

The Economic and Environmental Effects of Coal Mining: South Africa

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Abstract. South Africa is a country that combines considerable coal mines, coal reserves and natural resources, environmental issues, and water scarcity. Increasing concerns with the carbon footprint and carbon dioxide emissions worldwide have led to a growing number of scholars studying the coal mining field. According to the research, the influences of coal mining in South Africa are dissected. The positive influence is that coal mining improves the South African economy, expressive of impacts on export, domestic consumption, GDP, and employment. However, coal mining damages the environment, evidently in water and air, which harms people's and animals' health. Depending on the backgrounds and facts of South Africa, the environmental issues should be given more consideration because they may threaten South Africa in the long term. Fortunately, two environmental policies, including damage land tax (DLT) and environmental bonds, are referred to solve the issue brought about by coal mining. Therefore, the economic effects of coal mining are the benefits for South Africa; the environmental influences are the cost.

Keywords: South African Coal Mining, Economic Impacts, Environment Effects, Literature Review.

1. Introduction

In the world field, many scholars are obsessed with the coal mining field because it is a double-edged sword from the economic and environmental perspectives. Coal is a non-renewable resource with many hydrocarbons and carbon, a combustible black or brownish-black sedimentary rock. There are four types of coal, anthracite, bituminous coal, subbituminous coal, and lignite. They play different roles in various areas and industries. In the world, 41% of electricity, 70% of steel, and 90% of cement are produced by coal [1, 2]. Mathu and Chinomona indicated that mining has played an essential role in South Africa's economy because it is an earner of foreign currency in its economy, a contributor to aggregate output (GDP) and job opportunities [2, 3].

In South Africa's mining industry, the contributions and harmful impacts of coal mining emerged victoriously. Since 1923, coal has contributed to South Africa's economy and society. It is a significant energy source, which primarily benefits electricity and synthetic fuels. There are 64 coal mines in South Africa, including the largest scale in the world and minor scales of coal mines. Mpumalanga province is most prosperous coalfield place in South Africa, where produces over 70% coal [2]. Annually, the coal production in South Africa is 224 million tonnes [3]. However, coal is concerned that its pollution is at the largest level because it will produce pollution through mining, transportation, coal placing, planning, and using [4]. Because of the increasing prevention and concerns on climate change and global warming, in the last two decades, the carbon footprint and carbon dioxide emissions have been identified as global issues [2]. Thus, the environmental effects of coal mining are focusing by many scholars. Generally, the unit of carbon footprint is a ton, which measures human activities' impacts on producing the amount of carbon dioxide (CO₂) by burning fossil fuels. Moreover, carbon dioxide emission is distinguished as a greenhouse gas, which is produced by burning carbon and the respiration of living organisms [5]. Therefore, the positive and negative consequences of South Africa's coal mining clearly exist worldwide.

In this essay, the economic and environmental effects of coal mining in South Africa will be concerned, which is divided into four parts mainly, including facts, impacts, and environmental policies. The facts with literature review, data analysis, and figures are prime methods to assess the effects. Secondly, the impacts are based on facts that will reveal each impact's consequences and

current state. The DLT and environmental bonds will be referred to in the environmental policies. Finally, in the conclusively part, it will mention a summary and weakness of this essay.

2. The facts of South Africa

South Africa is one of the biggest nations in Africa [6]. They have 1,220,813 square kilometres of land surface and nine provinces. They have diversity natural resources, over 290 national parks, nearly 300 species of mammals, 860 types of birds, and 8,000 categorists of plants [7]. For the economic aspect, the prominent sectors are energy, mining, transport, agriculture, tourism, and manufacturing. The total population is 5962 million, and the proportions of females and males are 51.1% and 49.9%, respectively [8]. As the given data from The World Bank [9], Figure 1 was created with the South African population and labour force from 1990 to 2021. There is a massive gap between the population and labour force in South Africa. Although there is a slight increase in the labour force, the population and labour force were increasing at almost times. Another essential characteristic of South Africa is water scarcity. The reasons for insufficient water in South Africa include lack of water infrastructure investment and fix, drought caused by climate change, deteriorating water quality, and inequality of access to water [6]. Therefore, plants, animals, geographic features, the leading economic sector, and water are essential components of South Africa.

