors. These findings do not confirm the existence of the "curse" or "blessing" hypothesis. The existence of a positive relationship between metal, mineral and food prices and per capita GDP for all country income groups does not provide information about whether the abundance of resources is "curse" or "blessing". Similarly, a negative relationship between precious metal prices and GDP per capita only for low-middle and high income group countries does not confirm the validity of either of the hypotheses in question. Moreover, the fact that agricultural raw material prices have a negative effect on GDP per capita does not indicate the existence of either hypothesis. These findings are a result of classifying countries according to their income levels, rather than the abundance of their resources.

5. Conclusion and policy implications

Global commodity prices have followed a much more up-and-down course over the last two decades compared to previous periods. Changing commodity prices have affected the macroeconomic fundamentals of all countries. Existing literature has focused on the impact of changing commodity prices on the growth of low-income countries whose income depends on exports of a small number of commodities. However, little is known about the impact of commodity prices on the incomes of countries with different income levels. Additionally, there is also a significant gap in the literature regarding the impact of changes in the prices of many commodity groups on the income of a large sample group consisting of many countries. This study aimed to examine the impact of changes in commodity prices on the GDP per capita of countries in different income groups. For this purpose, the study analyzed the impact of seven groups of commodity prices such as beverage, energy, fertilizer, food, precious metal, agricultural raw material, and metal and mineral on the GDP per capita of four groups of low, lower-middle, upper-middle and high income countries.

According to the results of the study, energy and fertilizer price increases led to a decrease in the GDP per capita of all income group countries. The fact that the overwhelming majority of countries are net consumers and importers of these inputs in both agricultural and industrial production is consistent with this result. On the other hand, the results of the study showed that the increase in food and metal and mineral prices led to an increase in GDP per capita for all groups. Countries that are net producers and exporters benefit from the increase in the prices of these commodities. The results also confirmed that the rise in prices of precious metals and agricultural raw materials negatively affects the GDP per capita of some country groups. Especially high-income countries have enhanced their import of precious metals, which they see as an investment tool and safe haven. Again, upper-middle and high-income countries have increased the import of agricultural raw materials to meet their textile, furniture and housing needs. In addition, the results of the study indicated that beverage prices positively impact GDP per capita in high-income countries that are leading exporters, if not major producers, of commodities such as coffee and cocoa. One of the interesting results of the study is that strong and significant results were obtained between commodity prices and GDP per capita of countries, from lower income groups to higher income groups. In particular, all commodity prices have significantly affected the GDP per capita of high-income countries. These results overlap with the aims of the study. On the other hand Classifying countries according to their income levels, rather than the abundance of their resources, does not confirm whether the "resource curse" or "resource blessing" hypotheses exist.

The results of our study have some implications for countries affected by changes in commodity prices. As markets become more integrated in a globalizing world, all countries, regardless of their income level, have been affected by the changes in commodity prices. Thus, first of all, there is a need for international policies that require cooperation and solidarity as well as national policies. The fact that especially the prices of energy, fertilizer and agricultural raw materials have an income-reducing effect for almost all country groups reveals the importance of international cooperation. Secondly, the policies aimed at preventing, minimizing and compensating for the effects of commodity price movements must also be coordinated and integrated with each other. Thirdly, the support of high-income countries and international organizations is vital, especially in compensating for the loss of low-income countries, many of which are located in Africa and South Asia.

Although this study obtained substantial empirical findings, it is held limitations. This study covers a limited period of price data on beverage, energy, fertilizer, food, metal/mineral, agricultural raw materials, and precious metal. A more extended period may be the subject of future research. Moreover, future research could also investigate the impacts of commodity prices on other economic, financial, environmental, socio-cultural and even psychological indicators. In addition, the lack of sufficient studies in the literature on some independent variables such as beverage and agricultural raw materials offers opportunities for future research.

Data availability statement

Available on request.

CRediT authorship contribution statement

Ali Şen: Writing – original draft, Supervision, Resources, Methodology, Conceptualization. **Ahmet Gökçe Akpolat:** Writing –

original draft, Methodology, Formal analysis, Data curation, Conceptualization. **İsmail Balkan:** Writing – review & editing, Resources, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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