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Mineral extraction and processing industries: Do they have socioeconomic benefits in a developing country scenario?

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Abstract

Purpose. This study examined the benefits of modernization of small industrial units clustered in Mohmand Marble City, Pakistan focusing on objectives to estimate change in socioeconomic status of rural public living in proximity of Marble City as well as to evaluate increase in productivity of marble tiles and resultant revenue from marble business.

Methods. Primary data was collected from respondents to ascertain trends in 2015, 2016 and 2017. These values were projected to 2025 by using computational software GeoGebra. To validate socioeconomic impacts beyond 2025, values of variables were further projected to 2030 using exponential rate model.

Findings. Analysis indicated that because of vintage and outdated equipment and plants, presently small marble industrial units were operating at below the optimum potential. These industrial units were required to be clustered in modern Mohmand Marble City. Results showed that after modernization and clustering of small marble industrial units into a modern marble city, socioeconomic status of rural public will be exponentially enhanced, production of marble tiles will be substantially boosted and revenue will increase.

Originality. This study used innovative computational software GeoGebra for analysis of data at each stage. It also used catalyst model and exponential rate model to estimate effects of clustering and modernization of mineral industries. In a nutshell, this study is a unique combination of mathematical, computational and spatial framework.

Practical implications. The results, conclusions and policy recommendations are globally applicable especially for developing countries to modernize the mineral extraction and processing industries and boost their potential in mineral trade.

Keywords: *mineral economics, mineral extraction and processing, rural public, productivity, marble tiles, revenue, economic analysis*

1. Introduction

Marble is a valuable mineral that is globally used a building material after transforming into marble tiles of different shapes and sizes. It is extracted from metamorphic rock that is geologically composed of recrystallized carbonate minerals commonly known as limestone such as calcite or dolomite. However, extraction and processing of marble is a very sequential and intricate process. Unfortunately, in developing countries this complete process is yet far from modernization due to lack of advance technology and industrial development. This results into quantitative and qualitative wastages besides the issues of capacity and optimum efficiency. Realizing this problem, government of Pakistan took a policy decision in 2015 to cluster small marble industrial units of Mohmand District into modern marble state of the art industrial city called Mohmand Marble City that will have the status of special economic zone.

Recent research has indicated that special economic zones have dual benefits. On one hand special economic zones render conventional economic benefits of productive efficiency and investments attraction while on the other hand they help in improvement of socioeconomic life of households living in under developed rural areas nearby these special economic zones [1]. Moreover, these zones provide opportunities for workforce employment and skill development, better education and modern health facilities. Because of these zones modern energy means are extended to households living in surrounding areas [2]. Thus, due to modernization of technology and enhanced facilities, special economic zones act as catalyst for socioeconomic betterment of households, productivity enhancement, quantitative and qualitative efficiencies to achieve sustainable economic growth [3].

Under the umbrella of China Pakistan Economic Corridor, nine special economic zones have been planned in Pakistan. These zones are mostly located in rural areas [4]. It is expected that socioeconomic life of households living in adjacent rural areas will improve due modern facilities that these zones will bring to these rural areas, more the productivity and revenue will enhance due to advance technologies [4]. In the same context, Mohmand Marble City is being developed at District Mohmand which a rural under developed area in Pakistan. This city will house small marble industrial units that are already functioning in a disintegrated and disorganized manner in Mohmand District [5]. It is expected that

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availability of advance extraction and processing technologies and modern industrial facilities in Mohmand Marble City will boost marble industry manifold. However, this needs empirical validation which is prime objective of this study.

Consequently, this study elucidated threefold impacts of clustering of small marble industrial units into Mohmand Marble City. First, due to modern mineral industrial facilities change in socioeconomic index of rural households living in adjacent areas was estimated. Second, due to availability of advance mineral extraction and processing facilities enhancement in marble tile production was estimated. Third, impact on revenue from enhance production of marble tiles was estimated. For this, primary data on selected variables was collected for 2015, 2016 and 2017 from respondents. Values of these variables were initially projected to 2025 which is likely year of completion of Mohmand Marble City. Later these values were projected to 2030 to validate impacts in future. Results indicated that mineral extraction and processing with modern technology in Mohmand Marble City shall bring significant socioeconomic benefits.

This study has few novel and innovative contributions to its credit. For instance, the use of computational software GeoGebra for analysis of data at each stage, the use of differential calculus to estimate rate of change in each variable, the use of catalyst model to estimate catalyst effects of clustering and modernization of mineral industry and lastly the use of exponential rate model to estimate exponential socioeconomic impacts in future after completion of Mohmand Marble City. In nutshell, this study is unique combination of mathematical, computational and spatial framework to assess socioeconomic blessings of a mineral extraction and processing venture in a developing country scenario. The methodology, results, conclusions and policy recommendations are globally applicable especially for developing countries.

2. Contextual appraisal

Clustering of industries in special economic zones gained significance in early 60^s when world realized that clustering and agglomeration of industries can attract domestic and foreigner investors. Today, special economic zones in East Asia and Latin America are successful, while performance of majority of African and Asian zones is short of expected results. In essence clustering of industries in special economic zone is done to attract investment, develop industries with infusion of modern technology, increase exports and encourage policy reforms. Impacts of clustering of different industries on trade, productivity and investment have been investigated by researchers but estimation of impacts attributed to clustering of mineral industries has been a neglected area. Factually, like other industries, clustering of mineral industries in a special economic zone brings improved infrastructure, modern energy, and excellent education and health facilities to areas where these are located and, hence, these can benefit households in proximity along with increase in productivity and revenue generation.

2.1. Geology and morphology of marble reservoirs

Marble is basically a metamorphic rock having geological composition of carbonate minerals commonly known as limestone. Geology and morphology of rock deposits is strongly linked with the quality of marble reservoir. In 2014, Goudie and Viles elucidated process of weathering on Namib Plains in Africa that affected the quality of marble and granite stones. The geomorphological processes added value to marble and granite reservoirs and its texture and hardness improved [6]. In 2004, in a study on geology of marble rocks in Greece and Turkey, Herz indicated in 1988 that Greece and Turkey have huge marble reservoirs that should be explored for production of quality marble tiles. These tiles can be exported to other countries to boost trade [7]. In 2018 in a study on geology of Ark Marble Mine in Birjand, Kardan et al. explained the geological process of marble mineral. It was elucidated that marble is naturally available as limestone mineral rock in a layered form. Because of geological processes it has numerous natural patterns and textures that add to its beauty [8]. Similarly, in 2005 Melezhik et al. described the geotechnical aspects of Norwegian Catedonides. It was analytically explained in the paper that geology of calcite and dolomite rocks. The geochemical compositions of the two marble rocks were much different. Calcite is commercially more suitable than dolomite [9].