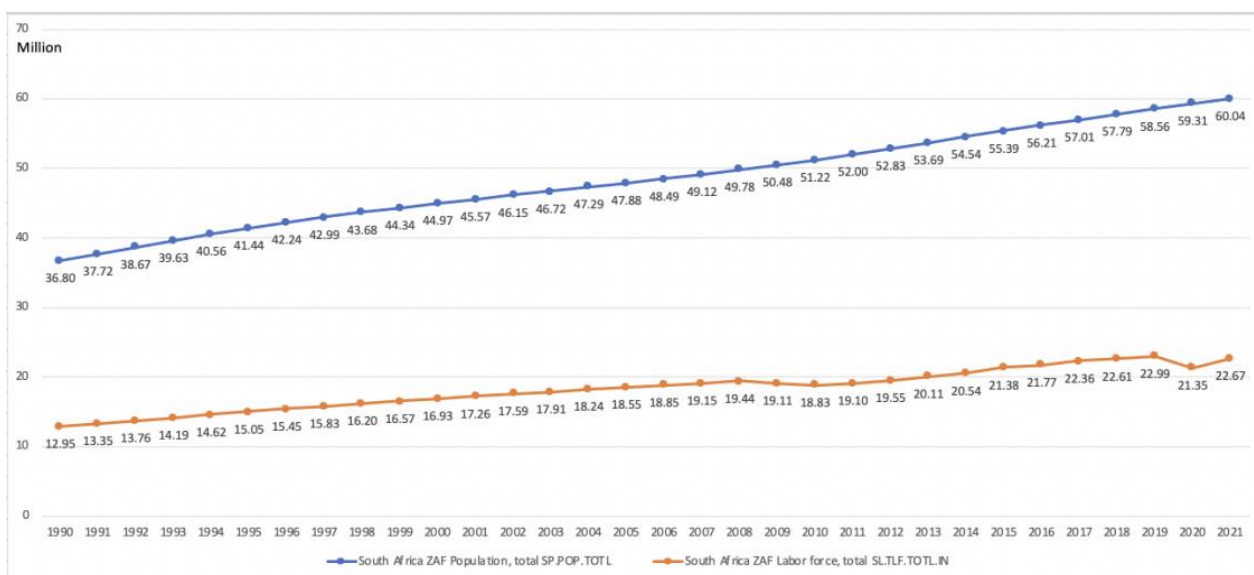


Figure 1. The population and labour force --- South Africa

Data source: The collected data is from The World Bank, but it is graphed by the author.

3. The literature facts of coal mining’s contributions in South Africa’s economy

From an economic aspect, coal mining impacts export, domestic consumption, GDP, and employment in South Africa.

3.1. Domestic consumption and export

Coal is a significant good in South Africa because the amount of coal is sufficient for domestic and export consumption [2]. The domestic consumption of coal is 75%, and 25% for export [3]. Five dominant coal firms produce beyond 80% of coal in South Africa, including Anglo American Thermal Coal, BHP Billiton's Energy Coal South Africa (BECSA), Exxaro Resources, Xstrata Coal, and Sasol Mining. Moreover, the junior miners established by Black Economic Empowerment companies will produce the rest of the coal. Eskom power stations are the major users of coal in South Africa [2]. The cost of coal is lower in South Africa because the thick coal seams are near the surface relatively. There are three-quarters of bituminous coal between 50-200m below the surface, and a

quarter of bituminous coal is between 15-50 m. According to the estimation, the economically recoverable coal reserves in South Africa are between 15 and 55 billion tonnes, which means the existing productive coal mines can be mined from 15 to 55 billion tonnes. The bituminous coal, metallurgical coal, and anthracite reserves are 96%, 2%, and 2%, respectively. Due to many coal reserves, they may expand their export. Thus, increasing their export earnings may decrease the current account deficit and a negative domestic trade balance [10]. In 2022, European sanctions against Russia invading Ukraine indicated that European countries could not import Russian coal. Some European countries, such as the Netherlands, Germany, Poland, Denmark, France, Italy, and Ukraine turned to import South Africa's coal [11]. Therefore, the domestic consumption and export of coal are both meaningful in South Africa.

