Resources Policy 76 (2022) 102583

Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol

The copper production and economic growth nexus across the regional and global levels

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ARTICLE INFO

Keywords:
Copper production
Economic growth
CCEMG
CS-DL
Natural resources

ABSTRACT

This study examined the copper production and economic growth nexus across the countries with a higher copper production in the regional and global levels from 2002 to 2016. The testing framework (cross-sectional dependence, panel unit root, and cointegration tests) and panel common corrected effects mean group (CCEMG) and cross-sectionally augmented distributed lags (CS-DL) estimators were employed. The main findings showed that all selected variables are cross-sectionally dependent and integrated at the first order, which implies the existence of long-run cointegration relationships. Except in Africa and Middle-East, copper production significantly contributes to increasing economic growth across the regional and global levels. Moreover, a unidirectional causal relationship running from economic growth to copper production is detected in Africa and Middle-East, and North-America. This causal link is running from copper production to economic growth in Europe and Central-Asia and at the global level. A bidirectional causal link was detected in Asia-Pacific, while the neutral causal link was noted in South and Central America. This study suggested the potential policy implications to strengthen the link between copper production and growth with respect to labor and capital.

1. Introduction

Natural resources gained growing importance towards global economic development for several decades. In this respect, TILTON (1989) argued that growing faster in the economy requires and stimulates the faster growth in natural resources consumption, such as aluminium, nickel, zinc, copper, lead, steel, and others. Thereafter, the International Union of Geological Sciences (IUGS) proposed the Resourcing Future Generations program to reach the global demand for natural resources (Oberhänsli and Lambert, 2014). Thus, the causal link between economic growth and natural resources, such as industrial metals was recently supported by Jaunky (2012) and Soulier et al. (2018).

After the second World war, the global economic recovery was led by the Cobb-Douglas production function, which relied on labor and capital (Douglas, 1976). The industrial revolution added alternative features to accelerated economic growth, which led to an increase in the natural resources/mineral demands in the Organization for Economic Cooperation and Development (OECD) countries and other developing countries (Malenbaum, 1977; Tilton and Tilton, 1990). From this, copper has received reasonable contribution in economic development of developed and developing countries due to its use in energy sectors to provide electricity, corrosion-resistant, electricity conductivity; construction and buildings such as roofing, cladding; transport, and other sectors (Li et al., 2017). These technological products are potential to rich countries and show how copper is highly connected to the global and national economic development. For instance (Hricik, 1988), argued that developed countries consume more copper production than developing countries, which led to a higher copper demend in developed nations. Jaunky (2013) added that economic growth influences the copper demand in rich countries.

The relationship between copper production and economic growth is rarely discussed, for instance only one study showed that precious metal production (gold, silver, and copper) have mixed effect on economic growth, specifically, copper production positively affect economic growth in Australia and South Africa, see Bildirici and Gokmenoglu (2019). On the other hand, Jaunky (2013) showed the causal relationships between copper consumption and economic growth, which runs from economic growth to copper consumption in the 16 World's top-rich countries over 1966–2010. The variations in the copper content of mined ores was noted to be different across regions over the several decades (Crowson, 2012), and its price volatility relied on extracted places, however, it is interesting to show how copper production

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https://doi.org/10.1016/j.resourpol.2022.102583
Received 5 March 2021; Received in revised form 5 January 2022; Accepted 26 January 2022

contributes to the global economy across regions. This can assist regional and global policymakers to stabilize the use of copper production towards sustainable economic growth. Furthermore, existing studies have investigated the effect of economic growth on mineral consumption in the context that the increase of economic growth leads to higher mineral consumption (Jaunky, 2013; Tilton, 1989). Other studies focused on the copper undiscovered deposit across regions, see (Dinda and Samanta, 2021; McCammon et al., 2004; Raines et al., 2007).

This study aims to examine the impact of the income generated from copper production on the economic growth across the countries that produce a higher level of copper production for the period of 2002–2016. Countries involved in this study classified into groups due to the reasonable differences across regional variations in copper production and copper price volatility on international market, and the patterns and changes in economic growth are different across regions. For instance, Crowson (2012) discussed on the different of copper yields and ore grades in some regions. Therefore, we noted that conducting this study across regional and global levels can grasp great impact for scientific support towards sustainable development.

This study has four features that differentiate it from existing studies conducted on natural resource, specifically, copper production and add a contribution to the literature: First, due to the copper production and copper price vary across the regional levels at each year, thus, this study investigates the relationship between copper production and economic growth by grouping the sampled countries into the regions and global panel. Second, this study examines the effect of copper production with respect to existing contributors of economic growth, such as labor and capital. These can help regional and global policymakers to understand the impact of copper production in the presence of other controlling variables of an economy. Third, most existing studies conducted in rich countries ignored the factor that a certain country can be rich without a presence of certain minerals, however, this study considered the countries that produce a higher level of copper production across the regional levels. Last but not least, this study uses the most recent panel estimators, such as common correlated effects mean group (CCEMG) proposed by Pesaran (2006), extended by Kapetanios et al. (2011), and panel cross-sectional augmented distributed lags (CS-DL) (Chudik and Pesaran, 2015). These estimators detect cross-sectional dependence, heterogeneity, and multicollinearities during the estimation process.