2.2. Marble tiles

Marble is used for making tiles of different varieties which are used in buildings both for decoration and facade. In 2014, Meyer et al. carried research on tile industry of Italy, Spain and Brazil. It was identified in the study that clustering of industries was very beneficial and it made value chain management easy. Moreover, clustering improved the quality of tiles [10]. In an analytical study of 1988, Pires et al. indicated significance of modern technology to increase value of marble tiles. It was highlighted in the study that laser cutting increases quality of marble tiles manifold compared to rough cutting. In marble industry laser cutting should be preferred [11]. Similarly, in 1988 Röder carried out research on Numidian marble in Tunisia. It was explained in the study that yellow colour and fine texture of the marble slates made Numidian marble highly unique. This marble was used by Roman to beautify their residences [12]. Sani presented his research about Nigerian Jakura marble in 2017. It was concluded in the study that exploration of Jakura marble for tiles production will result in significant economic growth for Nigerian economy [13].

2.3. Marble industry

Marble industries have been established by many developed and developing countries that have marble deposits on their landscape. Researchers have investigated development, clustering, production and revenue of marble industries. For instance, in 2019, Ahmad and Khan carried out research on socioeconomic impacts of marble industries in Mohmand District, Pakistan. It was explained in the study that with increase in the marble business in Mohmand District, the per capita income of industry owners is increasing which has improved their standard of living [14]. Beykan conducted study on Sile Shipwreck in 1988 and indicated that marble has been a great source of architectural elegance. Owing to its architectural value, business prospects of marble industries are rising with time [15]. A study conducted by Hamza and El Haggar in 2016 highlighted that innovation in marble and granite processing can give enhanced economic benefits. He highlighted that even waste of marble and granite is not a waste as it can be re-cycled and re-used [16]. Similarly, Long indicated in 2016 that Roman marble quarries exhibited huge economic value and it contributed to economic growth [17]. In 1985, Max wrote a book about Connemara marble indus-

try in Dublin. It was highlighted in the book that Connemara marble is the most distinguished marble industry in Ireland and it has significantly contributed to export of marble and earned economic benefits for country [18]. Similarly, in 2004 Meyer-Stamer et al. investigated evaluation and progress of marble industries in Italy, Spain and Brazil focusing on clusters. It was indicated in the study that marble industries in these countries are boosting and contributing substantially to overall socioeconomic growth of these countries [10]. Ratté and Ogden analyzed marble industries of Vermont in 1989. They concluded that marble, granite and slate industries of Vermont have contributed to socio-economic development of the areas. These industries have attracted investment and enhanced trade [19].

2.4. Clustering of small industries

In 2014, Aharonson et al. carried out research on innovative output that can be achieved by industrial clustering. It was highlighted in study that as a result of knowledge sharing, product innovation increases with industrial clustering which results in increased diversification and huge economic benefits [20]. Breschi carried out research on economic clustering and its relevance to geography. It was concluded in the study that geography of industrial clustering has significant impact on overall economic progress and socioeconomic wellbeing of population [21]. In 2017, Foghani et al. highlighted that industrial clusters should be promoted for greater economic development in the present environment of globalization [22]. In 2007, Karaev et al. indicated that by clustering small industries enhanced competitiveness and innovation can be obtained through knowledge and skill sharing within the constituents of cluster. This process may contribute to higher productivity and greater economic development [23]. In 2011, Long and Zhang explained the Chinese experience of industrial clustering and its performance. It was concluded that industrialization, technological development and productivity improved with clustering [24]. In 2006, Ryung et al. indicated the clustering of small and medium size enterprises will promote innovation and entrepreneurship. This may result in product diversification and enhanced exports [25]. In 2000, Sato elucidated the benefits of clustering of small firms in Ceper, Indonesia. Small firms in the cluster established linkages with assemblers and wholesalers that contributed to development of firms and industrialization [2]. In 2005, Tambunan indicated the critical factor of connectivity of cluster to market and increased business potential. It was explained in the study that if cluster linkage to market is ignored than the experience of clustering may not be successful [26].

2.5. Socioeconomic impacts of industrial clustering in special economic zones

Many researchers have investigated socioeconomic impacts of special economic zones in different regions of the world. In 2012, Aggarwal carried out an incisive study to elucidated social and economic impacts of special economic zones. It was concluded that these zones improve overall economic growth and social development of community. Similarly, it was explained in the study that special economic zones are no more associated with economic benefits only; rather special economic zones have huge social impacts on communities adjacent to special economic zones [3]. Similarly, Caniels has elucidated in 2005 that industrial and technological clusters in special economic zones increase innovativeness and improve quality of products and thus enhanced competitiveness is generated in firms. It was also highlighted that these clusters have huge social benefits in the form of improved facilities and job creation [27]. In 2016, Ghazali et al. carried out research on clustering of small and medium size enterprises to promote local economy. It was concluded in the study that by clustering small industries, local economy will benefit through enhanced opportunities of employment, innovation, collaboration and joint ventures by development of strong networks amongst the constituents [28]. In 2004, Helsley worked on economics of agglomeration and indicated how coherent and effective agglomeration of industries can augment process of economic growth in regional context [23]. In an incisive study in 1998, Litwack and Qian elucidated that special economic zones are catalysts for economic transition in different countries owing to socioeconomic impacts of these zones [29]. McCann explained in his 2011 online book that industrial clustering has been an excellent geo-economic strategy that ensured sustainable economic development and urban growth in many countries [30]. In 2017, Oyeyinka explained Nigerian experience of industrial clustering. It was highlighted in the paper that industrial cluster improved employment, reduced poverty and contributed to enhance living standards of communities [1]. Similarly, Plummer and Sheppard asserted the significance of structure and dynamics of industrialization based on geographical agglomeration in 2006. It was concluded in study that geographical grouping of industries accrued socioeconomic dividends in case of many developing countries [31]. Likewise, Walsh has indicated that by aligning social policy with development policy of special economic zones, socioeconomic blessings of special economic zones can be amplified manifold. Optimal social benefits of special economic zones can be achieved with effective orientation of social policy [32].