3.2. GDP and employment

Furthermore, South Africa's GDP and employment reflect coal successfully. In the economy, gross domestic production incorporates export and domestic consumption. Figure 2 shows that this chart with data illustrates the consumption of South African coal from 2007 to 2018 [12]. In 2017, there was the lowest point at 83.661 TOE mn. However, in 2008, there was a dramatic increase in the consumption volume, which was 93.336 TOE mn. And the amount of consumption raised continuously to 2009, which reached a peak of 93.824 TOE mn. Unfortunately, from 2009 to 2012, the consumption curve decreased steadily. And between 2013 and 2018, there was a significant fluctuation in this curve.

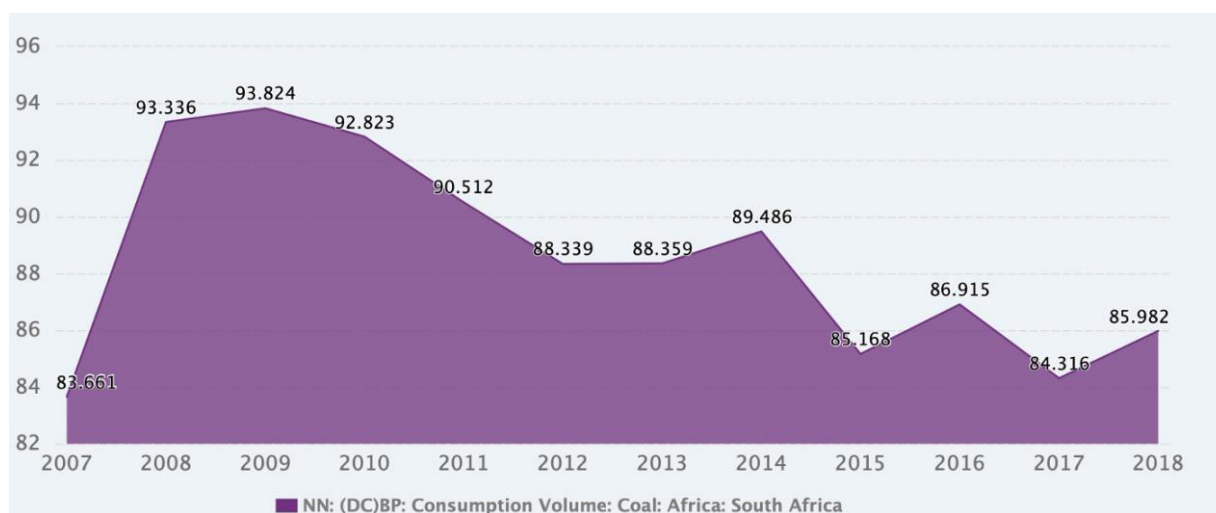


Figure 2. The consumption of South African coal

Data source: <https://www.ceicdata.com/en/indicator/south-africa/coal-consumption>

Figure 3 shows the table of coal consumption in South Africa, which indicate the high and relative stables in domestic consumption. There was a lower amount (exajoules) from 1998 to 2003 [13]. From 2005, the trend increased until 2009. At the same time, in 2009, it peaked at nearly 4 exajoules. However, in 2020 and 2021, coal consumption decreased by 3.56 and 3.53, respectively. This occurrence may be caused by COVID-19. It suppresses the economy, which reduces electricity demand. Moreover, according to the data, in 2019, coal production was 306 million metric tons in South Africa. It accounts for 2.3% of South Africa's GDP, which includes 40% to 45% of the sales income from the exported market [14]. In 2021, coal mining contributed 480.9 billion rands to its GDP [15].

