Oil Shale. 1999. Vol. 16, No. 4
pp. 377-382
ISSN 0208-189X
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https://doi.org/10.3176/oil.1999.4.11

STOCHASTIC MODELLING IN ESTONIAN OIL SHALE MINING ECONOMICS

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Oil shale mining production, inflation in Estonia, and oil and fuel market prices represent a series of interconnected links. Unfortunately, the last economic parameters could not be exactly predicted. In the present work stochastic methods of mathematical modelling are used to forecast Estonian oil shale economy in the future.

Introduction

Estonian state oil shale industries, including mining and power industry, were formed in the conditions of the former Soviet planned economy. The government established the main economic indicators, including costs and quality. Today's trend is the transition from the state to the market economy, with no practice of planned five-year programmes and state investments. Income is now the main goal of business activities. Social influences play an important part, and governmental policy lays great emphasis on workplace guarantees. Environmental protection, which was uncompromisingly political 10-15 years ago, is being established in a realistic way.

In the first half of 1998, the Master Plan until 2010 for the oil shale mining company *Eesti Põlevkivi* was completed. This Plan proceeds from deterministic forecasts concerning oil shale supply mainly for power generation. In spite of the fact that the author participated in drawing up the development plan, he regards the deterministic approach insufficient. This study attempts to advance a stochastic forecast of the Estonian oil shale industry.

Method of Modelling

The study is based on the standpoints and on the main data of the Master Plan. However, the forecasts rely only on basic parameters. This means that the principal initial data of forecast are random in certain limits. Using random data means that the determination of the forecasts is not exact. For example, provided at the beginning of the evaluation period, the expected annual growth of labour productivity is 5 %, it may be used in the

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calculation as a random number within the annual range of -1...+11 %. Similarly, at the end of the period, the annual growth of labour productivity may be within the limits of -0.2...+2 % (Fig. 1).

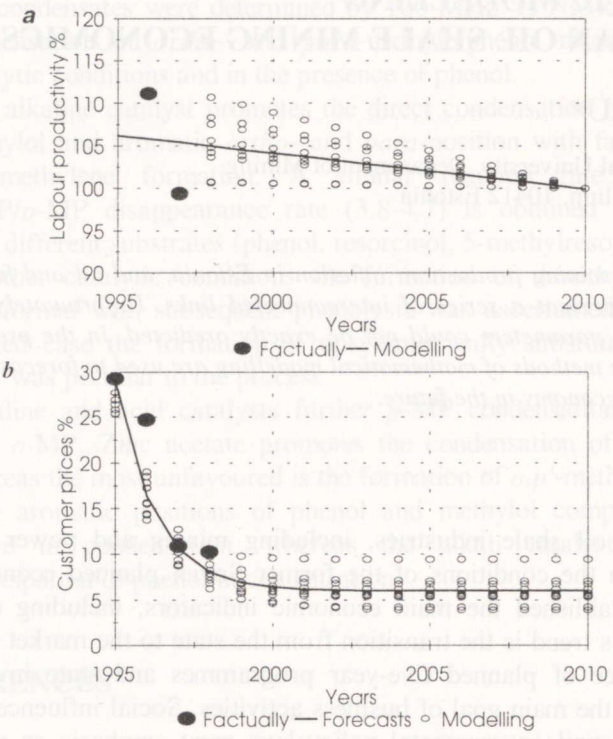

Fig. 1. An example of trends and forecasts: *a* - changes of labour productivity in oil shale mining, % with regard to the previous year; *b* - a decrease in consumer price (inflation rate) in Estonia; actual data were introduced and a forecast was done on the basis of authentic data [1]. Random results of modelling are shown

Likewise, a decrease in domestic inflation at the outset of the evaluation period and the inflation rate at the end of that period may vary. Therefore, provided the inflation rate is 6 % at the end of the period, in the calculation the final rate of inflation may be within 1-12 % (Fig. 1). The same may occur at random with any other initial data. The distribution of random numbers is mostly taken normal and in any case lognormal. Such a method presumes multi-tenfold calculating within one and the same scenario, and the conclusion is based on the analysis of the results.

Calculation of Income

The income is the product of commercial oil shale quantity and its price. Oil shale commerce depends on its market price. Naturally, the customer cannot accept a high price, however, we are not aware of the full extent of its range.

