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PRODUCTIVITY IMPROVEMENT FROM ECONOMIC CONCEPT TO AN ENGINEERING TOOL

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ABSTRACT: In broad terms, productivity is defined as the ratio of all outputs to all inputs. In this paper, productivity is distinctly used as an engineering tool and from practical viewpoint. With such engineering look, productivity is an adequate tool for evaluation of the advancement in competitive market, work assessment, profit/loss analysis, decision and even developing or changing the activity. Productivity measurement seems to be an easy task but this is a misconception. In fact the concept remains to be one of the most complex and unknown criteria. It is for this reason that attempts have been made here to accurately define productivity and hence simplify its measurement. A case study has been adopted and the productivity of Eastern Alborz Coal Mines in Iran has been calculated for years 2001-2008. The resulting values and the component models are then subject to analysis. These results are examined in terms of practicability and it is shown that the method prescribed is a pragmatic approach in all similar system situations.

INTRODUCTION

Productivity is the effective use of each factors of production which is defined as output to input (Oraee, 1998). With measurement of productivity during time, the trend of changes is defined. Increases or decreases of productivity are directly proportional to profit of company. Moreover, determination of productivity defined the ability of companies in competitive markets (Oraee, 2006). Productivity can be computed as partial and total. The partial productivity describes the ratio of output to each of inputs, including manpower, capital, energy, and etc., while the total productivity is the ratio of output to sum of inputs (Oraee and Pymander, 1998). The productivity is calculated for various purposes ((Oraee and Pomander, 1998), (Oraee, 1996, 2006) such as:

- The strategic, in competitive markets for survival and/or improvement.
- Technical, for verifying performance of various divisions.
- Planning, to verify profit/loss and the necessary decisions.
- Management, for development or change in kind of activities.

The productivity as a standard uses for estimation of efficiency and profitability. It helps the optimum allocation of resources. Therefore, the productivity can act as a parameter in forecasting and planning (Oraee, 1998).

In this study, the productivity of Eastern Alborz Coal Mines (EACM) is calculated. For this propose the total of outputs and inputs are computed for calculation of the total productivity and partial productivity including productivity of manpower, energy, and capital.

MINING OUTPUT

The first step in computing productivity is the measurement of outputs. The output is something that is produced, hence in mining definition, the output is the minerals. The output for EACM should be calculated in physical units (tons). The output also can be calculated as monetary units (US dollars), but this type of measurement is mostly for mines that produces the different types of minerals (Oraee, 1998). Table 1 (IMPASCO, 2009 and Soltani, 2009) shows the production of EACM during 2001 to 2008. To accurate analysis, selling price of coal also included. Moreover, in order to eliminate the

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inflation, based on inflation price index of wholesale of Iran (Price Index and Inflation, 2009), the prices are inflation adjusted. For this reason, the year 2001 is selected as a base and the index of each year is divided to the base year and the result is multiplied in to the selling amount of the same year.

Table 1 – The total output in EACM during 2001 to 2008

Year	2001	2002	2003	2004	2005	2006	2007	2008
Extracted coal (ton)	467,000	532,000	512,000	537,000	650,000	681,000	670,000	691,000
Concentrate (ton)	268,000	290,000	284,000	279,000	321,000	281,000	313,000	324,000
Price per ton of coal (US $)	68	73	83	101	113	126	133	186
Total sales (1000 US $)	18,000	21,000	24,000	28,000	36,000	35,000	42,000	60,000
Wholesale price inflation index	175	192	211	242	265	297	341	422
Inflation adjusted (1000 US $)	18,000	19,100	20,000	20,200	23,800	21,000	21,600	24,900

In Figure 1 the trend of production growth and inflation adjusted selling price of coal in each year compare to previous, during 2001 to 2008 is depicted. As seen in this figure, the trend of production and income (from selling coal) show significant changes and in some cases no harmony. For example, in 2006, in spite of growth in production (as compared with 2005), the income is decreased, on the contrary in 2007 although production decreased, but the income has increased.