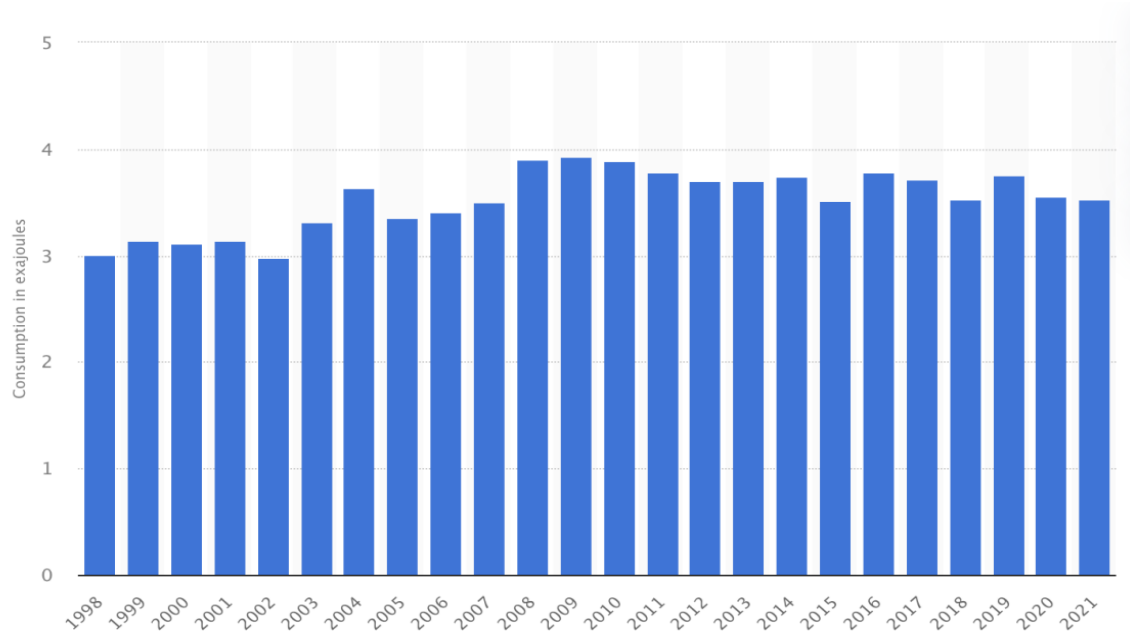


Figure 3. Coal consumption in South Africa, 1998-2021

Data source: <https://www.statista.com/statistics/265499/south-african-coal-consumption-in-oil-equivalent/>

Indeed, coal mining brought positive employment to South Africa, which means they provide healthy job opportunity corresponding to coal production. Figure 4 shows the relationship between employment and coal production [16]. From 2008 to 2014, although the coal production curve had a marked fluctuation, employment still increased during this period, excluding 2014. Then from 2014 to 2018, when there was a decrease in coal production, employment was reduced simultaneously. However, the decline in coal production was higher than the reduction in employment from 2014 to 2015, which are nearly 10,000,000 tonnes and 4,000 employees. In 2019, 21% of employees in the mining industry were working in the coal mining industry. Around 12,000 employees were working in the whole coal value chain, which accounts for 0.7% of the total workforce in this country [17]. As of 2021, the coal mining industry employed nearly 9,300 people in South Africa [18], and from 2002 to 2012, the employment rate of the coal mining industry increased by 75% [19].

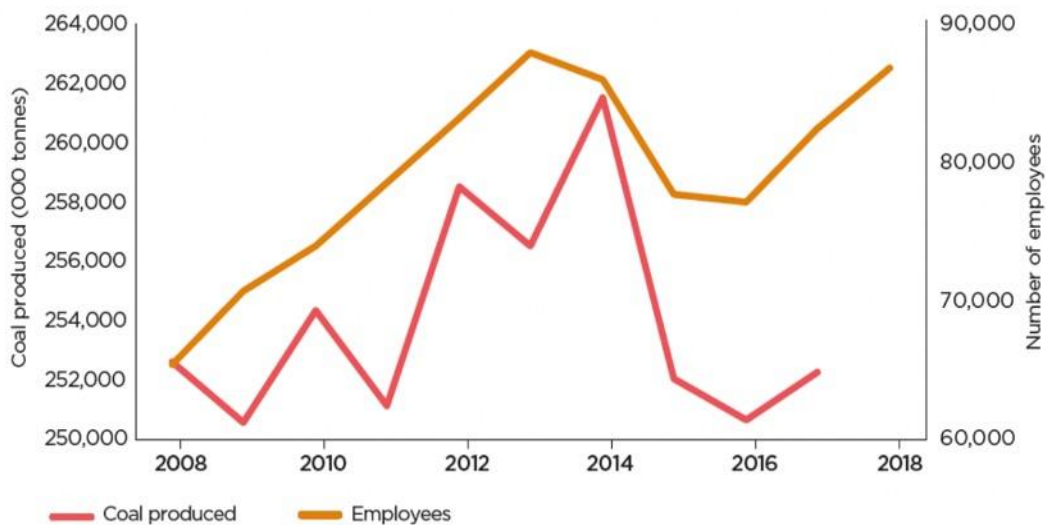


Figure 4. Coal production and employment in South Africa from 2008 to 2018

Data source: <https://www.miningforschools.co.za/lets-explore/coal/south-african-coal-mining-today>

4. The positive impacts of coal mining in South Africa

Although coal mining develops South Africa's economy, it simultaneously damages the local environment. Firstly, the pollution from coal mining destroys the air. Lastly, the highly acidic water created from coal mining damage water source in South Africa [3]. In the result, these two mentioned effects will be demonstrated in detail.