The rest of this study is illustrated as follows. Section 2 provides an overview of the existing literature on the metal consumption-growth nexus. Section 3 discusses the data, empirical model, and methods. Section 4 presents results and discussion. Section 5 provides the conclusion and policy implications.

2. Review on existing studies

There are growing studies on metal productions and their use towards sustainable development at country-specific, continental, and global levels. Tilton (1989) examined the consumption trends of six industrial metals (aluminium, nickel, zinc, copper, lead, and steel) throughout 1960–1973, and 1973–1985 in OECD, USA, and Japan. Tilton argued that economic growth stimulates metal consumption. The prediction of USA steel consumption up to 2010 revealed that the Gross National Income (GNI) contributes to determining the use of metal (Roberts, 1990). Roberts (1996) showed unexpected and unusual demand for copper, zinc, and lead in 32 countries, specifically, copper consumption was extremely higher than other metals in some countries, and this affects the global economy. Crowson (2012) examined the historical trends in the average copper content of mined ores and its effect on economic growth across the regional levels. The findings revealed that the average grades from African and Australian copper are higher than that of global level, while the copper production is least in North America and decreasing trends has seen in Latin America. As Crowson argued, due to the copper deposit issues and dynamic changes in the copper price, the mining operators have a significant impact on economic growth.

Various methods have been employed to examine the impact of metal consumption on economic growth. Labson and Crompton (1993) used the theory of cointegrated process to examine the relationship between metals consumption and economic activities in OECD, USA, UK, and Japan from 1960 to 1987. The results showed little evidence that supports the long-run relationships between those variables. In the same sense, Ghosh (2006) used cointegration and Granger causality to investigate the link between steel consumption and economic growth from 1951 to 1952 and from 2003 to 2004 in India. The findings indicated the one-way directional causal link, which runs from economic growth to steel consumption. Jaunky (2012) has used a panel Dynamic Ordinary Least Square (DOLS) estimator to examine the link between aluminium consumption and economic growth across 20 rich countries from 1970 to 2009. The results confirmed that an increase in economic growth leads to an increase in aluminium consumption, and a one-way directional causal link, which runs from aluminium consumption to economic growth was noted in the whole panel. Jaunky (2013) has used the Vector Error Correlation Models (VECM) to investigate the causal relationship between copper consumption and economic growth in 16 rich countries from 1966 to 2010. The main findings revealed that at the whole panel, a unidirectional link, which runs from economic growth to copper consumption was noted, while the mixed relationships were noted among the country-specific. Bildirici and Gokmenoglu (2019) have examined the relationships between precious metals production (copper, gold, and silver) and economic growth in seven countries with the highest production levels for the period of 1960–2016. The results confirmed the long-run relationship between these variables in the whole panel, and country-specific, and specifically, copper production noticed to positively affect economic growth in Australia and South Africa.

To the best of our knowledge, there is no study showed how copper production affects economic growth in the presence of labor and capital as they are prime inputs of economic growth. Very few studies focused on the high-income countries, and ignore how a higher level of copper production can accelerate the economic growth of a certain country as an alternative way of development. Besides, the effect degree of copper production on economic growth depends on the quantity of copper production and its price varies across the country-specific and regional levels. Therefore, unlike the studies that used the panel estimators, which do not allow cross-sectional dependence, heterogeneity, and multicollinearity among the variables, this study is interested to fill the gap by using the most recent estimators, such as CCEMG proposed by Pesaran (2006), advanced by Kapetanios et al. (2011), and CS-DL proposed by Chudik et al.(2016).

3. Data and methods

3.1. Data

The time-varying data have mined from various databases, such as The World Bank (Bank, 2018) and U.S. Geological Survey (USGS) science for a changing world (USGS, 2020), and the International market of natural resources known as Trading Economics (TE, 2021) for the period of 2002–2016, have employed. The 35 sampled countries considered in this study are those that produced a higher level of copper production in 2016 across the regional levels, see Appendix A. Both refined copper production measured in metric tons, transferred into pounds and annually historical copper price have used to estimate the aggregate of income generated from copper production; Gross Domestic Product (GDP) per capita is used as economic growth, labor and capital are used as control variables. All selected variables transferred into per capita by dividing the yearly total population, and transformed into the natural logarithm to achieve a robust analysis and avoid possible heteroscedasticity. Descriptive statistics of all selected variables are presented in Table 1.

3.2. Theoretical framework and mathematical model

This subsection shows the theoretical framework in which copper production affects economic growth with respect to existing economic indicators, such as labor and capital. While the labor and capital are famous contributors of an economy, existing empirical studies showed also the mixed relation of natural resources on economic growth in country-specific and sampled countries via various methods (Apergis and Payne, 2014; Bhattacharyya and Hodler, 2014; Boschini et al., 2013; Brunnschweiler, 2008; Dietz et al., 2007). Although the impact of copper production on economic growth is rarely discussed in panel of sampled top-World precious metal producers, most recent econometrical tests were not employed and leading economic indicators were ignored, see (Bildirici and Gokmenoglu, 2019; Jaunky, 2013; TILTON, 1989) for the case of metal consumption and economic growth. In this study, we employed labor and capital as exogeneous variables, since they usually play a key role of controlling economy of nations. Due to the lack of existing theoretical support of direct link between copper production and economic growth, most recent testing framework (cross-section dependences, CIPS unity root, and panel cointegration tests) and recent panel estimators (cross-sectionally augmented distributed lags and common correlated effect mean groups) were employed, see Fig. 1 for theoretical and methodological framework. Therefore, to effectively access the effect of copper production on economic growth, the main components of Cobb-Douglas production function, which are labor and capital (Douglas, 1976), are used as control variables, and then for the country i at the time t, GDP_{it} is given by the following mathematical function:

$$GDP_{it} = f(L_{it},\ K_{it}, CP_{it}) \tag{1}$$

For $i = 1, 2, \ldots N$ represent the country, $t = 1, 2, \ldots T$ time, GPD_{it} is the economic growth, L_{it} is labor, K_{it} is the capital, and CP_{it} is copper production. Therefore, the multivariate equation can be expressed as follow:

$$lnGDP_{it} = \alpha_{0i} + \alpha_{1i}lnL_{it} + \alpha_{2i}lnK_{it} + \alpha_{3i}lnCP_{it} + u_{it} \tag{2}$$

For α_{0i} is the unobserved country fixed effect, $\alpha_1 - \alpha_3$ are the long-run equilibrium coefficients, and u_{it} is the error term.

3.3. Testing framework

3.3.1. Cross-sectional dependence tests

The most crucial issue to be concerned with among the panel data is cross-sectional dependence, as suggested by Goldin (1966). To overlook this issue can lead to inconsistent estimates and misleading information. In this respect, H. M. Pesaran (2004) proposed Pesaran CD and standardized Lagrange Multiplier (LM) tests, and Breusch and Pagan (1980) proposed the Breusch-Pagan LM test for detecting cross-sectional dependence. The tests proposed by Pasaran are potential for large panel data size N and time T, and can be computed as follows:

$$LM = \sqrt{\frac{1}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\left(T_{ij}\mu_{ij}^2 - 1\right) \rightarrow N(0,1) \tag{3}$$

$$CD = \sqrt{2/N(N-1)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}T_{ij}\mu_{ij}^2 \rightarrow N(0,1) \tag{4}$$

equation (3) used for large size and changeable time T, and equation (4) used for large N and fixed T, however, the Breusch-pagan LM test is efficient for small size and T, can be computed as follows:

$$LM = \sum_{i=1}^{N-1}\sum_{j=i+1}^{N}T_{ij}\mu_{ij}^2 \rightarrow \chi^2\left(N(N-1)/2\right) \tag{5}$$

For μ_{ij}^2 is the correlation coefficients obtained from the residuals of equation (3), can be estimated as follows:

$$\mu_{ij} = \mu_{ji} = \frac{\sum_{t-1}^{T}\varepsilon_{ij}\varepsilon_{ji}}{\left(\sum_{t-1}^{T}\varepsilon_{ij}^2\right)^{\frac{1}{2}}\left(\sum_{t-1}^{T}\varepsilon_{jt}^2\right)^{1/2}} \tag{6}$$

where ε_{ij} *and* ε_{ji} are standard errors.

3.3.2. Pesaran CIPS unit root test

The Pesaran CIPS panel unit root test proposed by M. H. Pesaran

Table 1
Descriptive statistics.

Regions	Variables	Mean	Median	Maximum	Minimum	Observations
Africa and Middle-East	lnCP	1.330633	1.581526	2.31706	−0.72081	120
	lnGDP	3.374531	3.435238	4.330396	2.440997	120
	lnK	2.769947	2.880278	3.829857	1.573765	120
	lnL	0.41878	0.41765	0.31095	0.57174	120
North America	lnCP	1.477488	1.438618	2.217797	0.610547	45
	lnGDP	4.445763	4.667832	4.720618	3.951713	45
	lnK	3.792282	3.999248	4.098503	3.259644	45
	lnL	0.30798	0.29061	0.25281	−0.40534	45
South and Central America	lnCP	0.79849	0.935428	2.573741	−1.14172	75
	lnGDP	3.913338	3.970628	4.169591	3.526231	75
	lnK	3.201906	3.2235	3.57744	2.672139	75
	lnL	0.31772	0.31643	0.25678	−0.39025	75
Europe and Central Asia	lnCP	1.515366	1.503242	4.51307	−0.58506	165
	lnGDP	4.370646	4.484339	4.754261	3.603188	165
	lnK	3.724915	3.797276	4.153701	2.900984	165
	lnL	0.33215	0.31047	0.27477	−0.4902	165
Asia Pacific	lnCP	0.719172	0.671969	2.819065	−1.46776	120
	lnGDP	3.446195	3.350469	4.746079	2.621151	120
	lnK	2.796337	2.76414	4.199546	0	120
	lnL	−0.35722	−0.35416	−0.2322	−0.52547	120
Global level	lnCP	1.185497	1.182361	4.51307	−1.46776	525
	lnGDP	3.872768	3.901045	4.754261	2.440997	525
	lnK	3.225449	3.28286	4.199546	0	525
	lnL	0.35355	0.3371	0.2322	0.57174	525

CP: copper production, K: capital, L: labor.