Thus, from the contemporary research it can be safely concluded that marble industries are contributing to economy of countries across the globe wherever this natural resource is available. Moreover, to reap the optimum socioeconomic benefits from this natural resource, it is preferred to create an industrial zone with modern processing machines within manageable distance from the marble quarries to produce huge quantity of marble tiles. Such industrial zone will also bring prosperity to households in surrounding of industrial zone.

3. Marble resources in Pakistan

Pakistan is blessed with huge reservoirs of natural mineral resources including marble. Pakistan has an estimated 297 billion tons of marble and granite reserves in the hilly regions. Marble is the 5th largest contributor to GDP of Pakistan. Marble tiles and other products are being exported to different countries around the globe. Currently, China is the top most natural stone consumer followed by US. China accounts for 60% of Pakistan's total marble exports. China and Italy purchase raw products like slabs and blocks, process it and then re-export value-added items to other countries. Russia and the US, as well as Middle Eastern and European countries demand finished marble products, and thus constitute less than 10% of our export. Saudi Arabia alone imports marble products worth $1500 million. This indicates the dire need for developing technology to capture value-added export markets. The current contribution of industry through export of marble and granite amounts to $134 million.

In a recent document, Pakistan Stone Development Company elucidated that marble and stone trade can reach to $2.5 billion in short term if policy and structural bottlenecks are removed.

In case of Pakistan, most of processing units in country are prepared with local man-made crude cutting machines consuming high electricity expenditure. Over 2000 processing units are operational in the country and more than 1200 quarries are operational. Besides, industry has provided jobs to around 200000 individuals. Pakistan's annual quarry production is 3.82 million tons. Country's annual production of marble tiles is around 2.5 million tones, which contributes merely 2% to global market. Despite many constraints faced by industry, sharp increase in its exports during last decade shows its high potential for trade.

Mohmand is a district of Khyber Pakhtunkhwa Province of Pakistan. It has mountainous topography with few plain spots. Its current population is 466984 with a growth rate of 1.77. Male population is 238003 while female population is 228981. Total area of Mohmand district is 2296 square kilometers. As shown in Figure 1, Mohmand Marble City is located in Mohmand District roughly at a half an hour distance from Peshawar, the capital of Khyber Pakhtunkhwa Province, Pakistan.

Figure 1. Location of Mohmand Marble City

There are many marble reservoirs in District Mohmand. Tiles from Mohmand marble have many varieties of colour and texture and composition. About 7000 million tons of good quality marble exists in complete Mohmand district. Currently, more than one thousand million tons of marble stone are excavated annually from different mines of Mohmand Agency that indicates underutilization of huge reservoir present in the area. Present capacity of marble industry in Mohmand is production of 800 million tons of marble tiles. This indicates that presently marble industry in Mohmand is operating at below the optimum potential. Main reasons for this are; lack of capacity to handle huge marble reservoir, vintage and out-dated machines and processes, lack of infrastructure, energy break downs, lack of innovation, lack of skilled labour and professionals, and lack of interest by investors. However, presence of huge marble reservoir attracted planners and, now; a marble city is being developed in District Mohmand.

Mohmand Marble City is spread over 353 acres. This modern state of the art city is being established at the cost of 16.5 million US$. Marble city is comprised of 295 modern, well equipped industrial processing and production units. Marble city offers many investment and employment opportunities. It will bring energy, infrastructure, and education and health facilities with it that will benefit producers, labour and households in surrounding. In district Mohmand, unemployment is extensive which shall be reduced to some extent as construction of marble city offers 18000 direct jobs. Marble city is well connected with road, air and railway network as shown in Table 1. This connectivity will help in transforming Mohmand Marble City as hub of marble industry.

Geology of Mohmand marble reservoir indicated that it contains chromite, silica sand, dolomite, manganese, quarts, and feldspar at different locations of district. After quarrying, raw pieces of rocks are transported to respective marble factories where these raw junks are converted into fine marble tiles through a sequential manufacturing process (Fig. 2).

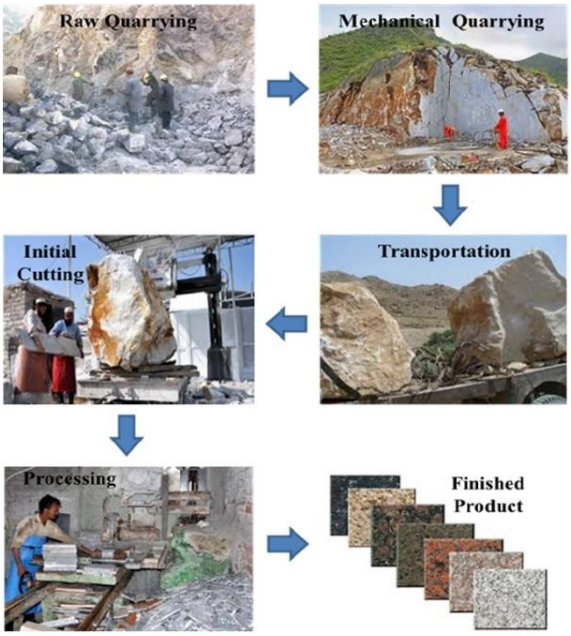

Figure 2. Manufacturing process of marble tiles

4. Theoretical building blocks of study

Socioeconomic status of households 'S' living in the rural villages surrounding Mohmand Marble City, annual production of marble tiles 'P' and revenue generated 'R' were taken as dependent variables. To find out value of socioeconomic status of households, six explanatory or independent variables were selected. Description of variables is shown in Table 2.

Using Leonhard Euler functional notation, socioeconomic status was taken as function of six selected explanatory variables as shown in Equation 1:

$$\text{Socioeconomic status of households } (S) = f\,(I, W, E_m, E_f, H, E). \quad (1)$$

Five temporal nodes were used to find out values of socioeconomic status of households, marble tiles production and revenue generated from marble tiles trade.