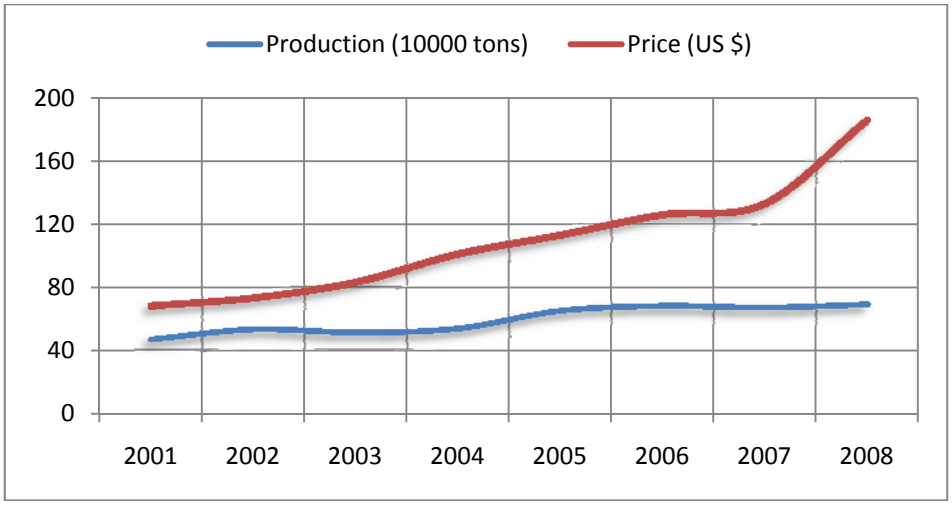

Figure 1 – The trend of production and inflation adjusted selling price of coal in EACM during 2001 to 2008

1. Mining input

The mine input is divided into various divisions that their summation is the total mine input. In this research, also the mine input of EACM is divided into three groups: 1) manpower, 2) energy, and 3) capital input. Accordingly each input is considered, separately.

The manpower input

The manpower input has an important role in productivity calculation. The accepted unit for manpower is either working hours (time) or number of workers (Oraee, 1996). While the level of education, technical knowledge, expertise, service records, and similar criteria effect on labor cost. Obviously the efficiency and therefore the cost of inexperience labor in compare to an expert one, and or the comparison of each expert labor with an engineer is far different. Therefore, if the manpower is defined by number or working hours it is required the labor cost be defined based on particular index. Obviously, such a calculation is not easy and accurate. Thus, calculations of manpower input based on labor cost solve this problem. As, the salary difference always is a criteria in position of a personnel. In other words, using the costs to calculate the manpower input, relying on market-power to adjust the

value of each person with various skills. In the use of monetary unit for labor input must also be done inflation adjusted. Therefore, the consumer price index of Iran (Price Index and Inflation, 2009) has been used. The manpower data (Soltani, 2009) of EACM during 2001 to 2008 is presented in Table 2.

In Figure 2, variation in number and costs of personnel during 2001 to 2008 is shown. As can be seen, although the number and cost of personnel during these years have been declining, but reduce in rate of personnel number is more than personnel costs. In other word, the costs per person increases, that probably is due to technical knowledge and skills of personnel, or the policies of labor laws during 2005 to 2008. The first reason causes growth of total productivity, while the other's reduces the total productivity.

