CHAPTER VIII
SUMMARY OF FINDINGS, SUGGESTIONS AND CONCLUSION

India, being the second largest populated but a developing country of the world faces multifarious problems such as poverty, unemployment, low per capita income, scarcity of capital, and other political and social problems hampering its development process. The natural resources including the mineral resources play a vital role as raw materials for almost every industry in transforming the Indian Economy. The abnormal increase in population and the resultant increase in the consumption of commodities warrant a higher level of mineral production for India in particular and the world in general. The economic development in the modern period is highly dependent on the strategic zircon minerals and it is stated by Elangovan (2007) that there is modern technology in zircon mineral.

8.2 Findings of the Study

The present study has analyzed the growth of production, consumption and uses of zircon during 1980-81 to 2007- 08. It has been analysed through averages, annual growth of production and consumption of zircon, index numbers and compound growth rate.
The data on the production of zircon in the world for the period of 27 years from 1980-81 to 2006-07 are given in Table 4.1. During the decade from 1980-81 to 1989-90 the production of zircon in the world showed increase with some fluctuations. The annual growth rates were positive, except for three years. The index numbers of the production of zircon in the world increased by 2.01 times. During 1990-91 to 1999-2000, the production of zircon in the world increased from 7,88,000 tonnes in 1990-91, and it touched the highest value in 1,01,5000 tonnes in 1994-95. During 2000-01 to 2006-07, the production of zircon in the world increased from 9,39,000 tonnes in 2000-01 to 1,52,400,0 tonnes in 2006-07 with some fluctuations. The average production of zircon in the world was 1,201,571.42 tonnes in this period. The index numbers of the production of zircon in the world increased by 1.07 times in 2000-01 to 2006-07.

During the decade from 1980-81 to 1989-90 the production of zircon in India increased from 15,000 tonnes in 1980-81 and it touched the higher value 17,500 tonnes in 1989-90, showing increase with some fluctuations. The annual growth rates were positive, except three years. The index numbers of the production of zircon in India’s increased by 2.01 times. During 2000-01 to 2007-08, the production of zircon in India increased from 27,119 tonnes in 2001-02 to 35,976 tonnes in 2007-08 with some
fluctuations. The average production of zircon in India was 26211.80 tonnes in this period. The annual growth rate of the production of zircon in India remained positive during 2000-01 to 2007-08, except for three years.

The forecasting analysis various trend models like linear, quadratic, exponential, logarithmic and cubic models are used and these models are forecast the India’s zircon production. The ARIMA model also employed. According to the estimated ARIMA model for zircon production, India’s zircon production anticipated to register an increase upto 36,282 tonnes in the year 2020 with a 95 percent confidence interval ranging from 27,889 tonnes to 36,281 tonnes from it’s observed value to 20,535 tonnes during the year 2007-08. Hence, the zircon production is more viable in India. Therefore, the first hypothesis namely, ‘the zircon industry is more viable in India’ is valid.

During the decade from 1980-81 to 1989-90 the production of zircon in Tamil Nadu touched 3,547 tonnes in 1980-81 and it touched the higher value 5,978 tonnes in 1989-90, showed increase with some fluctuations. The index numbers of the production of zircon in Tamil Nadu increased by one time. During the decade from 1990-91 to 1999-2000 the production of zircon in Tamil Nadu showed an increasing trend with some fluctuations.
During 2000-01 to 2007-08, the production of zircon in Tamil Nadu increased from 7,513 tonnes in 2007-08 to 15,930 tonnes in 2007-08. The annual average production of zircon in Tamil Nadu was 7,769.9 tonnes in this period.

The data on the consumption of zircon in India for the period of 28 years from 1980-81 to 2007-08. During the decade from 1980-81 to 1989-90 the consumption of zircon in India touched from 15,000 tonnes in 1980-81 the higher value of 17,500 tonnes in 1989-90, showing an increasing trend. During 1990-91 to 1999-2000, the consumption of zircon in India increased from 15,000 tonnes in 1990-91, and it decreased to 2,300 tonnes in 1994-95, then it increased to 11,150 tonnes in 1997-98, and it touched the highest value in 20,772 tonnes in 1998-1999. During 2000-01 to 2007-08, the consumption of zircon in India increased from 24,102 tonnes in 2000-01. The annual average consumption of zircon in India was 22011.30 tonnes in this period. The annual growth rate of the consumption remained positive during 2000-01 to 2007-08, except for three years. The index numbers of consumption of the zircon in India increased by 2.78 times in 2000-01 to 2007-08.
The study discloses that India’s zircon consumption is best fitted with the ARIMA (1, 1, 0) model and it has displayed significant ‘t’ co-efficient and the least standard error value among the class of fitted models. The model has predicted that India’s zircon consumption would increase to 36,490 tonnes in the year 2020. Hence, the zircon consumption is more viable in India. Therefore, the first hypothesis namely, ‘the zircon industry is more viable in India’ is valid.