4.1. Air pollution

The occurrences of coal mining and combustion in South Africa are similar to other countries' reports. Mining and burning coal bring the first hazardous issue, air pollution, which causes global climate change. In operation and abandoned coal mining pollute the air through particulate matter and gas emissions, including sulphur dioxide (SO_2), methane (CH_4), oxides of nitrogen (NO_x), and hydrogen sulphide (H_2S). The particulate matter is generated in the process of blasting, wind erosion (exposed coal mining), delivery, and machining [4]. Gas emissions can be divided into two aspects, carbon dioxide (CO_2) from coal and other poisonous gases. South Africa was the 12th largest producer of greenhouse gases in 2021 [20]. The greenhouse gases incorporate CO_2 , fluorinated gases, methane, water vapour, and nitrous oxide. In South Africa, a high level of CO_2 result from the higher utilization level of coal [4]. According to the Our World in Data website, there is brief information about emissions of CO_2 in South Africa, which generate Figure 5 in two curves [21]. The blue curve shows the production-based emissions of CO_2 in a million tons annually from 2000 to 2020. Additionally, the grey curve represents the emissions of CO_2 based on production from coal (million tons). From 2000 to 2020, the overall trends of these two curves are increasing. Importantly, there is a positive relationship between them because emissions of CO_2 and CO_2 from coal increased simultaneously. Furthermore, they have a small gap, meaning the emission of CO_2 from coal accounts for an extensive number of all CO_2 production in South Africa. Indeed, spontaneous combustion is a unique situation in South Africa. When air comes to coal mine tunnels, oxidation (coal) and chemisorption will result in spontaneous combustion. The autonomy of spontaneous combustion relies on the climate, rank, dimensions of exposed coal mining, moisture level, and pyrite content. If spontaneous combustion exists, carbon monoxide (CO), SO_2 , H_2S , and NO_x will be produced. These categories of gases have harmed the air and atmosphere [4]. Therefore, coal mining has a hazardous influence on the air in South Africa.