Table 2 – The manpower input in EACM during 2001 to 2008

Year	2001	2002	2003	2004	2005	2006	2007	2008
Total of personnel	2,248	1,983	1,692	1,466	1,240	1,117	1,058	973
Number of underground personnel	1,679	1,562	1,484	1,275	1,056	964	922	846
Number of coal face workers	319	298	207	206	161	174	149	150
Total wages and salaries (1000 US $)	13,000	9,000	10,000	9,000	10,300	10,000	10,700	13,300
Consumer price inflation index	178	206	238	275	308	339	402	504
Inflation adjusted (1000 US $)	13,000	7,800	7,500	5,800	5,900	5,300	4,700	4,700

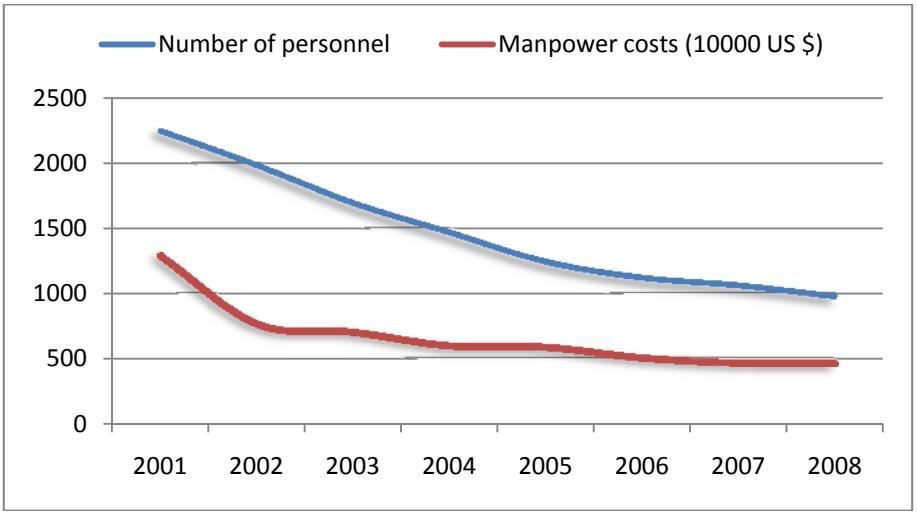

Figure 2 – The variation in number and costs of manpower in EACM during 2001 to 2008

Energy input

The energy is a part of the raw materials (Oraee, 2006), but in this research the energy input is calculated, distinctly. Because, the cost of energy is an important part of raw materials costs and in Iran, the variation of energy cost is not depend on variation of market prices and the laws of supply and demand. Energy is measured by the unit such as kilo-Watt per hour, kilograms, and litters. The summation of different type of energy the BTU unit is used. Since, the summation all inputs is for calculation of total productivity, in this study the total cost of energy is used. The electricity and fossil fuels are the main energy consumption in EACM, which in *Table 3* is given based on costs (Soltani, 2009). These costs by using consumer price index of Iran (Price Index and Inflation, 2009) for various years are inflation adjusted.

The trend of inflation adjusted prices variation during 2001 to 2008 is given in Figure 3. Although, the final price is decreased, however the sinusoidal fluctuations indicate the change in productivity during these years.

Table 3 – The energy input in EACM during 2001 to 2008

Year	2001	2002	2003	2004	2005	2006	2007	2008
Costs of fuel and electricity (1000 US $)	390	540	560	520	590	630	820	780
Consumer price inflation index	178	206	238	275	308	339	402	504
Inflation adjusted (1000 US $)	390	470	420	340	340	330	360	280