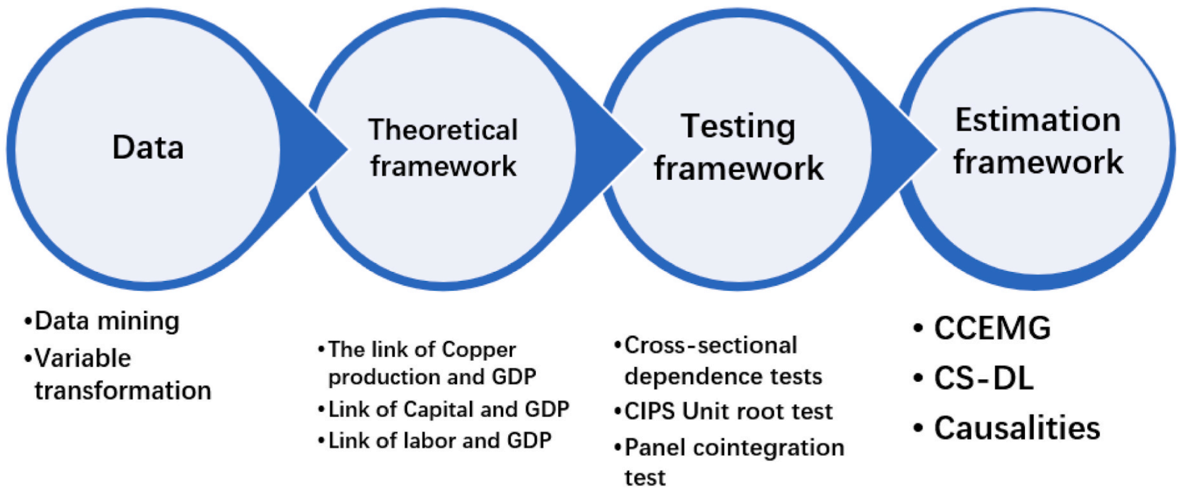

Fig. 1. Theoretical and methodological framework.

(2007) is a potential unit root test for panel data, which allows the cross-sectional dependence by considering the average of lagged levels and differences for each unit. This approach is denoted as cross-sectionally augmented Dickey-Fuller, and can be computed as follows:

$$\Delta y_{it} = \psi_i + \alpha_i y_{i,\,t-1} + \beta_i \bar{y}_{t-1} + \sum_{j=0}^{p} d_{ij} \Delta \bar{y}_{t-j} + \sum_{j=1}^{p} \xi_{ij} \Delta y_{i,t-j} + u_{it} \tag{7}$$

For $\bar{y}_{t-1}$ and $\Delta\bar{y}_{t-j}$ are the cross-sectional averages of lagged levels, and first difference, respectively. The cross-sectionally augmented Dickey-Fuller (CADF) statistics used to compute the CIPS statistic in the following equation:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i \tag{8}$$

3.3.3. Panel cointegration test

The error correction panel cointegration test proposed by (Westerlund, 2008; Westerlund and Edgerton, 2007), which is effective for cross-sectional dependence by applying an error correction term (ECT) and test two different null hypotheses (no cointegration in some panel and no cointegration in all panels) has been employed. It is computed as follows:

$$\Delta z_{it} = \alpha_i^{'} d_i + \vartheta_i \left(z_{i(t-1)} + \pi_i^{'} y_{i(t-1)} \right) + \sum_{j=1}^{m} \varphi_{ij} \Delta z_{i(t-1)} + \sum_{j=0}^{m} \varphi_{ij} \Delta y_{i(t-1)} + \omega_{it} \tag{9}$$

For ϑ_i is the adjustment term, d_i is a vector of deterministic components, while other parameters introduce the nuisance in the variable of interest. Thus, referred to the estimates of ϑ_i, the statistics of Westerlund ECT based panel cointegration tests can be determined as follows:

$$G_\tau = \frac{1}{N}\sum_{i=1}^{N} \frac{\vartheta_i}{SE(\vartheta_i^{'})} \tag{10}$$

$$G_\alpha = \frac{1}{N}\sum_{i=1}^{N} \frac{T\vartheta_i}{\vartheta_i^{'}(1)} \tag{11}$$

where G_τ and G_α are group mean statistics that test the null hypothesis of no cointegration in some panels. The rejection of this hypothesis implies the existence of cointegration for at least one cross-sectional unit in the panel. The group mean statistics, which tests the cross-sectional in all unit of panels can be computed as follows:

$$P_\tau = \frac{\hat{\vartheta}_i}{SE(\hat{\vartheta}_i)} \tag{12}$$

$$P_\alpha = T\hat{\vartheta}_i \tag{13}$$

The rejection of the null hypothesis implies no cointegration for the whole panel. This test is more efficient when T > N, and for T < N, it requires the adjustment of lags and leads to get reliable results.

3.4. Estimation framework

3.4.1. Panel cross-sectional augmented distributed lags (CS-DL)

Due to this study uses panel data, which mostly have cross-sectional dependence across cross-national studies, the panel CS-DL test proposed by Chudik et al.(2016) has employed. This test allows and estimates the effect of the possible cross-sectional lags and cross-sectional average variables on the variable of interest. Thus, the CS-DL equation can be written as follows:

$$y_{it} = \alpha_i + \beta_i y_{it-1} + \delta_{0i} x_{it} + \delta_{1i} x_{it-1} + \sum_{l=0}^{PT} \sigma_{il}^{'} \bar{z}_{it-l} + u_{it} \tag{14}$$