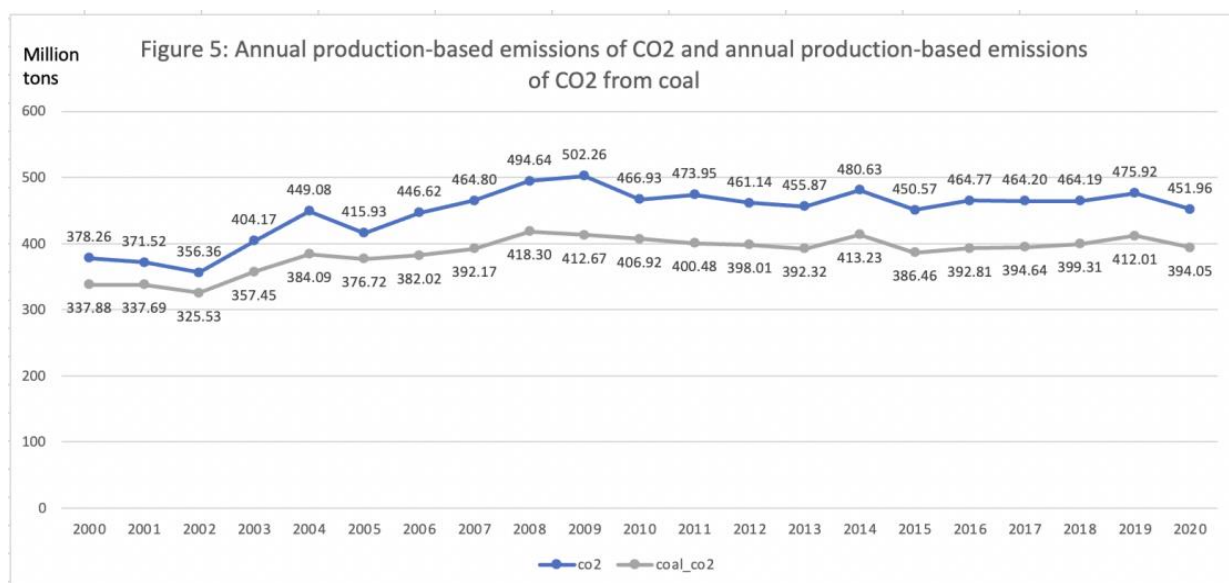


Figure 5. Annual production-based emissions of CO_2 and annual production-based emissions of CO_2 from coal

Data source: The collected data is from the Our World in Data, but it is graphed by the author.

4.2. Acid mine drainage

Acid mine drainage (AMD) is a central issue in the South African environment, which affects the surface, groundwater, and rivers in South Africa [3]. AMD is the highly acidic water draining from coal mines. Under the natural situation, when some coal seams are exploited, the sulphide minerals may be exposed to the water and air. Then AMD will be the result. For example, the mineral pyrite is one of the common sulphide minerals and a normal minor constituent of coal mining. When the mineral pyrite has oxidized, sulfuric acid will be produced. Because of the infiltration by rainwater, sulfuric acid will drive toxic metal species to drain acid water into ground waters. Additionally, AMD also occurs in the abandoned coal mines because it may fill up with water and flooding or decanting above ground finally [22]. South Africa has at least 400 abandoned coal mines [23]. As Figure 6 shows, AMD exists in the coal mines and gold mines areas in South Africa. As mentioned, Mpumalanga has most of the coal mines in South Africa. At the same time, Mpumalanga is the origin of South Africa's essential rivers. Regrettably, the waterways are indeed polluted by the toxic metal species and AMD. For example, the Olifants River, originating from Mpumalanga, has been considered the most polluted [3]. Therefore, AMD from coal mines truly impacts South Africa's water harmfully.

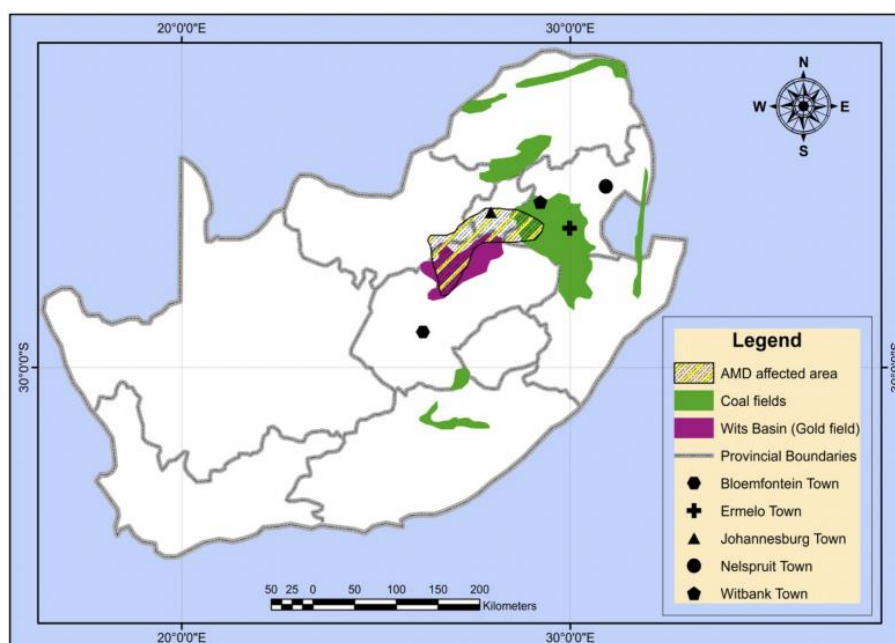


Figure 6. The allocation of AMD and coal mines

Data source: <https://www-tandfonline-com.ezproxy.library.sydney.edu.au/doi/full/10.1080/17480930.2015.1044046>

5. Impacts of coal mining in South Africa

5.1. The positive impacts of coal mining in South Africa

From South Africa's economic perspective, coal mining has a contributive and effective impact on this country.