Table 1. Description of connectivity of Mohmand Marble City

Project	Area (acres)	Type	Distance (kilometers)					
			Motorway / highway	Airport	Railway station	Dry port	Sea port	City centre
Mohmand Marble City	353	Marble industry	33	40	40	40	–	38

Table 2. Description of dependent and independent variables

Variables	Symbol	Description
Dependent variables		
Socioeconomic index	*S*	Index showing socioeconomic status of households living in areas surrounding MMC.
Marble tile production	*P*	Quantity of marble tiles produced (million tons per year).
Revenue generated	*R*	Revenue generated by selling of marble tiles (million US$ per year).
Independent variables for estimation of socioeconomic index (*S*)		
Per capita income	*I*	Average per capita income of households (US$ per year).
Employment	*W*	Average annual number of workers in in marble industry in District Mohmand.
Male education	E_m	Average annual enrolments of male students in educational institutes (public and private schools, colleges and above).
Female education	E_f	Average annual enrolments of female students in educational institutes (public and private schools, colleges and above).
Health	*H*	Average annual number of patients in public and private hospitals, basic health units, treatment centres.
Energy	*E*	Average annual per capita electricity consumption (kilowatt hours) of households.

These five nodes included: 2015 as t_1 which was the bench mark year for collection of data; 2016 as t_2, 2017 as t_3, 2025 as t_4 which was taken as the year of likely completion and commissioning of Mohmand Marble City and 2030 as t_5 which was taken as year for which future impact of Mohmand Marble City was required to be estimated. Temporal nodes are indicated in Figure 3.

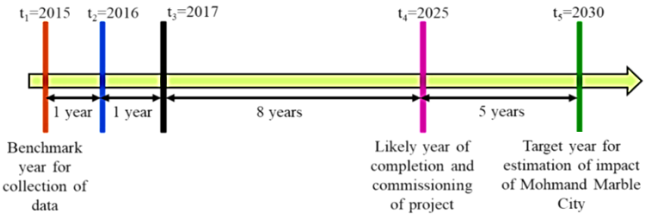

Figure 3. Temporal nodes for study

Socioeconomic status of households was calculated for 2015, 2016 and 2017 by using mathematical framework of dynamic time variant model as given in Equation 2-4.

In Equation 2, "ω" was dynamic constant that was dependent on prevailing socioeconomic conditions. It could take value from 0 to 0.99. Since, work on Mohmand Marble City is still in progress; its value was taken as 0.25 representing initial conditions.

$$\text{Socioeconomic index } S\ (2015) = \left[\omega \frac{\sum_1^n \left[v_{t_1} \right]}{\sum_1^n \left[\left(v_{at_3} - v_{at_1} \right) \right]} + \frac{\sum_1^n \left[v_{t_a} \right] - \sum_1^n \left[v_{t_1} \right]}{T \sum_1^n \left[\left(v_{at_2} - v_{at_1} \right) \right]} + Tx \frac{\sum_1^n \left[v_{t_1} \right] + \sum_1^n \left[v_{t_2} \right] + \sum_1^n \left[v_{t_a} \right]}{\omega \left[\sum_1^n \left(v_{t_a} \right) - \sum_1^n \left(v_{t_1} \right) \right]} \right]; \quad (2)$$

$$\text{Socioeconomic index } S\ (2016) = \left[\omega \frac{\sum_1^n \left[v_{t_2} \right]}{\sum_1^n \left[\left(v_{at_3} - v_{at_1} \right) \right]} + \frac{\sum_1^n \left[v_{t_3} \right] - \sum_1^n \left[v_{t_2} \right]}{T \sum_1^n \left[\left(v_{at_3} - v_{at_2} \right) \right]} + Tx \frac{\sum_1^n \left[v_{t_1} \right] + \sum_1^n \left[v_{t_2} \right] + \sum_1^n \left[v_{t_3} \right]}{\omega \left[\sum_1^n \left(v_{t_2} \right) - \sum_1^n \left(v_{t_1} \right) \right]} \right]; \quad (3)$$

$$\text{Socioeconomic index } S\ (2017) = \left[\omega \frac{\sum_1^n \left[v_{t_a} \right]}{\sum_1^n \left[\left(v_{at_3} - v_{at_2} \right) \right]} + \frac{\sum_1^n \left[v_{t_2} \right] - \sum_1^n \left[v_{t_1} \right]}{T \sum_1^n \left[\left(v_{at_3} - v_{at_1} \right) \right]} + Tx \frac{\sum_1^n \left[v_{t_1} \right] + \sum_1^n \left[v_{t_2} \right] + \sum_1^n \left[v_{t_3} \right]}{\omega \left[\sum_1^n \left(v_{t_a} \right) - \sum_1^n \left(v_{t_2} \right) \right]} \right]. \quad (4)$$

Similarly, "*v*" was numerical value of explanatory variable in particular year whereas "v_a" was annual average numerical value of explanatory variable. Moreover, "*n*" indicated number of explanatory variables for estimation of socioeconomic index and "*T*" was the temporal span in years.

To explain dynamic time variant model, just glance Equation 2 that indicates that it was a unique mathematical framework owing to its constituents. It contained three distinct parts. First part represented by $\omega \frac{\sum_1^n \left[v_{t_1} \right]}{\sum_1^n \left[\left(v_{at_3} - v_{at_1} \right) \right]}$ was kinetic component. Second part represented by $\frac{\sum_1^n \left[v_{t_3} \right] - \sum_1^n \left[v_{t_1} \right]}{T \sum_1^n \left[\left(v_{at_2} - v_{at_1} \right) \right]}$ was distributive component. Third part represented by $\frac{\sum_1^n \left[v_{t_1} \right] + \sum_1^n \left[v_{t_2} \right] + \sum_1^n \left[v_{t_3} \right]}{\omega x T \left[\sum_1^n \left(v_{t_3} \right) - \sum_1^n \left(v_{t_1} \right) \right]}$ was temporal component. Similar is the case with Equation 3 and 4. Thus, it was a wholesome and comprehensive mathematical model covering essential dynamic and temporal variations in values of explanatory variables for socioeconomic index.

Value of socioeconomic index of rural households was estimated for 2025. This was done by using computational software, GeoGebra. However, after completion and operationalization of Mohmand Marble City, it is expected that socioeconomic index of rural households "*S*", production of marble tiles "*P*" and revenue "*R*" will increase exponentially. Future values of these variables were estimated for 2030 by computational software, GeoGebra using novel mathematical framework of exponential rate model as shown in Equation 5. The formula may look different compared to traditional exponential function's formula because in this case we were interested in effects of Mohmand Marble City after likely completion of construction in 2025 and not from the bench mark year 2015.

$$S, P, R \text{ value in } 2030 = v_{2025} + \left[\frac{(1+\mu)^t - 1}{\mu} \right], \quad (5)$$

where:

μ – was rate of annual increase in the values of "*S*", "*P*" and "*R*" from 2015 to 2025;

t – was the temporal span after completion and commissioning of Mohmand Marble City;

v – were values of variables in 2025.