For $i = 1, 2, \ldots., N$, and $\bar{z}_t = N^{-1}\sum_{i=1}^{N} z_{it} = (\bar{y}_t, \bar{x}_t, \bar{f}_t)^{'}$, where β_0 and δ_0 obtained by arithmetic averages of least squares estimators of β_i and δ_{0i} based on the Pesaran (2006) (Pesaran, 2006), and f_t is the unobserved common factor with heterogeneous factor; α_i and u_{it} are intercept and error term. The long-rung coefficients can be estimated in this equation:

$$\hat{\theta}_{cs-DL} = \frac{\sum_{l=0}^{q} \hat{\delta}_{il}}{1 - \sum_{l=1}^{p} \hat{\beta}_{il}} \tag{15}$$

3.4.2. Common correlated effect means groups (CCEMG)

The recent panel CCEMG proposed by (Pesaran, 2006) and extended by Chudik and Pesaran (2015) has been used in this study. The CCEMG estimator estimates the effect of cross-sectional average regressors on the variables of interest. This is the unique feature that makes CCEMG better than the previous versions, which assume the cross-sectional effect. CCEMG can be estimated in the following equation.

$$y_{it} = \alpha_i + \sum_{l=0}^{p} \beta_{il} y_{it-l} + \sum_{l=0}^{q} \delta_{il} x_{it-l} + \sum_{l=0}^{Z} \mu_{il} \bar{z}_{it-l} + u_{it} \tag{16}$$

where $\bar{z}_t = (\bar{y}_t,\, \bar{x}_t)^{'}, \bar{y}_t = n^{-1}\sum_{i}^{N} y_t$ and $\bar{x}_t = n^{-1}\sum_{i}^{N} x_t$, for (p, q, z) are the lags.

In this estimator, the linear combinations of the cross-sectional averages of the variable of interest and regressors, which are the observed common effects are employed with coefficients presented in Kapetanios et al. (2011). Therefore, CS-DL and CCEMG provide similar conclusions based on the estimated confident interval of each regression coefficient. More importantly, CS-DL can detect the multi-collinearity between the cross-sectional averaged variables and drop them out in the estimation process, however, CS-DL can produce better results than those from CCEMG, see (Jan Ditzen.xtdcce2, 2018).

3.4.3. Causality test

This study used the causality test proposed by Dumitrescu and Hurlin (2012), determine the directional of the causal relationship between variables. This directional causal relation can be seen in three ways: Bi-directional causal or two-way directional causal relations, which runs from one variable to the other, and vice-versa; unidirectional causal or one-way directional, which runs from one variable to the other; and neutral causal relationship. Thus, the causality test expressed as follows:

$$y_{i,t} = \alpha_i + \sum_{k=1}^{K} \delta_i^k y_{i,t-k} + \sum_{k=1}^{k} \beta_i^k x_{i,t-k} + \varepsilon_{it} \tag{17}$$

where y *and* x are variables to be tested, α is the individual fixed effect, δ and β are the autoregressive parameter and regression coefficient, respectively, which are different across groups. k gives information about the optimal lag and identical for all cross-sectional units. The hull hypothesis of this test is based on the regression coefficient, and associates with the individual Wald statistics of Granger non-causality averaged across the cross-sectional units, which is written as follows:

$$W_{i,T} = \widehat{\theta}_i^{'} R^{'} Z_i^{'} Z_i\Big) \Big(Z_i^{'} Z_i\Big) \left(Z_i^{'} Z_i\right)^{-1} R^{'}\Big]^{-1} R\widehat{\theta}_i \tag{18}$$

For more detail about the parameters, see (Dumitrescu and Hurlin, 2012).

4. Results and discussion

This section presents the results that show the impact of the income generated from copper production on economic growth with respect to the control variables, such as labor and capital. These results are obtained from the testing framework (cross-sectional dependence, panel unit root, Westerlund cointegration tests), and estimation framework (CS-DL, CCEMG, and causalities) across the regional and global levels.

4.1. Cross-sectional dependence and panel unit root tests results

Table 2 presents the results obtained from the cross-sectional dependence tests proposed by Pesaran (2004) and Breusch and Pagan (1980). From the table, the test statistics reject the null hypothesis of no cross-sectional dependence at 1%, 5%, and 10% significance levels across the regional and global levels. This implies the existence of cross-sectional dependence among the selected variables. The cross-sectional Im, Pesaran, and Shin (CIPS) unit root test proposed by M. H. Pesaran (2007) has been employed, and results are presented in Table 3. From this table, the null hypothesis of the unit root was rejected at the first difference order for all variables across regional and global levels. This indicates that the cointegration of all selected variables is integrated at the first order of integration.

4.2. Results of panel cointegration test

The Westerlund panel cointegration test proposed by (Westerlund, 2008; Westerlund and Edgerton, 2007) has been employed and the results are presented in Table 4 at the regional and global levels. From the table, the test statistics reject the null hypothesis of no cointegration in the favor of its alternative, which confirms the existence of cointegration in all panels. These results confirm the cointegration relationships between the income generated from copper production and economic growth across the regional and global levels, while labor and capital are control variables. The presence of subpanels and panel cointegration causal link between these variables assisted the main purpose of this study and allowed us to examine the input from copper production to economic growth at the global and regional levels.