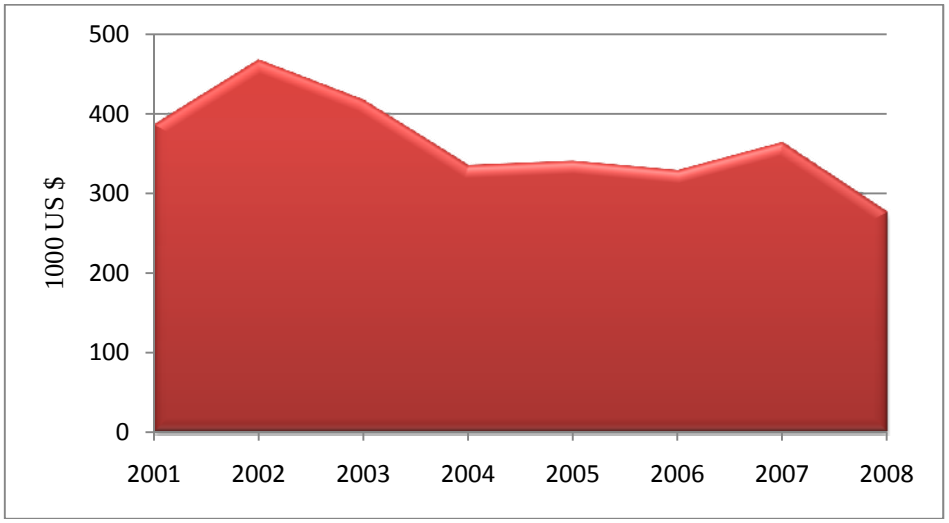

Figure 3 – The trend of inflation adjusted energy cost in EACM during 2001 to 2008

Capital inputs

The capital includes buildings, machinery, equipment, and the amount of reserves in a particular point of time, such as the end of calendar year (Oraee, 1996). Building maintenance and repairs are needed, machinery and equipments get depreciated and the new investments will be necessary. Therefore, the calculation of capital inputs is difficult. If the buildings and machineries be rented by company, the calculation of capital costs is quite easy (Oraee and Pomander, 1998). Otherwise, in productivity calculation the depreciation costs as a capital costs is used. In this research, the depreciation of building by straight-line method with life of 30 years is computed. The industrial machinery by declining-balance method with depreciation rates of 35 percent is depreciated. The light vehicles by straight-line method with life of 6 years have been calculated. Also, the properties and working equipments by declining-balance method with depreciation rate of 15 percent and the office supplies and furniture by straight-line with life of 15 years have been depreciated. Moreover, properties, machineries and equipments based on final price are included in the calculation. The cost of overhaul and maintenance and the minor repairs on occurrences are included as the current cost of the same year. The depreciation costs are given in Table 4 (Soltani, 2009).

The costs of spare parts, industrial parts and timber, arc and other tunnel equipments for the years of 2001 to 2008 given in Table 5 (Soltani, 2009). In addition, the wholesale price inflation index of Iran (Price Index and Inflation, 2009) has been used for inflation adjusted. The costs of transportation and maintenance of EACM during 2001 to 2008 is shown in Table 6 (Soltani, 2009). The costs for the said years based on the consumer price inflation index of Iran (Price Index and Inflation, 2009) are inflation adjusted.

Table 4 – The depreciation costs in EACM during 2001 to 2008

Year	2001	2002	2003	2004	2005	2006	2007	2008
Depreciation costs (1000 US $)	700	700	1,400	1,300	1,400	1,900	2,100	2,600

Table 5 – The costs of spare parts, industrial parts and timber, arc and other tunnel equipments in EACM during 2001 to 2008

Year	2001	2002	2003	2004	2005	2006	2007	2008
Spare parts, industrial parts (1000 US $)	1,000	1,000	900	1,100	1,200	1,400	1,100	1,000
Timber, arc and tunnel equipments (1000 US $)	39	16	8	2	8	8	18	18
Total (1000 US $)	1,000	1,000	900	1,100	1,200	1,400	1,100	1,000
Wholesale price inflation index	175	192	211	242	265	297	341	422
Inflation adjusted (1000 US $)	1,000	900	700	800	800	800	600	400

Table 6 – The costs of transportation and maintenance in EACM during 2001 to 2008

Year	2001	2002	2003	2004	2005	2006	2007	2008
Maintenance costs (1000 US $)	700	600	800	900	2,200	2,400	1,500	2,600
Transportation costs (1000 US $)	600	700	500	800	1,400	600	1,800	2,200
Total (1000 US $)	1,300	1,300	1,300	1,700	3,600	3,000	3,300	4,800
Consumer price inflation index	178	206	238	275	308	339	402	504
Inflation adjusted (1000 US $)	1,300	1,100	1,000	1,100	2,100	1,600	1,500	1,700

Also, the costs of work equipments, stores, bank loans, and the other capital expenditures with annual interest rate of 15 percent (Soltani, 2009) are given in Table 7 (Price Index and Inflation (2009).