Accordingly, two marginal values (limits) of unacceptable price exist in the model – a lower and an upper one. If oil shale price exceeds the lower value, the consumers will purchase less. If the price reaches the upper limit, the consumers stop buying. These limits depend on the consumers' technical and commercial opportunities and they can vary. The results presented in this paper are characterised by the following limits:

Oil shale consumer	Lower unacceptable price, EEK/t	Upper unacceptable price, EEK/t
Oil plant	90	110
Cement plant	100	140
Power stations	Equivalent price of coal	Indefinite

The lower limit of unacceptable oil shale price for oil plants (according to the oil yield at processing 16 %) is approximately 1/10 of the crude oil market price. Since spring to autumn 1999, crude oil price has decreased; correspondingly, the referred lower limit – 90 EEK/t was too high for this period. The equivalent price of coal takes into consideration the differences in coal and oil shale combustion efficiencies.

In addition, oil shale price depends on the character of consumption. It is expected that in the future the price for the season consumer (power stations) will still be 30 % higher on the average than for the continuous consumer (oil and cement plants). All the scenarios foresee that the output of oil shale (ton per annum) is equal to its saleable quantity.

Calculation of Expenses

Labour cost calculation is based on the number of workers and on their wages. Closing of a mine results in a decrease in the manpower and in the growth of labour productivity. Mining enterprises will be closed as a result of shrinking oil shale business. The growth of labour productivity in the model was taken as retarding. At the outset of the evaluating period, the annual growth of labour productivity was on the average 5 %, and at the end 1 %. The rise in wages was taken proportional to domestic inflation.

The costs of materials and power depend on their specific consumption and price. The specific consumption of explosives obviously depends on the level of technology. The price of explosives is growing moderately. The specific consumption of electricity is steady. The price of electricity grows proportionally to the price of oil shale.

Fuel (crude and diesel oil, gas, etc.) was taken as steady; the price will increase proportionally to global inflation.

According to the practice in Estonia, the **royalty** is growing proportionally to domestic inflation.

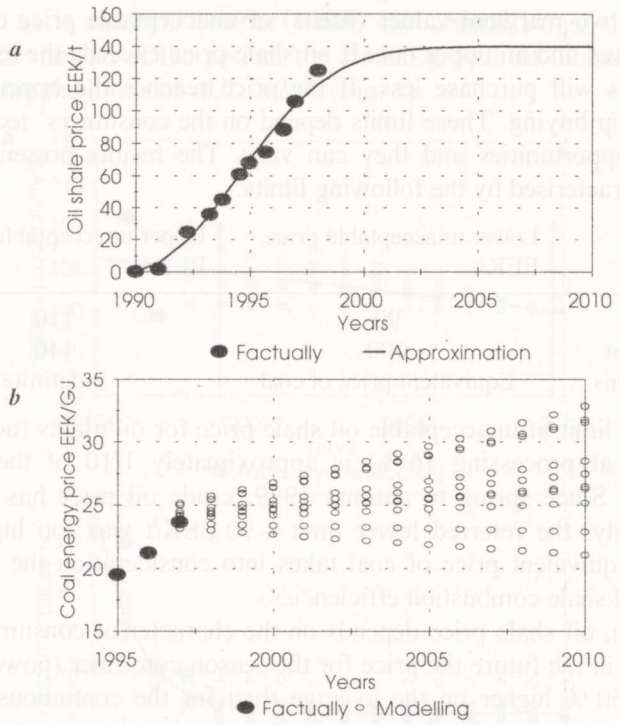

Fig. 2. Oil shale and coal price forecasts in the model: *a* - an increase in oil shale price (factual and approximated without addition of coal price); *b* - the average price of coal in Estonia [1], and a sample at the random value of the modelled coal price. If the price of oil shale (independent of coal price) stabilises on the marginal 140 EEK/t, then the probable price level in modelling will depend upon the price level of coal if it rises, the price of oil shale can exceed the level of 200 EEK/t

Capital costs were taken from the Master Plan of *Eesti Põlevkivi* AS. The relationship between the interest rate of a long-term loan (k) and consumer price index (i) is as follows:

$$k = 0.97i + 4.6$$

The equation was approximated on the basis of economic indicators of advanced industrial states (USA, Japan, Germany, France, UK, Italy, Canada, Netherlands, and Sweden) in 1994-1997 [2].

Process of Modelling

The economic activity of the mining industry was modelled on the basis of the income-costs balance method. A number of scenarios were calculated with varied trends of an increase in oil shale price.