4.3. CCEMG and CS-DL estimates

Table 5 presents the regression coefficients (long-rung relationships between selected variables) estimated from CCEMG and CS-DL estimators at the regional and global levels. Although most of the findings provide similar conclusions, recently, Jan Ditzen (2018) showed that CS-DL provides more accurate results than CCEMG. The results from both estimators show that labor and capital significantly and positively affect economic growth in all regions and at the global level, but the effect degree is higher for estimates obtained from CS-DL than those of the CCEMG estimator. This is due to the CS-DL estimator detected the cross-sectional averaged variables and possible multicollinearities and dropped them out in the estimation process, while CCEMG estimates the effect of cross-sectional averaged variables.

In the case of regional and global levels, except African and Middle-East regions, copper production significantly contributes to increasing economic growth across the regional and global levels. This implies that most countries with a higher level of copper production are developing and developed countries, and have developed industrial sectors that use copper production towards sustainable development. These results are consistent with Bildirici and Gokmenoglu (2019), who confirmed the existence of long-run causal relationships between precious metals production (copper, gold, and silver) and economic growth in seven countries, especially copper production highly contributes to an increase of economic growth and the relationship vary across the economic activities in the country-specific. Our results are also in a similar direction with those obtained from studies conducted on industrial metals and growth nexus, see (Ghosh, 2006; Labson and Crompton, 1993). For

Table 2
Results of cross-sectional dependence tests.

Regional	Breusch				Pesaran CD			
	lnGDP	lnL	lnK	lnCP	lnGDP	lnL	lnK	lnCP
A.M	290.784*	230.705*	275.471*	133.029*	10.117*	1.023**	8.087*	10.203*
N. A	36.608*	16.748*	17.110*	40.407*	6.041*	0.816***	3.860*	6.352*
S. C. A	134.111*	67.510*	120.024*	89.484*	11.572*	7.355*	10.934*	9.188*
E.C.A	348.329*	250.026*	294.267*	377.294*	12.224*	0.605	8.357*	16.589*
A. P	401.028*	254.171*	141.535*	263.095*	20.021*	0.546	8.601*	15.626*
Global panel	5835.678*	4247.772*	3906.869*	4603.767*	56.405*	9.068*	30.174*	61.614*

A.M: Africa and Middle-East, N.A: North America, S.C.A: South and Central America, E.C.A: Europe and Central Asia, A.P: Asia Pacific; L: Labor, GDP: Economic growth, K: capital, CP: copper production.
*, **, and *** indicate significant levels of 1%, 5%, and 10%, respectively.

Table 3
Results of CIPS unit root test.

Regional	Levels with constant and trend				1st difference with only constant			
	lnGDP	lnL	lnK	lnCP	lnGDP	lnL	lnK	lnCP
A.M	−2.068	−1.842	−1.609	−2.691	−3.005*	−3.253*	−2.699*	−3.772*
N. A	−0.695	−1.684	0.225	−2.239	−2.243***	−3.090*	−2.882**	−3.389*
S. C. A	−1.440	−1.553	−2.736	−1.626	−2.390**	−2.436**	−3.081*	−3.072*
E. EA	−2.339	−2.277	−2.300	−2.076	−2.572*	−3.208*	−2.822*	−3.322*
A. P	−1.339	−1.980	−1.166	−1.831	−2.431***	−2.480**	−2.310***	−3.422*
Global panel	−1.523	−1.786	−1.714	−2.286	−2.148**	−2.631*	−2.814*	−3.511*

*, **, and *** indicate significant levels of 1%, 5%, and 10%, respectively.

Table 4
Cointegration results.

Dependent: Economic growth				
Region	Gτ	Gα	Pτ	Pα
Africa-middle-East	−2.779*	−2.637	−4.320*	−3.927*
North America	−1.365	−1.989	−2.837**	−3.262***
South-Central America	−1.099	−1.673	−2.264**	−4.218*
Europe-Central Asia	−1.449***	−3.702	−4.074**	−2.898**
Asia Pacific	−1.625**	−2.961***	−4.118**	−3.263*
Global panel	−3.558*	−7.410***	−6.456*	−1.909**

*, **, and *** indicate the significant level of 1%, 5%, and 10%, respectively.

instance, Huh (2011) showed the presence of a long-run relationship between steel consumption and economic growth in Korea.

The findings of this study revealed that the effect degree of copper production on economic growth is weaker than those of the labor and capital. This comparative information is seen from the regression coefficients, which imply the impact of explanatory variables on the response variable, and they are in the similar meaning of the general context of Cobb-Douglas production function (Douglas, 1976). Referring to CS-DL estimates, a 5% increase in copper production leads to a 0.139%, 0.100%, and 0.046% increase in economic growth in North America, South and Central America, and the Asia Pacific, respectively. A 10% increase in copper production leads to a 0.039% and 0.046% increase in economic growth in Europe and Central Asia and at the global level, respectively. These findings are coinciding with those obtained by Jaunky (2013) who confirmed the long-rung relationship between copper consumption and economic growth within 16 rich countries. Furthermore, our findings are consistent with Jaunky (2012), who indicated that aluminium consumption contributes to increasing GDP in the panel of 20 rich countries.

Table 5
Results of estimators.

Dependent: Economic growth						
Regions	CCEMG			CS-DL		
	lnL	lnK	lnCP	lnL	lnK	lnCP
Africa and middle-east	0.919**	0.086**	0.003	2.856**	0.202**	0.043
North America	0.100**	0.289*	0.021**	0.465**	0.336*	0.139**
South-Central America	0.128***	0.184*	0.014**	0.904***	0.177**	0.100**
Europe-Central Asia	0.084***	0.210*	0.009**	2.381**	0.040**	0.089***
Asia Pacific	0.856**	0.091*	0.052***	2.810**	0.116*	0.039**
Global panel	0.061**	0.150*	0.002***	2.458*	0.476*	0.046**

*, **, and *** indicate significant levels of 1%, 5%, and 10%, respectively.