Using this mathematical and computational software, data was analyzed and results were obtained which have been discussed in the ensuing sections.

5. Research design and data collection

A very comprehensive research design was chalked out for data collection. Data was required to be collected on three variables; socioeconomic index "*S*", marble tile production "*P*" and revenue generated "*R*". Data on these variables was required to be collected initially for 2015, 2016 and 2017. Primary data was collected through questionnaires, interviews and field visits. Secondary data was collected from available documents on relevant websites, records available with district administration and relevant ministries. Sample composition was diverse and mix. Respondents were selected randomly without any bias or affiliation. Total sample was 400 respondents. Respondents were helped to comprehend the questions being asked in the questionnaire. Data collection methodology is explained below.

5.1. Data collection for socioeconomic index of households

Socioeconomic index of households "*S*" was a subjective dependent variable. Therefore, data on its constituent explanatory or independent variables such as per capita income, employment, education, health and energy was required to be collected to estimate its value. For this purpose, primary data was collected from the households of surrounding rural villages; Umar Banda, Nawab Sher Koroona, Utmanzai and Shal Koroona. Four teams collected data from households of four villages (one team per village). Sample size was 200 respondents (50 respondents from each village) for this variable. Questionnaire was translated in native Pashto language for easy comprehension of households. Sample composition is shown Table 3.

Table 3. Sample composition

Respondents	Education	Gender	Age (years)	Size (numbers)
Households	Educated	No gender bias	18-50	200
Marble factory owners (producers)				50
Workers				50
Investors				20
Retailers (sellers)				20
Wholesalers				20
Consumers (purchasers)				20
Technical experts				20
Total sample size				400

Source: author's work

5.2. Data collection for quantity of marble tiles and revenue generated

As marble tile production "*P*" and revenue generated "*R*" were quantitative variables, therefore, data for these variables was collected directly from factory owners (producers), workers, investors, retailers, wholesalers, consumers and technical experts. For this purpose, one team was formulated with a distinct questionnaire specially designed for respondents from marble industry. Respondents knew values of annual quantity of marble tiles produced and revenue generated in 2015, 2016 and 2017. Sample size for this variable was 200 respondents as shown in Table 3.

5.3. Use of mathematical and computational software

After collection, data was sifted, tabulated and fed into computational software, GeoGebra for analysis. GeoGebra is a dynamic mathematical package that contains solution packages for problems related to geometry, algebra and calculus. It has user friendly facilities to create spreadsheets, plots and graphs with relevant details including trend equations. Data was processed by software after numerous iterations and attenuations. Results obtained from data processing have been discussed in ensuing section.

5.4. Research design

Study was completed using a systematic research scheme comprising distinct steps. At each stage of research, errors were avoided by careful handling of data and efficient use of computational software. Overall research design that was adopted for study is shown in Figure 4.

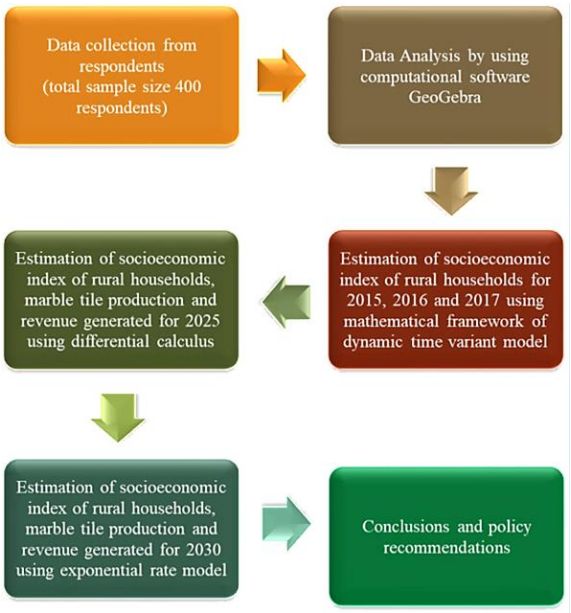

Figure 4. Research design

6. Data analysis

6.1. Socioeconomic index of households "S"

Data was summarized and tabulated on Excel sheets. These excel sheets also indicated important descriptive statistics for the data. Computational software GeoGebra has the ability to import Excel sheets into its system. Summarized data sheets of explanatory variables for socioeconomic index are shown in Table 4. Data was imported into software to estimate socioeconomic index of rural households for 2015, 2016 and 2017. Equations 2, 3 and 4 were used for estimation of socioeconomic index of rural households living in proximity to Mohmand Marble City. Values of socioeconomic index for 2015, 2016 and 2017 were 145.16, 438.84 and 1024.88. Summary of calculation is shown in Table 5.

It is worth mentioning here that work on Mohmand Marble City started in 2015 under China Pakistan Economic Corridor. As a first step, marble industries in District Mohmand were facilitated in quarrying, production, transportation and manufacturing processes. Similarly, transportation of manufactured marble tiles to markets was streamlined and related taxes and duties were relaxed. Investors were invited to invest in the fast-growing marble industry.

Table 4. Summary of data on explanatory variables for estimation of socioeconomic index of rural public living in undeveloped rural villages adjacent to Mohmand Marble City

Variables	Umar Banda	Nawab Sher Koroona	Utmanzai	Shal Koroona	Average	Standard deviation	Skewness	Kurtosis
				2015				
I	115409	103908	99670	102789	105444	6881.1	1.585	-0.23
W	6906	4689	5303	5893	5698	943.6	0.542	-3.21
E_m	5233	4981	5117	4940	5068	133.6	0.529	-5.40
E_f	1093	956	890	933	968	87.7	1.417	-0.71
H	3209	6109	7090	8211	6155	2143	-1.087	-1.79
E	349	693	671	761	619	183.7	-1.734	0.13
				2016				
I	118906	109676	98609	124708	112975	11403.3	-0.529	-4.23
W	5908	6098	3908	7609	5881	1519.5	-0.476	-1.58
E_m	5833	6309	6023	4905	5768	607.4	-1.386	-0.86
E_f	1018	1023	936	988	991	39.9	-1.229	-2.43
H	6506	6098	5339	2789	5183	1668	-1.529	-0.85
E	613	724	615	544	624	74.4	0.787	-1.29
				2017				
I	104507	113505	123506	126610	117032	10049.3	-0.564	-5.21
W	4605	7203	7101	6505	6354	1206	-1.640	-0.57
E_m	5809	6503	5590	6303	6051	424	-0.037	-6.88
E_f	1289	1233	813	936	1068	230	-0.191	-7.49
H	3119	3980	5998	6809	4977	1717	-0.024	-6.94
E	530	740	620	754	661	106.0	-0.570	-5.79