Table 7 – The costs of work equipments, stores, bank loans, and etc. in EACM during 2001 to 2008

Year	2001	2002	2003	2004	2005	2006	2007	2008
Work equipments and store (1000 US $)	800	500	2,400	2,000	1,900	1,800	1,600	1,400
Bank loans (1000 US $)	0	0	0	0	0	300	0	0
Other capital expenditures (1000 US $)	0	0	0	0	0	0	0	0
Total (1000 US $)	800	500	2,400	2,000	1,900	2,100	1,600	1,400

Table 8 shows the total of capital inputs of EACM during years of 2001 to 2008 which are calculated **based on tables 4 to 7.**

Table 8 – the total of capital inputs in EACM during 2001 to 2008

Year	2001	2002	2003	2004	2005	2006	2007	2008
Total of capital costs (1000 US $)	3,800	3,200	5,500	5,200	6,200	6,400	5,800	6,100

In Figure 4, the trend of capital inputs of EACM is depicted. According to this figure, the capital inputs showing the increasing trends, which can reduce the capital productivity or even the total productivity.

In Figure 5, the share of each cost in total costs during 2001 to 2008 is given in percentages. As can be seen, the share of personnel costs are reduced during these years, but the share of capital costs with the same ratio has increased. While, the energy costs is almost constant.

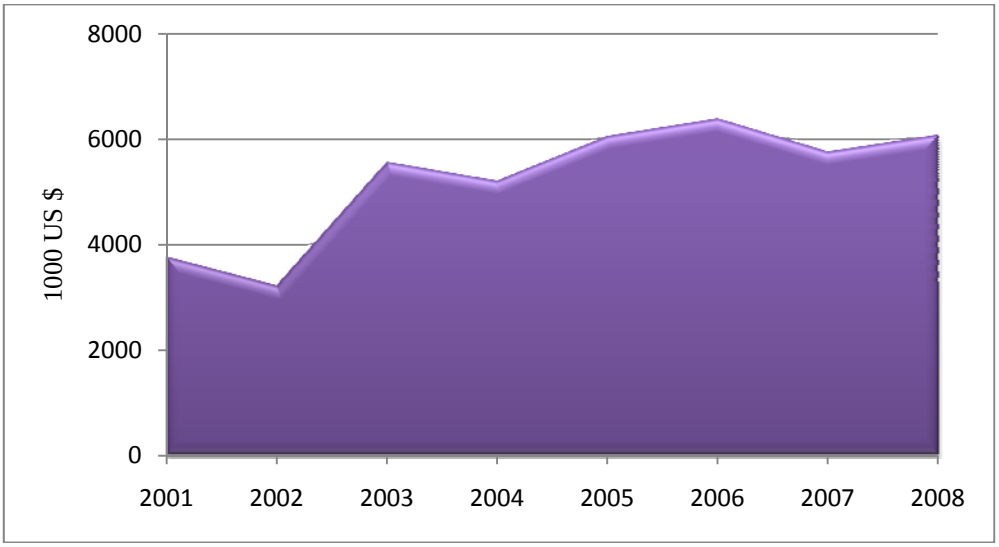

Figure 4 – The trend of capital cost in EACM during 2001 to 2008

Thus, the total inputs of EACM including the manpower, energy, and capital are as in Table 9.

Table 9 – Total inputs in EACM during 2001 to 2008

Year	2001	2002	2003	2004	2005	2006	2007	2008
Manpower input (1000 US $)	13,000	7,800	7,500	5,800	5,900	5,300	4,700	4,700
Energy input (1000 US $)	390	470	420	340	340	330	360	280
Capital input (1000 US $)	3,800	3,200	5,500	5,200	6,200	6,400	5,800	6,100
Total (1000 US $)	17,200	11,500	13,400	11,300	12,400	12,000	10,900	11,000

PRODUCTIVITY CALCULATION IN EACM

Productivity calculated according to the either monetary units or physical units. Using monetary units in define of output and input indicating the economic productivity or profitability (Oraee and Pomander, 1998). At this point, by using the ratio of output (as monetary unit) per total inputs, the total productivity and next with using the inputs of personnel, energy and capital, the partial productivity of the EACM during 2001 to 2008 are calculated and presented in Table 10.