During the decade from 1980-81 to 1989-90 the end uses of zircon in the ceramic industry showed increase with some fluctuations. In 1980-81 the end uses of zircon in the ceramic Industry was 51 tonnes and it touched the higher value 1,680 tonnes in 1986-8, then 1,300 tonnes and it increased to 1800 tonnes in 1989-90. The annual growth rates were positive expect for two years. The index numbers of zircon in the ceramic industry showed an increasing trend. During 1990-91 to 1999-2000, the end uses of zircon in the ceramic industry in increased from 1650 tonnes in 1990-91, and it touched the highest value in 9,000 tonnes in 1997-98, then it increased 11,000 tonnes in 1998-99, and it touched the highest value in 12,365 tonnes in 1999-2000, and then decreased to 21,956 tonnes in 1999-2000. During 2000-01 to 2007-08, the end uses of zircon in the ceramic industry increased from 148392 tonnes in 2000-01 and decreased to 16,999 tonnes in 2005-06, then
it decreased to 12,329 tonnes in 2007-08 with some fluctuations. The average end uses of zircon in the ceramic industry was 14,595.30 tonnes in this period.

During the decade from 1980-81 to 1989-90 the end uses of zircon in the foundry industry showed an increasing trend. The annual growth rates were positive. The index numbers of end uses of zircon in the foundry industry increased by 2.36 times. During 2000-01 to 2007-08, end uses of zircon in the foundry increased from 4,671 tonnes in 2001-02 to 5,696 tonnes. The average the end uses of zircon in foundry industry was 3766.88 tonnes in the period 2007-08.

During the decade from 1980-81 to 1989-90 the end uses of zircon in refractories industry showed a growing trend. The annual growth rates were positive. The index numbers of the end uses of zircon in refractories industry increased by 1.23 times. During 2000-01 to 2007-08, the end uses of zircon in the refractories industry increased. The average of the end uses of zircon in the refractories industry was 1,499.87 tonnes in this period. The index numbers of zircon in the refractories industry increased by 1.03 times in 2000-01 to 2007-08.
During 1999-2000 to 2007-2008, the end uses of zircon in the chemical Industry increased from 1,568 tonnes in 1999-2000, and it touched the highest value in 2022 tonnes in 2001-2002, then it decreased to 534 tonnes in 2002-03, and it touched the highest value in 1,403 tonnes in 2007-08. During the decade from 1999-2000 to 2007-08 the end uses of zircon in the chemical Industry showed an increasing trend with some fluctuations.

During the decade from 1999-2000 to 2007-2008 the end uses of zircon in the television face plates/glass industry showed an increasing trend. The average value of the end uses of zircon in the television face plates/glass industry stood at 595.89 tonnes in this period. The annual growth rate of the end uses of zircon in the television face plates/glass industry was positive during 1999-2000 to 2007-2008 except for two years.

During 1998-89 to 2007-2008, the price of zircon in Tamil Nadu increased from Rs.13500/- per tonnes in 1998-99, and it touched the highest value in Rs.15000/- per tonnes in 2000-01, and there is no change from 2000-01 to 2002-2003. It increased to Rs. 22000/- per tonnes in 2004-05 and it touched the highest value is Rs.35000/- per tonnes in 2007-2008. The
average price of zircon in Tamil Nadu was Rs.21166.67/- per tonnes in this period.

The results of the trend analysis imply that the total production of zircon in the world increased by 28,880.85 tonnes during the period from 1980-81 to 1989-90. The regression co-efficient of the semi log linear model implies that the total production of zircon in the world increased at the compound growth rate of 13.56 per cent per year. The regression co-efficients in both the models are significant at the five per cent level. The value of the adjusted $R^2$ is 0.79 in the simple linear regression model and it is 0.78 in the semi log linear model in this period. Around 76 per cent of the variations in the dependent variables are explained by the independent variables in the simple linear model. The total production of zircon in India’s increased annually by 72,750 tonnes after 2000-01 to 2007-08. The regression co- efficient of the semi log linear model implies that the total production of zircon in India increased at the compound growth rate of 6.18 per cent per year.. The value of adjusted $R^2$ is 0.82 in the simple linear model, and it is 0.83 in the semi log model.