Table 5. Summary of calculations for socioeconomic index

Calculations	2015	2016	2017
Dynamic constant "ω"	0.25	0.25	0.25
Duration "*T*"	3	3	3
$\sum_{1}^{n}\left[v_{t_1}\right]$	495803	–	–
$\sum_{1}^{n}\left[v_{t_2}\right]$	–	525685	–
$\sum_{1}^{n}\left[v_{t_3}\right]$	–	–	544568
$\sum_{1}^{n}\left[\left(v_{at_3}-v_{at_1}\right)\right]$	12191	–	–
$\sum_{1}^{n}\left[\left(v_{at_3}-v_{at_2}\right)\right]$	–	4721	–
$\sum_{1}^{n}\left[\left(v_{at_2}-v_{at_1}\right)\right]$	–	–	7471
$\left[\sum_{1}^{n}\left(v_{t_3}\right)-\sum_{1}^{n}\left(v_{t_1}\right)\right]$	48765	–	–
$\left[\sum_{1}^{n}\left(v_{t_3}\right)-\sum_{1}^{n}\left(v_{t_2}\right)\right]$	–	18883	–
$\left[\sum_{1}^{n}\left(v_{t_2}\right)-\sum_{1}^{n}\left(v_{t_1}\right)\right]$	–	–	29882
S value (using Equations 2, 3 and 4)	*S* (2015) = 145.16	*S* (2016) = 438.84	*S* (2017) = 1024.88

Available record indicated that many investors invested in marble industries and private sector investment of 13.6 million US$ was recorded in the marble industry in 2015. Positive business environment was shaped up when government gave many relaxations to marble tiles producers. All these steps had effect on socioeconomic status of rural households living in proximity to Mohmand Marble City. Consequently, just after a year socioeconomic index of rural households raised by 202% compared to its value in 2015. Similarly, its value in 2017 further increased by 133.5 compared to its value in 2016. So, three aspects were very evident from this estimation; one, confidence of investors, producers, wholesalers, consumers improved as a result of start of work on clustering of marble industries in Mohmand Marble City and related government actions. Second, growing and progressive marble industry environment was shaped up by establishment of Mohmand Marble City. Third, socioeconomic status of rural households living in underdeveloped rural villages improved due to start of work on Mohmand Marble City and government's facilitative actions.

6.2. Marble tile production "*P*"

The finished products from marble industry are fine quality marble tiles. Raw material obtained from marble reservoir is processed through manufacturing mechanism which results into an output of excellent quality marble tiles of different types. These types are indicated in Figure 5.

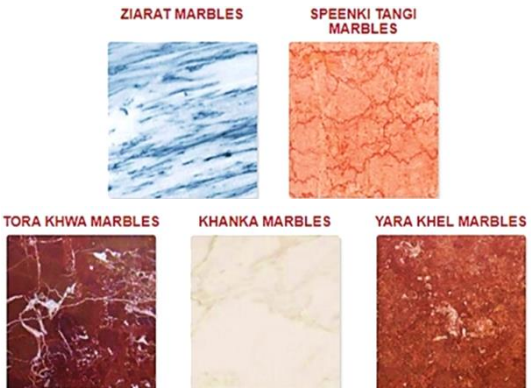

Figure 5. Marble products in Mohmand District

Data values of quantity of marble tiles produced in District Mohmand in million tons per year were directly obtained from marble industries through interviews and discussions with producers and industrialists. Data values obtained from respondents is shown in Table 6.

Table 6. Annual marble tile production "P"

Year	Marble stone quarry (million tons per year)	Production of marble tiles (million tons per year)	Increase (%) production of marble tiles
2015	2000	436	–
2016	6000	503	15.36
2017	14000	813	61.63

Source: author's work

Start of work on construction of Mohmand Marble City and friendly steps of government for marble industries resulted in boosting marble tile production by 15.3% in 2016 and 61.6% in 2017. This indicated that Government's will to establish of Mohmand Marble City under China Pakistan Economic Corridor has motivated producers, workers and consumers of marble industry manifold.

6.3. Revenue "*R*"

As production of marble tiles increased, correspondingly, the revenue generated increased. Data of revenue generated by selling of marble tiles (million US$ per year) was obtained from producers and investors through interviews and discussions. Summary of the data is shown in Table 7.

Table 7. Summary of annual revenue "R"

Year	Average rate (million US$ per ton)	Production of marble tiles (million tons per year)	Selling (% of quantity)	Revenue (million US$ per year)	Increase (%) in revenue
2015	0.36	436	70%	109.87	-
2016	0.28	503	82%	115.49	5.1%
2017	0.28	813	89%	202.60	75.43%

Source: author's work

Table 5, 6 and 7 gave values socioeconomic index, annual production of marble tiles and annual revenue generated for 2015, 2016, and 2017. To find out representative equations, these values were fed into computational software GeoGebra. Digital graphs along with representative equations of three variables and co-efficient of determination "R^2" values are shown in Figure 6.

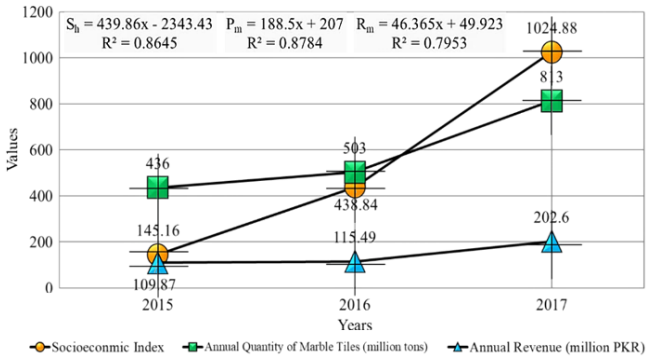

Figure 6. Digital graphs of data for 2015, 2016 and 2017

Critical observation of Figure 6 revealed that these variables are correlated with each other, meaning thereby that when production increased, revenue increased and socioeconomic status of households improved. Moreover, digital graphs for the three variables exhibited linear tendency. The co-efficient of determination values for the three graphs indicated accuracy of the estimates.