Table 7
Results of causality test.

Regions	Causal	W-stat	Hypothesis	Causal	W-stat	Hypothesis
Africa and middle-East	L→GDP	6.810*	G	GDP→L	2.047	N
	K→GDP	4.776**	G	GDP→K	4.936***	C
	CP→GDP	1.783	N	GDP→CP	4.876***	C
North America	L→GDP	4.320**	G	GDP→L	2.864	N
	K→GDP	3.971***	G	GDP→K	2.964	N
	CP→GDP	3.683***	G	GDP→CP	1.839	N
South-and-Central-America	L→GDP	4.900***	G	GDP→L	3.749	N
	K→GDP	3.229***	G	GDP→K	2.216	N
	CP→GDP	2.663	N	GDP→CP	1.319	N
Europe and Central Asia	L→GDP	1.706	N	GDP→L	6.217*	C
	K→GDP	4.512***	G	GDP→K	5.187**	C
	CP→GDP	4.189***	G	GDP→CP	2.383	N
Asia Pacific	L→GDP	3.087	N	GDP→L	4.555***	C
	K→GDP	19.151*	G	GDP→K	2.856	N
	CP→GDP	4.547***	G	GDP→CP	6.317*	C
Global panel	L→GDP	3.868***	G	GDP→L	4.244**	C
	K→GDP	7.458*	G	GDP→K	4.031**	C
	CP→GDP	3.712***	G	GDP→CP	3.305	N

*, **, and *** indicate significant levels of 1%, 5%, and 10%, respectively, C: conservative, G: growth, and N: neutral.

4.4. Causalities

Table 7 presents the causalities results obtained from the test proposed by Dumitrescu and Hurlin (2012), between copper production and economic growth across regional and global levels. The main concern to determine the causal relationships is to see whether the income from copper production stimulates the economic growth concerning the presence of labor and capital or economic growth leads to higher use of the copper production.

From the table, in the case of Africa and the Middle-East region, the one-way directional causal relationship is noted between copper production and GDP, which runs from GDP to copper production; bidirectional causal link is detected between GDP and capital; and unidirectional relationship, which runs from labor to GDP. In the case of North America, a one-way directional causal relationship, which runs from copper production, labor, and capital to GDP is detected. Furthermore, a unidirectional causal link, which runs from Labor and Capital to GDP is noted, while a neutral causal relationship is detected between GDP and copper production in the South and Central American region. In the case of Europe and Central Asia, a bidirectional causal relationship is noted between GDP and capital; a unidirectional causal link runs from GDP to labor and from copper production to GDP is detected. In the Asia Pacific, a bi-directional causal link is noted between copper production and GDP, one-way causal relationships, which are running from GDP to labor and from capital to GDP are detected.

At the global level, bi-directional causal relationships are noted between GDP and labor and capital, and a unidirectional causal link is detected between copper production and GDP, which is running from copper production to GDP. These findings are consistent with Jaunky (2013), who indicated the long-run unidirectional causal relationship, which is running from GDP to copper consumption in a whole panel of 16 rich countries. Again, our results are coinciding with those estimated by Labson and Crompton (1993) for industrial metals, including copper in the OECP, USA, UK, and Japan. Furthermore, our results are in the same direction as those obtained by Jaunky (2012), who detected the unidirectional causality running from aluminium consumption to GDP. Fig. 2 presents the overall causalities results between copper production and economic growth with respect to labor and capital. The findings reveal that copper production stimulates economic growth in North America, Europe and Central Asia, and at the global level. This view is different from that in Africa and Middle-East region, whereas the unidirectional causal link is running from growth to copper production, while copper production stimulates economic growth and vice-versa in the Asia Pacific.

This study has some limitations. The study was limited to the number of sampled countries due to the unavailability of control variables although some countries have a higher level of copper production. Several missing observations in the variable of interest led to the removal of some countries in the study to avoid the bias results and misleading information.

5. Conclusion and policy implications

Previous studies examined the impact of natural resources on economic growth, while the least attention was taken on the link between copper consumption and economic growth. These studies conducted in country-specific and sampled World-top rich countries, ignore the difference variations in the copper production and economic growth across regions. While studies consider various regions can grasp a reasonable contribution towards sustainability development across regions and global level. To respond to these deficiencies, this study examines the impact of income generated from copper production on economic growth in 35 sampled countries, which are top-copper producers across the regional and global levels from 2002 to 2016. To effectively access the long-run impact of copper production and economic growth, existing input of nation economy, such as labor and capital have used as control variables in the production function. To clearer access the presence of long-run relationship between copper production and economic growth, testing framework performed, which enclosed cross-sectional dependence, CIPS panel unit root, and Westurland cointegration tests. The most recent estimators, such as CCEMG and CS-DL are employed to estimate the long-run relationship between variables. Mostly the main findings are those obtained from CS-DL which is most recent than CCEMG and lastly, Dumitrescu Hurlin causality test has used to test the causation between selected variables.