Figure 6 shows the trends of total and partial productivity including personnel, energy, and capital based on monetary unit during 2001 to 2008. According to this figure, the trend of the personnel productivity changes and the capital productivity are compatible with the total productivity. These three productivity indexes reduce significantly in 2003, but showing almost constant onwards. The sinusoidal fluctuations in trends of productivity are a sign of system instability.

The trends of the energy productivity during these mentioned years were instable. As such after dramatic decrease in 2005 and 2006, reaching to a constant trends in 2007, but shows the sudden increases in 2008. According to the Figure 6, the increases of the energy productivity in 2008, is an unusual result as the capital productivity decreased and also the global price of energy has been increased in the same year.

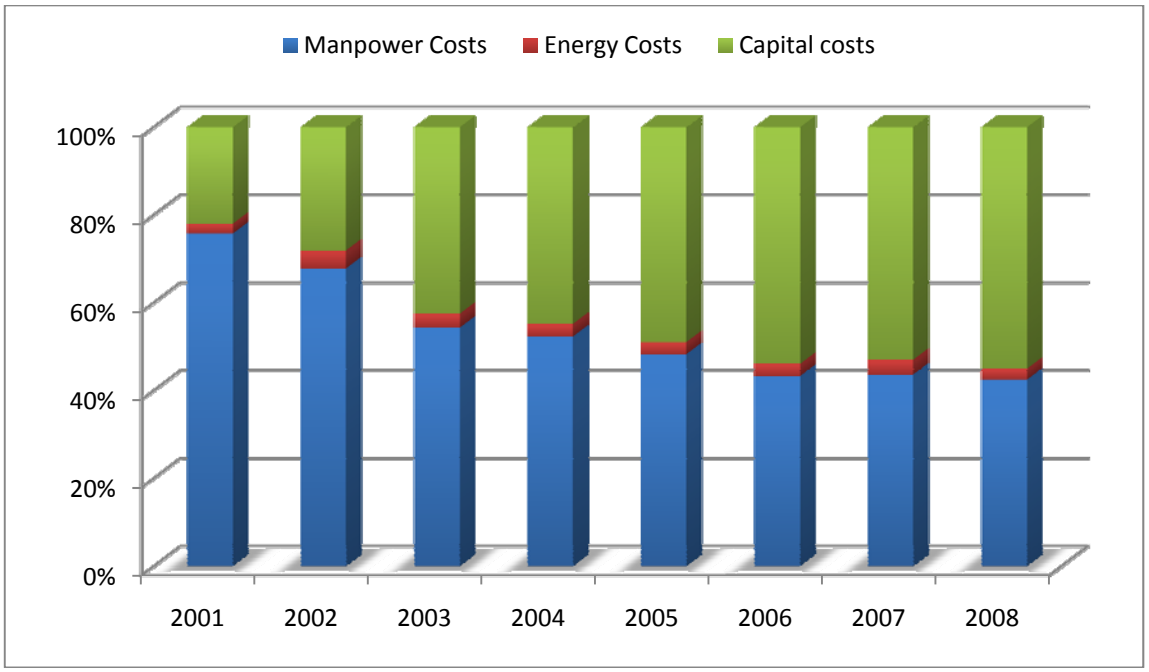

Figure 5 – The share of each cost component in EACM during 2001 to 2008

Table 10 – Productivity at EACM based on monetary units during 2001 to 2008 ($/$)