6.4. Projected values of variables for 2025

After estimation of variables for 2015, 2016 and 2017, we had to estimate projected value of socioeconomic index of households, production of marble tiles and revenue for next temporal node i.e. 2025, the year of likely completion and commissioning of Mohmand Marble City. This was important to estimate values for year 2025 because after 2025 Mohmand Marble City will start impacting the values of three variables and previous trend may change. For this estimation process, rate of change values and differential calculus was used. Rate of change or slope of line is the first differential of the line's representative equation. Calculations are shown in Table 8.

Table 8. Estimation of socioeconomic index, quantity of marble tiles and revenue for 2025

Year	Equation	R^2	Rate of change or slope	Values for 2025
Socioeconomic index "*S*"	S_h = 439.86x – 343.43	0.864	$\frac{dS_h}{dx} = 439.86\frac{dx}{dx} - 0$ $\frac{dS_h}{dx} = 439.86$	x =10 for 2025 S_h = 439.86(10) – 2343.43 = 2055.6
Quantity of marble tiles "*P*"	P_m = 188.5x + 207	0.878	$\frac{dP_m}{dx} = 188.5\frac{dx}{dx} - 0$ $\frac{dP_m}{dx} = 188.5$	x =10 for 2025 P_m = 188.5 (10) – 207 = 1678 million tons per year
Revenue "*R*"	R_m = 46.365x + 49.92	0.795	$\frac{dP_m}{dx} = 46.365\frac{dx}{dx} - 0$ $\frac{dP_m}{dx} = 46.365$	x =10 for 2025 R_m = 46.365 (10) – 49.92 = 413.73 million US$ per year

Source: author's own work

Values of three variables obtained for 2025 from differential calculus were plotted in relation to values in 2015, 2016 and 2017. Resultant digital graphs are shown in Figure 7.

A critical glance on Figure 7 revealed that similarity in trend and rate of increase still existed for three variables. Values of socioeconomic index of households, marble tile production and revenue increased linearly with almost same trend and rate. Rate of increase in values is shown in Table 9.

Values in Table 9 were significant. It validated the fact that values of three variables increased with almost same average annual rate (roughly over 10%), almost linearly. It also indicated the existence of correlation between the three variables.

Table 9. Rate of increase in the values of variables

Year	Value 2017	Value 2025	Increase	Rate (%)	Time span (years)	Annual rate (%)
Socioeconomic index "*S*"	1024.88	2055.6	1030.72	100.5	10	10.05
Quantity of Marble Tiles "*P*"	813	1678	865	106.39	10	10.63
Revenue "*R*"	202.6	413.73	211.13	104.21	10	10.42

Source: author's own calculations

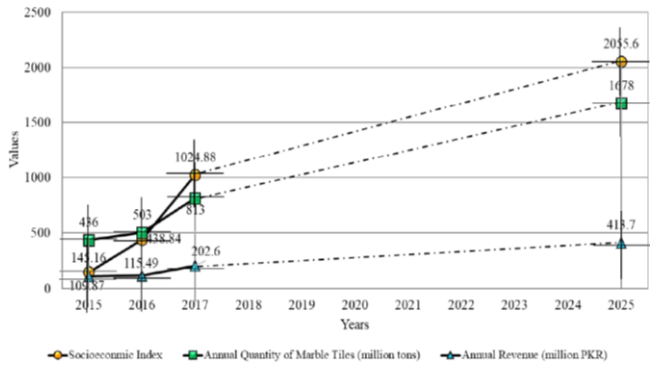

Figure 7. Digital graphs of data extended to 2025

Now, it could be easily inferred that, ceteris paribus, if one variable was increasing with a specific rate, other two would increase with almost the same rate. But there was a twist to this fact; the completion and functioning of Mohmand Marble City that will have a different impact on these variables.

It is expected that Mohmand Marble City may be completed and fully functional by 2025 which shall change the prevailing trend due to following reasons:

– latest technology, machines and manufacturing tools including modernized packing and lifting machines will be used in marble city;

– improved infrastructure and communication network including roads and parking will be available in marble city;

– uninterrupted energy, improved health and educational facilities will be available;

– greater job opportunities with increased pay for experts and workers;

– modern transportation and cargo facilities that will ensure efficient handling of raw material and finished products;

– improved working and living environment for technical experts and workers;

– relaxation by government in custom duties, taxes and tariffs as a result of legal framework for Mohmand Marble City.

6.5. Projected values of variables for 2030

These above mentioned seven factors will exponentially increase value of socioeconomic index of rural households living in surroundings of Mohmand Marble City, quantity and quality of marble tiles and consequently revenue generated. This increase was required to be estimated. This was done by computational software GeoGebra and mathematical framework of exponential rate model as shown in Equation 3. Summary of calculation is shown in Table 10. Table 10 clearly indicated that Mohmand Marble City will have exponential effect on values of three variables. Values jumped exponentially from 2025 to 2030. To get a clear picture, these values were plotted using GeoGebra as shown in Figure 8.

Table 10. Summary of calculations for exponential rate model

Year	Equation	μ	v_{2025}	t (years)	Values in 2030
Socioeconomic index "*S*"	$S,P,R\ value\ in\ 2030 = v_{2025} + \left[\frac{(1+\mu)^t - 1}{\mu}\right]$	10.05	2055.6	5	18448
Production of marble tiles "*P*"		10.63	1678	5	21693.35 million tons per year
Revenue "*R*"		10.42	413.73	5	19054.36 million US$ per year

Source: author's own work

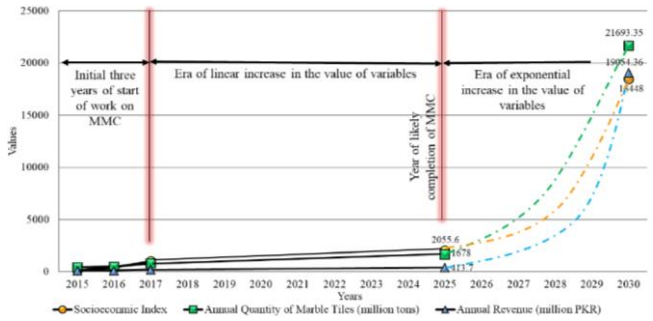

Figure 8. Digital graph of data extended from 2025 to 2030

In fact, Table 10 summarized the whole study. It showed that in initial three years of initiation of the project, socioeconomic index of households, quantity of marble tiles and revenue had a kick start. From 2017 to 2025, values of three variables increased with a linear trend. In 2025, it is likely that Mohmand Marble City will be completed and functional. Therefore, from 2025 onwards values of three variables increased exponentially. By 2030, we shall achieve a high socioeconomic index for the households living surrounding of Mohmand Marble City, we shall be able to annually produce 2.17 billion tons of excellent quality marble tiles and generate revenue of 19 billion US$ per year.