Firstly, coal mining exploration protects and enhances domestic consumption and exports in South Africa. For domestic consumption, 75% of electricity is generated by burning coal in South Africa [2]. As the prediction, in the next decade, coal will still be the major source of generating electricity in South Africa. When the demand for coal (generating electricity) maintains at a high level or increases to a higher level, the supply and consumption of South African coal will not decrease. Moreover, electricity positively affects economic and social development and fortune creation. Capital, labour, and production technologies may improve at a rational level through the consumption

of electricity. When the economy is increasing, the electricity demand will increase following [24]. Thus, if other countries have greater electricity demand, they may seek to import coal. South African coal reserve may satisfy their needs because they have 15 to 55 billion tons of coal. In other words, because of enough coal reserves in South Africa, they have the potential to develop their economy through export. Therefore, coal mining improves the South African economy through domestic consumption and exports.

Secondly, another contribution of coal mining in South Africa is the proportion of GDP. GDP is in the national account that is measures aggregate output. The formula of GDP can be:

$$GDP = C + I + G + (X - M) \quad (1)$$

- C means the consumption, which is a largest section of GDP.
- I is investment or fixed investment.
- G represent the government spending on the goods or services.
- X indicates the exports.
- M means imports.
- $(X - M)$ are net exports.

As mentioned, coal has contributed to South Africa's consumption and export market. Figures 2 and 3 illustrate that in 2008, 2009, and 2010, South African coal consumption was higher. As Figure 3 shows, until 2021, although there is some fluctuation, the consumption does not reduce significantly. Furthermore, due to the mass amount of coal reserves, South Africa has the potential to expand its export market. Currently, because of the global situation and the EU's fifth package of sanctions, the export of South Africa indeed increased this year. In the formula of GDP, when the number of exports is more significant; and the number of imports is smaller, the net exports and GDP will be greater. Therefore, maintaining domestic consumption and expanding the exports of South African coal can impact their GDP effectively.

Thirdly, as Figure 4 shows, employment increased when coal production grew, which means they have a positive relationship. According to the research, Coal mining benefits not only this industry's employment but also the relevant industries. Thus, if the consumption and demand of coal are sustainable, employment from the coal mining industry and their directly supporting industries will be impacted conclusively.

5.2. The negative impacts of coal mining in South Africa: externalities

In this part, externalities of coal mining in South Africa are applied to analyze the non-economic values. In economics, externality indicates the benefits or costs of economic activity, which involve positive and negative externality. Significantly, it should account for the individual who did not directly join in that economic activity. However, South Africa's coal mining case must consider the negative externalities.

South African coal mining damages air and water, threatening people's and animals' health. The particulate matter and gas emissions from coal mining will result in coal mine dust lung disease (CMDLD). Silicosis and Coal Workers' Pneumoconiosis (CWP) are the usual occupational lung diseases in South Africa. CWP is also called black lung (BL), which is inhaling coal dust, including coal mine dust and pure coal dust, in the long term. The dust will accumulate in the lungs resulting the fibrosis and swelling. The most dreadful consequence is death [4]. Moreover, the toxic metal species from exploring coal mines will lead to other categories of cancers associated with respiratory and cardiovascular issues [3]. For people who live in coal mining communities, they have higher death rate and potential to develop chronic illnesses than other communities' people. Chronic illnesses include lung and kidney disease, cancer, and hypertension. The research illustrates that the increasing risks of having lung and kidney disease, and hypertension are 64%, 70%, and 30%, respectively [4]. Children who live in the coalfield are more likely to be affected. They may have problems with decreasing IQs, asthma, mental retardation, and permanently losing intelligence [4, 25]. Mpumalanga province has 3.6 million people in total. However, the children in a quarter of

households have asthma persistently, which is double the countrywide asthma rate [25]. Moreover, water pollution also directly damages human and animal health. Mpumalanga's river has been polluted, which means most rivers in south Africa are noxious. These rivers are the elemental supplier of dams, which serve humans' drinking water, aquatic lives, other animals, and agriculture. Based on the research, in Mpumalanga, the rivers were detected the existence of heavy metals involving lead (*Pb*) and cadmium (*Cd*). After using polluted water in agriculture, the heavy metals will damage the soil and be absorbed and accumulated by the plants. The animals that eat these plants, drink contaminated water, and live or breed in polluted rivers will accumulate these heavy metals inside. Unfortunately, many aquatic lives were dead caused of the heavy metals [26]. If people eat these animals or drink polluted water, they will have health issues and biochemical disorders [4, 26]. In the coalfield, some children's blood was found the high level of heavy metals and birth flaws cover neural tube defects [4]. Additionally, the water source is more valuable in South Africa because of water scarce. People should protect their water source to ensure their water access. Significantly, water pollution danger water sources and lives at the same time. People's and animals' healthy problems decrease social safety and well-binges in South Africa. Thus, water pollution is a severe issue in South Africa.