The total production of zircon in India’s increased annually by 534.95 tonnes during the period from 1990-91 to 1999-2000. The regression co-
efficient of the semi log linear model implies that the total production of zircon in India’s increased at the compound growth rate of 4.92 per cent per year. The regression co-efficient in both models significant at five per cent level. The value of the adjusted $R^2$ is 0.71 in the simple linear regression model and it is 0.70 in the semi log linear model. It means that the total production of zircon in to India has registered a linear trend in this period. Around 70 per cent of the variations in the dependent variables are explained by the independent variables in the simple linear model.

The results of the trend analysis imply that the total production of zircon in Tamil Nadu increased by 240.35 tonnes during the period 1980-81 to 1989-90. The regression co-efficient of the semi log linear model implies that the total production of zircon increased at the compound growth rate of 5.65 per cent per year. The regression co-efficient in both models are significant at the five per cent level. The value of adjusted $R^2$ is 0.67 in the simple linear regression model and it is 0.71 in the semi log linear model in this period. The regression co-efficient in both models are significant at five per cent level. The value of the adjusted $R^2$ is 0.75 in the simple linear regression model and it is 0.76 in the semi log linear model. It means that the total production of zircon in the world has registered a linear trend in this
period. Around 75 per cent of the variations in the dependent variables are explained by the independent variables in the simple linear model.

The results of the trend analysis imply that the total consumption of zircon in India’s increased by 1280.46 tonnes during the period 1980-81 to 1989-90. The regression co-efficient of the semi log linear model implies that the total consumption of zircon in India’s increased at the compound growth rate of 48.14 per cent per year. The regression co-efficient in both models are significant at the five per cent level. The value of the adjusted $R^2$ is 0.67 in the simple linear regression model and it is 0.79 in the semi log linear model in this period. Around 73 per cent of variations in the dependent variables are explained by the independent variables in the simple linear model.

The regression co-efficient of the semi log linear model implies that the end uses of zircon in the ceramic industry increased at the compound growth rate of 59.20 per cent per year. The regression co-efficient in both models are significant at the five per cent level. The value of the adjusted $R^2$ is 0.62 in the simple linear regression model and it is 0.70 in the semi log linear model in this period. Around 65 per cent of variations in the
dependent variables are explained by the independent variables in the simple linear model.

The regression co-efficient of the semi log linear model implies that the end uses of zircon in foundry industry increased at the compound growth rate of 47.84 per cent per year. The regression co-efficient in both models are significant at the five per cent level. The value of the adjusted $R^2$ is 0.68 in the simple linear regression model and it is 0.80 in the semi log linear model in this period. Around 74 per cent of variations in the dependent variables are explained by the independent variables in the simple linear model.

The regression co-efficient of the semi log linear model implies that the end uses of zircon in the refractories industry increased at the compound growth rate of 47.84 per cent per year. The regression co-efficient in both models are significant at the five per cent level. The value of the adjusted $R^2$ is 0.68 in the simple linear regression model and it is 0.79 in the semi log linear model in this period. Around 71 per cent of variations in the dependent variables are explained by the independent variables in the simple linear model.
The results of the trend analysis imply that the price of zircon in Tamil Nadu increased by 2284.84 tonnes during the period from 2000-01 to 2007-08. The regression co-efficient of the semi log linear model implies that the prices increased at the compound growth rate of 11.40 per cent per year. The regression co-efficient in both models are significant at the one per cent level. The value of the adjusted $R^2$ is 0.86 in the simple linear regression model and it is 0.90 in the semi log linear model in this period. Around 88 per cent of the variations in the dependent variables are explained by the independent variables in the simple linear model.

**Economic Viability Study**

The present study has analysed the viability of a zircon mining plant producing zircon mineral enriched areas of Thoothukudi, Tirunelveli and Kanyakumari districts in Tamil Nadu. The capacity of the plant is considered as 1080 tonnes per annum capacity. The capital cost of zircon is estimated under three heads, viz., mining sector, processing sector and transportation segments and the total capital cost is worked out to be at Rs. 1055/- lakhs. The operating cost is also estimated under the three sectors and it is found to be at Rs. 566/- lakhs. The annual revenue and the cash flow of
the zircon mining enterprise are calculated to be in the order of Rs. 972.00 lakhs and Rs. 406 lakhs.