7. Conclusions and policy recommendations

After detailed analysis of data, it is concluded that socioeconomic index of rural households, marble tiles production and revenue from marble trade will increase exponentially after clustering of marble industries in Mohmand Marble City. Overall trend curve for selected variables before construction of Mohmand Marble City exhibited linear trend while after completion of construction trend changed to exponential growth in marble trade, revenue and socioeconomic status of rural households living in underdeveloped rural villages adjacent to Mohmand Marble City. Overall trend is clearly depicted in figure 8. However, results of this study are not only applicable to Mohmand Marble City; rather,

these are generally applicable to all industrial clusters at the global level, especially those located in the developing countries in underdeveloped rural areas.

Based on data analysis, findings and results of this study few policy recommendations are proffered for optimal reaping of benefits and consolidation of socioeconomic gains from industrial clusters at the global level.

Developed and developing countries have huge potential of mineral extraction, processing and refined marble trade as building material. Sizeable marble reservoirs are available in different parts of the globe. However, policy framework for marble extraction and processing to produce tiles needs refinement for most of the countries. This policy re-orientation is essential to facilitate intra and interstate trade, knowledge sharing, qualitative and quantitative improvements in marble products with infusion of modern technologies. Similarly, there is a need to align trade policy to promote marble trade covering both inland trade and exports to other countries. To give boost to marble extraction and processing and attract local and foreign investments, short term relief in tariffs and trade incentives package may have to be considered by different countries.

Presently marble industry is in crude shape in developing and under developed countries lacking modern machines and advance quarrying, extraction and processing techniques. Because of these shortcomings developing and under developed countries could not tap their optimal potential thus far. Some of the pertinent areas for improvement are suggested below. With these improvements marble trade will boost manifold in poor countries.

Modern mechanized marble quarrying, mining, extraction and processing techniques need to be used for optimum output from raw mineral reservoir. Current blasting practices in developing countries cause a huge loss of precious marble stone. Global quarrying statistics show that standard wastage of marble in poor countries is 45% due to lack of modern machines and equipment. To minimize these losses, a global drive is necessitated for provision of modern mining machines on rebated rates to manufacturers and producers in poor developing and under developed countries.

Extraction, cutting, storing and transportation of marble products may be focused significantly in developing and under developed countries. Modern cutting tools, transportation means need to be introduced and ware houses need to be developed. This will improve the efficiency, productivity and quality of the whole process.

Infrastructure development and clustering of marble industries may be done at all potential sites where reservoirs are available in developing and underdeveloped countries. Marble sector cannot be expanded without sound infrastructure including availability of energy and road network.

Mine safety, rescue and labour welfare procedures need to be streamlined to attract skilled and unskilled labour towards marble industry. This aspect is presently neglected in developing and under developed countries which usually results in fatal incidents.

Innovation and entrepreneurship are productivity and growth multipliers and marble trade at the world level is grossly lacking these two aspects. Therefore, proper framework for innovation and entrepreneurship need to be developed for longer and sustainable industrial marble production in all countries engaged in marble trade. Designs, texture, dimensions and other factors of quality should be based on market demands.

Marble extraction and processing for production of beautiful marble tiles is not an easy business. Ease of doing business index may be very low for marble business, especially in developing countries. Therefore, there is a need to facilitate local and foreign investors to overcome shortfalls and difficulties. Thus, comprehensive policy framework aiming at facilitating investors may be formulated immediately by all countries.

Skilled manpower can play a cutting-edge role in optimizing quarrying operations and manufacturing process. Therefore, governments of countries engaged in marble trade should establish vocational and skill training centers at appropriate locations close to marble reservoirs.

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Добувна та переробна галузі: їх соціально-економічна ефективність в умовах країни, що розвивається

Е. Гюль

Мета. Дослідження ефективності модернізації невеликих промислових підприємств, згрупованих у комплексі Марбл-Сіті, Моманд, Пакистан, для оцінки змін у соціально-економічному статусі сільського населення, що проживає в безпосередній близькості від Марбл-Сіті, а також збільшення виробництва мармурової плитки та доходів мармурового виробництва.

Методика. Первинні дані були зібрані у респондентів для визначення спрямованості змін у соціально-економічному статусі сільського населення у 2015, 2016 та 2017 роках. Ці значення були зпрогнозовані до 2025 року із використанням обчислювального програмного забезпечення GeoGebra. Для подальшого прогнозування значення змінних до 2030 року було використано експоненційну модель.

Результати. Аналіз показав, що через застаріле обладнання нині невеликі підприємства із виробництва мармуру працюють не оптимально. Ці виробничі потужності за проектом мали увійти до складу сучасного Моманд Марбл-Сіті. Результати дослідження підтверджують, що після модернізації та об'єднання невеликих підприємств у сучасний мармуровий комплекс соціально-економічний статус сільського населення експоненційно підвищиться, виробництво мармурової плитки значно зросте, а доходи від нього збільшаться. Дослідження є унікальним поєднанням математичного, обчислювального та просторового підходів.

Наукова новизна. Вперше використано інноваційне обчислювальне програмне забезпечення GeoGebra для поетапного аналізу даних, а також використано каталітичну та експоненційну моделі для оцінки впливу кластеризації і модернізації гірничодобувної промисловості.

Практична значимість. Результати, висновки та соціально-економічні рекомендації даного дослідження застосовні для модернізації галузей видобутку і переробки корисних копалин, а також підвищення їх потенціалу в торгівлі мінеральними ресурсами у всьому світі, особливо в країнах, що розвиваються.

Ключові слова: *економіка гірничої промисловості, видобуток та переробка корисних копалин, сільське населення, продуктивність, мармурова плитка, дохід, економічний аналіз*