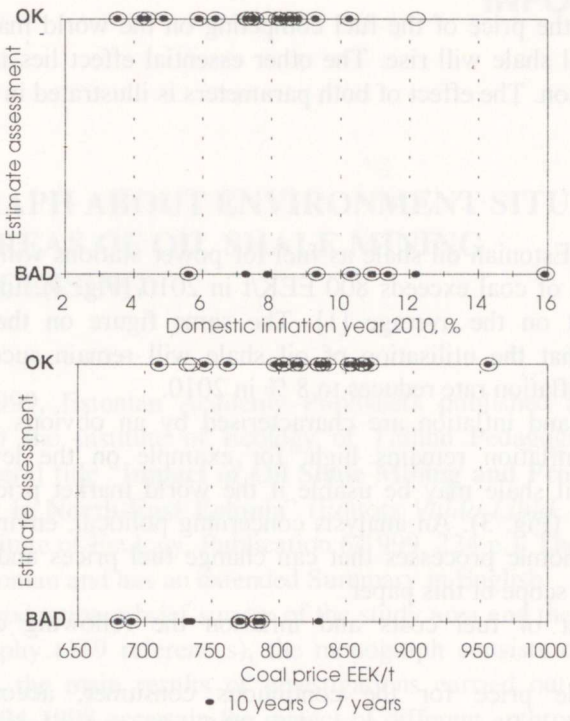

Fig. 3. Graphic presentation of oil shale industry's performance: profitable (OK) or non-profitable (BAD) in 2010.

The expected price trend was approximated on the basis of a past increase provided that the cost of oil shale energy cannot be extended higher than the equivalent price of coal (Z_{coal}), the most common replacement fuel. The trend in oil shale price ($Z_{oil\ shale}$) is described by the equation

$$Z_{oil\ shale} = Z_{coal}\ (1 - \exp - ((t - t_0)/\tau)^C)$$

where t is the prognostication year;

t_0 is the first year of price trend evaluation (1989);

τ and c are trend parameters.

Coal price was taken as a variable with a random trend, the mean trend being +1 % per year. The evaluation prognosis for fuel price is shown in Fig 2.

The calculations were reiterated within the same scenario for 20-30 times. The main criterion was the difference between the net present value (NPV) of seven- as well as ten-year cash flow and NPV of loans. It means equalising the internal rate of return with zero, as in this case we have to deal with a strategic economic object. The model enables us to do calculations at any internal rate of return or fix it for an anticipated inflation.

The quantity and price of oil shale consumption and efficiency of oil shale mining depend first of all on the world market price of fuel. The price of coal was taken as a basis. Thus, the price of oil shale may rise along with

an increase in the price of the fuel competing on the world market, because the need for oil shale will rise. The other essential effect lies in the level of domestic inflation. The effect of both parameters is illustrated in Fig. 3.

Conclusions

1. The use of Estonian oil shale as fuel for power stations will be beneficial if the price of coal exceeds 800 EEK/t in 2010 (Fig. 3). In 1997, it was 710 EEK/t on the average [1]. The same figure on the right graph indicates that the utilisation of oil shale will remain successful if the domestic inflation rate reduces to 8 % in 2010.
2. Fuel price and inflation are characterised by an obvious synergism. If domestic inflation remains high, for example on the level of 12 %, Estonian oil shale may be usable if the world market price rises up to 950 EEK/t (Fig. 3). An analysis concerning political, environmental and global economic processes that can change fuel prices and inflation are outside the scope of this paper.
3. Independent of fuel costs and inflation the following considerations apply:

- If oil shale price for the continuous consumer, according to the government policy, is not more than 30 % cheaper, oil shale processing will be closed in 2000 and cement industry purchases half as much.
- If the government stops subsidization of oil shale concentration, oil industry will be closed immediately; cement industry could consume oil shale until 2000 and then will have to use other fuels or to open an oil shale opencast at the factory.
- Oil shale output was modelled approximately as 7.5 million tonnes in the year 2010, which is lower than indicated in the State Power Development Plan in 1998 (10.5 million tonnes per year), but it is higher than the authors forecast in 1988, equalling 5.35 million tonnes per year in 2010 [3].
- 10-year economic indicators of the Estonian oil shale industry are lower than 7-year ones, referring to a decreased utility of Estonian oil shale-based power industry.

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Received June 1, 1999