The economic return analysis shows that for the base case, the capital cost, operating cost, and annual revenue are Rs. 1055/-, Rs.566/-, and Rs. 972/- lakhs, respectively. The internal rate of return (IRR) is estimated at 24.5 per cent and is observed to be well above the average current rate of interest at 14.25 per cent (State Bank of India, 2011). This indicates that the zircon mining venture is economically feasible in the study area, proving the first hypothesis, that is zircon mining is economically viable. The payback period of the zircon mining ventures is estimated as 2.5 years.

**Risk Impact Analysis**

The risk impact analysis has been worked out for 10 per cent upward and downward changes in capital cost, operating cost, and annual revenue.

For 10 per increase in the capital cost i.e., from Rs.1055/-lakhs to Rs.1160.5/-lakhs, the internal rate return decline 26.5 per cent and the payback is 2.3 years from their respective base case values of 24.5 per cent and 2.5 years. For the case of 10 per cent increase, the IRR and the payback period change to 22.5 per cent, and 2.85 years, respectively.
The sensitivity analysis shows that for 10 per cent upward shift in the operating cost, the IRR decrease 22.75 per cent from the base case IRR and the payback period stood at 3 years. In contrast to this, for 10 per cent downward shift in the operating cost, the IRR increase to shift in operating cost, IRR declines to 32.5 per cent and the payback period for this case stood at 2.2 years.

The risk impact analysis shows that for 10 per cent increase in the annual revenue, the IRR and the cash flow increase 28.5 per cent and Rs. 503.2/-lakhs, respectively from that of the base case IRR 24.5 per cent and Rs. 406/-lakhs. For the 10 per cent down case, the IRR and net cash flow decrease to 22.5 per cent and Rs. 308.8/-lakhs, respectively. The payback period works out to be 2.9 years, respectively.

The risk impact analysis has been worked out with respect to the unforeseen changes expected to occur greatly in capital cost, operating cost, and annual revenue. Hence, a 10 per cent and variation in the important parameters, that is, capital cost, operating cost and annual revenue expect 25 per cent decrease in annual revenue do not affect the economic feasibility of the zircon industry is held true.
Moreover, the development of the zircon mining industry designed in tune with the environment may also bring valuable foreign exchange to our country since most of the heavy minerals produced are exported. In addition, the zircon industry development may go a long way in narrowing down the income inequality found between the villages and cities of the coastal and other regions.

The sensitivity analysis employed to accommodate the risks associated with zircon mining venture in economic viability has pointed out that of the three important factors, annual revenue is the most influential factor in determining the viability of the venture. It is observed here that an unexpected rise of capital cost, operating cost and annual revenue by 10 per cent and downward by 10 per cent has not significantly affected the profitability of the zircon mining unit in the study area. Therefore the second hypothesis that, ‘a 10 per cent variation in the important parameters that is, capital cost, operating cost and annual revenue do not affect the economic feasibility of zircon industry in India’ is proved and accepted.

**Trend Analysis and ARIMA Models**

India’s zircon production is analysed with various trend models and the best fitted models viz., linear, quadratic, cubic and exponential trends
have given the estimated value of 38,084.46 tonnes, 22,277.39 tonnes, 48,143.38 tonnes, respectively, for the year 2020, which are all well above the production level of 17,500 tonnes in the year 2008. The ARIMA (2,0,0) model has anticipated this production for the year 2020, to be at the 36,282 tonnes which may range from 27,889 tonnes to 36,381 tonnes at 95 per cent confidence interval.

The increasing trend in world zircon production has been witnessed according to the estimated models and this quantity is expected to rise to the level of 4,455,873 tonnes and the forecast by the AR (1,1,0) model is 2,604,143 process is found to be the best fitting model to this differenced series and the fit assumes no MA term. The model has predicted that world zircon production would increase to 2,604,143 tonnes in the year 2007-08.

According to the estimated trends, the quadratic, cubic and exponential trend models have forecast Tamil Nadu’s zircon production for the year 2020 at 24,232 tonnes 57,397 tonnes and 13,729 tonnes respectively. Among the ARIMA models tried ARIMA (1,1,0) fitted well and has projected the Tamil Nadu’s production upto 12,067 tonnes All these forecast values are found to be higher than the Tamil Nadu production of the year 2008.
The forecasting trend models have predicted India’s zircon consumption for the year 2020 to be 2.5 times more than that of the year 2008, except for the exponential trend model. The exponential trend model has estimated it to be very near the current level of consumption. The ARIMA (1,1,0) model has predicted the consumption to be more than 36,490 tonnes. The above forecasting analysis of production and consumption of zircon proves the hypothesis, “the trends in production and consumption of zircon in India are increasing in the future” to be true.