Year	2001	2002	2003	2004	2005	2006	2007	2008
Total productivity (1000 US $/1000 US $)	1.0	1.7	1.5	1.8	1.9	1.8	2.0	2.3
Labor productivity (1000 US $/1000 US $)	1.4	2.4	2.7	3.5	4.0	4.0	4.6	5.3
Energy productivity (1000 US $/1000 US $)	46	41	48	59	70	64	60	89
Capital productivity (1000 US $/1000 US $)	4.7	6.0	3.6	3.9	3.8	3.3	3.7	4.1

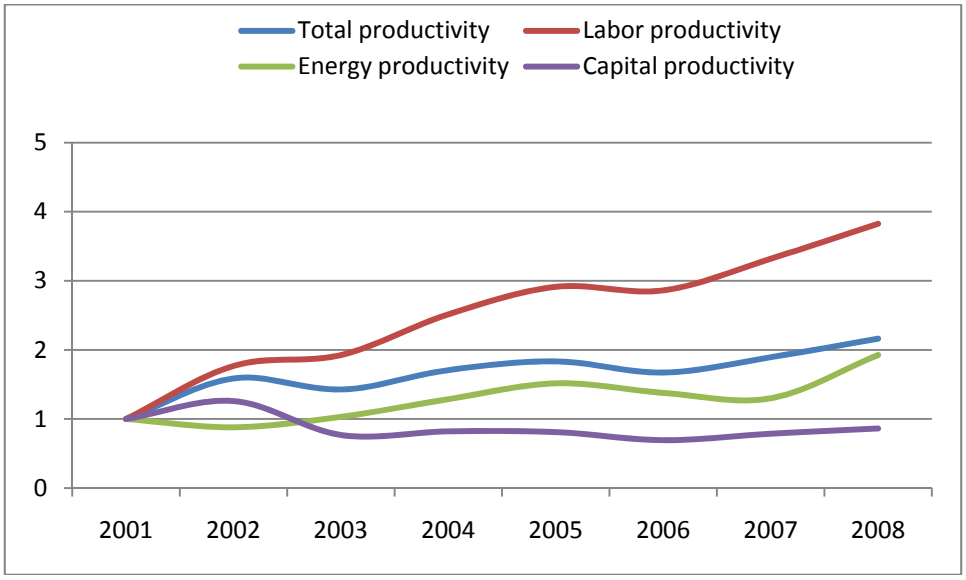

Figure 6 – Variations in total productivity and partial productivity based on monetary units during 2001 to 2008 ($/$)

The productivity of EACM based on physical units (physical per monetary unit) during 2001 to 2008 is given in Table 10.

Table 10 – Productivity at EACM based on physical and monetary units (ton/1000 US $) during 2001 to 2008

Year	2001	2002	2003	2004	2005	2006	2007	2008
Total productivity (ton/1000 US $)	27	46	38	48	52	57	61	63
Labor productivity (ton/1000 US $)	36	68	68	93	110	128	143	147
Energy productivity (ton/1000 US $)	1,197	1,132	1,219	1,579	1,912	2,064	1,861	2,468
Capital productivity (ton/1000 US $)	123	166	93	103	105	106	116	113

In Figure 7 also the trend of total productivity and partial productivity that includes productivity of manpower, energy, and capital based on physical unit per monetary unit are presented. As can be seen, the trend of total productivity variation with productivity of manpower and capital are similar, but the trend of energy productivity is different and shows the sinusoidal behavior.