Consequently, coal mining in South Africa has a negative influence on environment, which harm people's and animals' health further.

6. Environmental policies

A discussion of the impacts of South African coal mining on the economy and environment will be drawn, following the cost-benefit analysis frame (CBA). CBA is the analytical and systematic model or method that evaluates the desirability of a project and its cost and benefits by social appraisal. In the non-renewable sources area, externalities associated with environmental effects are usually utilized by CBA when correcting market failures. In addition, CBA is a formal technique and the fundamental process of government decision-making that led people to deal with the scarce resources in societies advisably and reasonably [27]. According to the principle of CBA, the mentioned benefits and harms of South African coal mining will be compared. Importantly, two environmental policies will be introduced, damage land tax (DLT) and environmental bonds.

For the CBA, the economic impacts of coal mining in South Africa are the benefits; and the environmental impacts of South African coal mining are the costs. Coal mining may develop or protect the South African economy by expanding its exported market and maintaining its domestic consumption. However, there is circular logic. When there is increasing domestic consumption, the environment will be perniciously affected because more coal mines may be explored, and the demand (burning) for coal will increase. People may spend money on coal mining pollution and treatments when the environment threatens or harms people or the ecosystem. If people spend money on medicines and projects protecting the environment, their profits or earnings may decrease. Moreover, if the ill rate is increasing continuously, their labour force and social well-being may reduce. As a result, their economy may be enhanced by coal mining, but after many decades or over a hundred decades, their economy may be negatively impacted by coal mining.

The government may use two environmental policies to solve and prevent environmental issues without the economy back. DLT or environmental bonds, which internalize the externality rationally. DLT is one of the government's taxes on coal mining companies, which price the pollution. Companies with a higher pollution level will pay a higher tax. South African government may utilize DLT to regulate coal mining companies. Furthermore, environmental bonds require companies to deposit an amount of money into escrow as bonds or financial assurances. Before the regulators approve a mining proposal, companies should agree on an environmental contract. This environmental contract concerns the estimations of environmental damage and their corrective measures. If companies do not apply to follow their environmental contract, the regulators can withdraw the bonds. It does not require companies to pay extra government money (tax) [28].

Presently, coal mine rehabilitation and future low-pollution mining coals are necessary because there are over 400 abandoned coal mines in South Africa [23]. If abandoned coal mines suffers neglect, it may produce more AMD to harm the environment. For all abandoned coal mines, if coal companies do not rehabilitate them within the required time, the government can charge DLT. For the operating coal mining and future coal mining, the government can charge them rational DLT and sign an environmental contract (environmental bonds) to prevent high pollution from companies. Therefore, South Africa may develop these two environmental policies and enhance the regulation.

7. Conclusions

In conclusion, this essay involves a brief background of South Africa, the economic and environmental impacts of South African coal mining, and the solutions. The features of South Africa are the diversity of species and plants, the rich mines, a higher population with a lower labour force, and water scarcity. Under the structure of CBA, the economic effects of South African coal mining are the benefit because it indeed increases the South African economy for nearly a hundred years (since 1923). However, it damages the South African environment, which contaminates South African air and water. Polluted air and water undermine people's and animals' health directly and indirectly. As a consequence of a lower labour force and water scarcity, the environmental impacts are significant and more concerned than their economic influences. Thus, two environmental policies (DLT and environmental bonds) have been introduced to solve its issues without preventing economic development. Although this essay evaluates both sides' impacts and solutions, it does not show the cost of environmental damage and coal mine rehabilitation. This is a drawback of this essay. Because of a lack of data, the accurate calculations of CBA cannot be represented. If there is a calculation of CBA, the cost and benefits of coal mining and rehabilitations can be quantization. Therefore, the economic and environmental influences of South African coal mining are mainly through literature review and existing data analysis to be elucidated.

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