The initial findings from testing framework confirmed the presence of cross-sectional dependence, panel unit root was rejected at the first difference, and all selected variables cointegrated at the first order of integration, which implied the presence of long-run relationship between copper production and economic growth across regions and global level. The results from both panel estimators show that labor, capital, and copper production contribute to increase economic growth in all regions and at the global level. More specifically, from the long-run estimates effect degree of copper production is weaker than those of labor and capital. Based on the CS-DL estimator, the effect of copper production on economic growth is positive and significant at the global level and in North-America, South-Central America, Europe-Central Asia, and Asia Pacific region, while it is insignificant in Africa and Middle-East region. On the other hand, labor and capital positively and significantly impacted economic growth in all regions and at the global

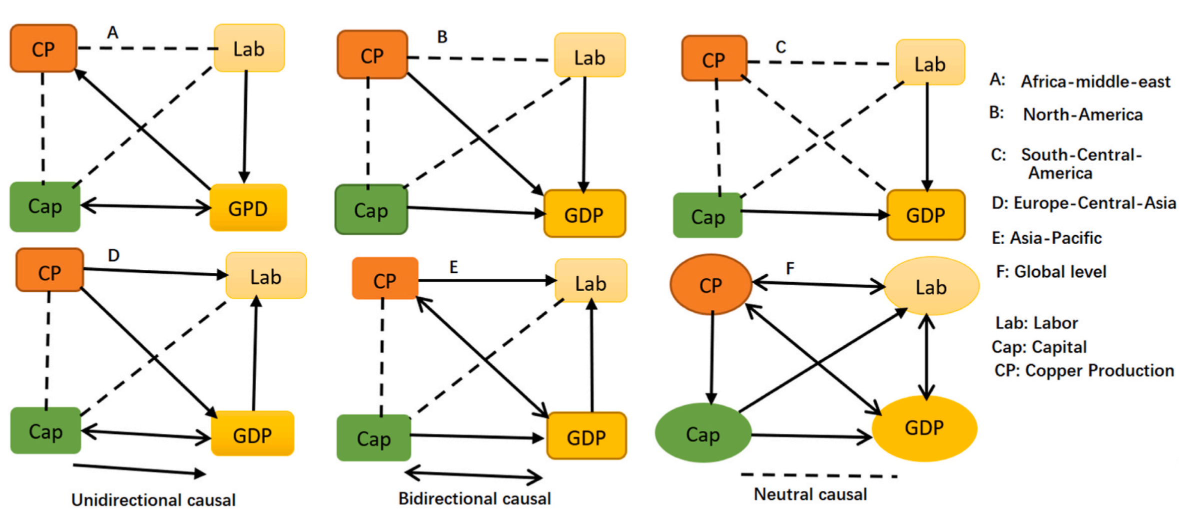

Fig. 2. Graphical representation of directional causations.

level. We also found the causality relationship between copper production and economic growth. A unidirectional causal relationship runs from economic growth to cooper production was noted in Africa and Middle-East, and causal link runs from copper production to economic growth was seen in North America and Europe and Central Asia, and at the global level. A bidirectional causal link was noted between copper production and economic growth in the Asia Pacific. Again, a neutral relationship was noted between copper production and economic growth in South-Central America. Furthermore, a bidirectional, unidirectional, and neutral causations were noted between economic growth and control variables (labor and capital) across regions and global level.

Based on our findings and limitations, policy implications are addressed to the national, regional, and global policymakers as follows: first, the noted relationship between copper production and economic growth implies that specific mineral can be considered as an additional determinant of an economy in case the mineral is highly abundant. Again, labor and capital may be used to stabilized economic growth in the presence of a higher copper production and make a long-run prediction of copper demand with respect to economic growth. Second, although, the effect degree of copper production is weak compared to those from existing contributors of growth, copper mining activities and industry can be intensively monitored to meet sustainable development across regional and global level. Third, causation results suggest that investing in mining sector is needed to convert unidirectional and neutral causation between copper production and growth to be feedback. The copper price also should be stabilized on the international market to maintain the growth stability at the country-specific, regional, and global levels.

Declaration

Ethics approval is not applicable.
Consent to participate is not applicable.
Consent for publication is not applicable.

Data availability

The datasets generated during and/or analyzed during the current study are available in The World Bank, U.S. Geological Survey (USGS) science for a changing world (USGS, 2020), and Trading Economics (TE, 2021) databases.

Declaration of competing interest

The authors declare that there is no conflict of interest.

Acknowledgment

This study was supported by the National Natural Science Foundation of China (grant number: 71991482), China Scholarship Council (grant numbers 201906410051), and the Fundamental Research Funds for National Universities, China University of Geosciences (grant number: 2201710266).

Appendix A. List of sampled countries in each region

Regions	No of countries	List of countries
Africa and Middle-East	8	Republic Democratic of Congo, South Africa, Botwsana, Saudi Arabia, Eritrea, Maurtania, Namibia, and Tanzania
North America	3	USA, Canada, and Mexico
South and Central America	5	Algentine, Chile, Peru, Brazil, and Colombia
Europe and Central Asia	11	Austria, Cyprus, Italy, Spain, Turkey, Sweden, Belgium, Finland, Portugal, Romania, and Serbia
Asia Pacific	8	Australia, India, Indonesia, Mongolia, Myanmar, Philipines, Pakistan, and China

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