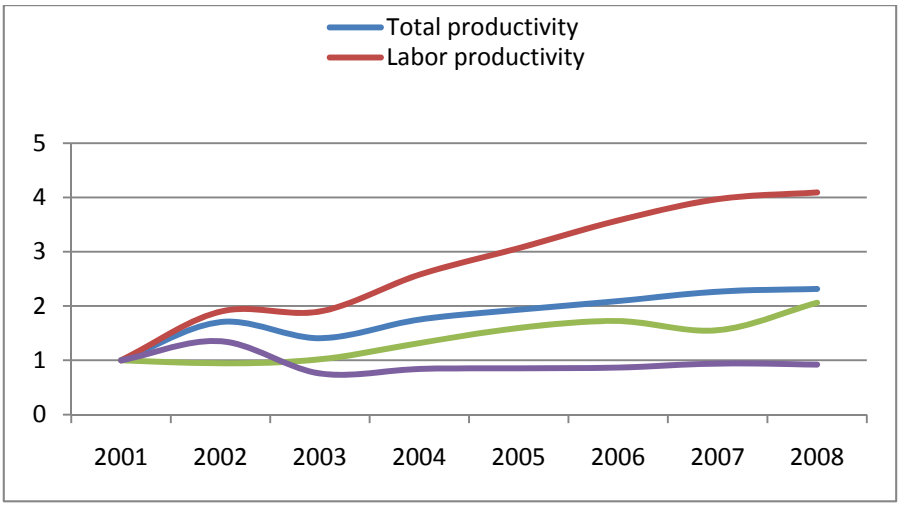

Figure 7 – Variations in total productivity and partial productivity based on physical and monetary units (ton/$) during 2001 to 2008

The Figure 8 shows the trend of total productivity based on monetary unit (US dollars/US dollars) and physical unit (ton/US dollars) during 2001 to 2008. As expected, until year 2004 these two indexes of total productivity are similar, but in 2005 the trend of total productivity based on monetary unit extremely decreases in opposite of the other index! In 2006 it reaches to lowest limit and increases progressively for the two next years!

CONCLUSION

Although, the productivity is a simple economic concept defines as an output to input ratio, but from an engineering view is a critical tool. Such a tool is a key role on evaluation, analysis, comparison, and generally in decision-making processes for knowledge-base economy. The trend of variation of total productivity based on physical per monetary unit shows that the EACM may lead to an unsuitable economic status. While the trend of changes on total productivity based on monetary unit indicating a partial growth in recent years. Such a growth may be either based on inflation index stated by central bank of Iran during these periods or based on engineering and economic concept. Perhaps, growth in partial productivities such as productivity of manpower, capital and particularly, energy may be essential for improvement of EACM. In this connection, mechanization is key factor as it improves productivity beside the other important factors like administrative and management. To ignore the above said factors would reduce the competitive ability of EACM in market. With increases the

production costs especially, energy cost (based on real price, not subsidies) producing of coal may not have economic justification, ever.

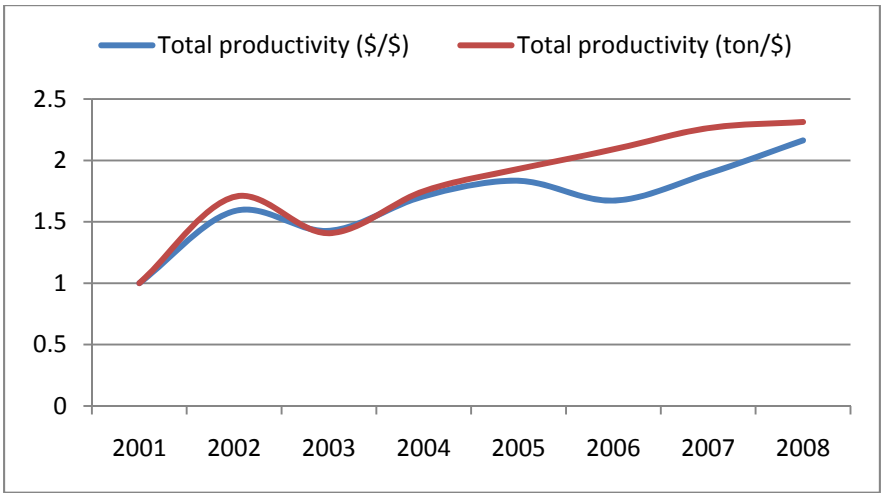

Figure 8 – Variations in total productivity and profitability at EACM during 2001 to 2008

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