The trend models applied on end uses of zircon in the ceramic industry display poor goodness of fit. Among the ARIMA models applied, the best model is ARIMA (1,1,0) and the predicted ceramic consumption for the year 2020 according to this model is 34,715 tonnes.

The end uses of zircon in the foundry have been projected by the cubic trend models is best model. The best fitted ARIMA (2, 1, 3) model has evaluated the end uses of zircon in the foundry industry for the year 2020 to be -2223 tonnes.
The present research thus identifies an upward trend in the production of the zircon and thus proves the hypothesis that zircon mineral production is increasing.

In the case of zircon, multiple regression analysis identified that Tamil Nadu’s zircon production, India’s zircon production, world zircon production, India’s zircon consumption, price of zircon in Tamil Nadu, and India’s zircon consumption and end uses of zircon in the ceramic, foundry, refractories industries are important variables. India’s zircon consumption is the only major variable propelling its production activities.

**Suggestions and Recommendations**

The results of the forecasting analyses of the present study also have identified an increasing trend in the zircon mineral market. Hence, it is suggested that zircon mineral production should be increased to cope with the industrial needs of the Indian and world markets.

The present study finds that the zircon mineral is economically feasible in the Central Coast of Tamil Nadu and has forecast a significant growth in the zircon mining business and zircon mineral production in India will increase in the future. Therefore, it is suggested that similar such studies may be carried out replicated in other potential zones of the Indian coastal
areas. This kind of studies may attract new investors form all over the
country and help to reduce the income inequality between coastal rural and
urban societies.

It is suggested that the mining industry may come forward through
sponsorship to strengthen the infrastructural facilities of the R&D
Institutions and Universities like the CMRI, the Indian School of Mines, the
RRL (Bhubaneswar) the RRL (Bhopal), the RRL (Trivandrum), the CESS,
Trivandrum, the NML, Jamshedpur, the academic institutions and
Government agencies such as Indian Rare Earths, the BARC & AMD, the
Indian Bureau of Mines, etc.

Mining industry and R & D institutes interaction through Brain
Storming Sessions would to be organize, which would be oriented to
encourage transfer of modern eco-friendly technology in the field of mineral
beneficiation and evolve such technology to solve the problems of existing
operating plants.

The royalty for mining may be revised considering the mined
products. Part of the royalty can be/should be utilized in rehabilitation
programmes for society and sponsoring some of the R & D activity.
The expected demand growth for zircon is also driven by the anticipated trend towards higher quality in ceramic, refractories and castings generally. Much of the recent Chinese and Indian industrial growth has been undertaken on a very low cost basis, and this has led, for example, to the use of lower cost and relatively low quality refractories. Manufacturers in these countries are progressively expected to turn towards higher quality inputs, a shift which should favour the use of zircon.

The underlying future demand for zircon is forecast to be strong. Growth is expected to be 3.8% between 2006 and 2010, and 4.5% pa between 2011 and 2020, provided zircon is not supply-constrained. This growth rate can be compared to the historical growth rate of about 2.8%.

The setting up of a zircon mineral industry or an industry concentrating on the value addition processes is highly capital intensive. Due to financial crunch, the government finds it difficult to start new public sector undertakings in this field. Therefore, it is necessary to allow the private sector individually or in collaboration with the Public Sector Units through a judicious mix as emphasized by the Government of India’s Industrial Policy Act 1991. Private entrepreneurs may be permitted to start their own units for zircon minerals mainly for the purpose of the overall
development of the heavy mineral industry. It is also recommended that favourable, promotional and supportive financial, industrial and trade policies should necessarily be introduced to have a strong export oriented mineral industry to reign and lead the future world zircon mineral market.

**Conclusion**

The production of zircon in the world, India and Tamil Nadu has shown a positive trend over the study period. The average consumption of zircon in India depicts a positive trend in the end uses of zircon in the ceramic, foundry, refractory, chemical, and Television face places/Glass industries. The increased consumption pattern of Indian industry pushes the price of zircon in Tamil Nadu and the researcher found that the zircon mining venture is economically feasible in Tamil Nadu. Hence, the researcher comes to the conclusion that the zircon mining industry will be fruitful in the short and long terms. It will also bear fruits in aspects like employment, environment, and regional inequality.