FUZZY ANALYSIS OF ECONOMIC EFFICIENCY OF INVESTMENT IN PRODUCTION OF ELECTRIC VEHICLES

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Abstract

A strategy by which the current EU legislation addresses the environmental aspects of greenhouse gas emissions and the depletion of fossil fuels is to actively promote the expansion of the electric vehicle market. The penetration rate of electric vehicles varies from country to country depending on the incentives stimulating demand for this commodity. Given the uncertainties about the amount of initial investment needed in its production, the future market price and the amount of demand, only intervals of the values at which the volume of future production will be realized can be reliably estimated. We are thus in a state of uncertainty on the input side of the evaluation process, with the result the output that is uncertain as well. Under such a situation the fuzzy approach based on the algebra of intervals presented in the paper is a suitable tool for answering the question, whether the system of subsidies offered by the government is adequate and promotes desirable market growth. In contrast to the conventional approach based on standard evaluation procedures, the fuzzy approach will also provide above-standard information that can help the investor in making his decision.

Key words: electric vehicle, subsidy, fuzzy interval

JEL Code: C44, C58, C61

Introduction

The traffic is the cause of various unwholesome pollutants and noise. As such, it requires considerable social costs that perform significant burden on public expenditures (Holtsmark & Skonhoft, 2014). As a result, many countries have systems that enables the government to collect income in the form of fuel taxes, road taxes etc.

Costs related to electrical vehicles have been treated much more leniently both for the producers and buyers. This covers various tax exemptions as well as diverse driving privileges, exemption from parking fees in city centers and in some countries, battery charging at zero cost. As a result of this policy, the sales of electro vehicles have increased dramatically over the last decade. Among the five largest electric vehicle markets in the EU in 2018 belongs Germany with 67 505 cars sold, which performs 2,0 % GDP per capita in the amount of € 41 000, United Kingdom with 59 911 cars sold - 2,5% GDP (€ 37 600) France 45 587 cars sold - 2.1% GDP (€ 36 200), Netherlands 29 695 cars sold - 6.7% GDP (€ 44 900) and Sweden with 28 327 cars sold - 8.0% GDP (€45 900) (Dvořák & Šidlák, 2020).

The number of electric cars in the Czech Republic in 2018 was estimated to 2 000. Due to the strict emission standards in the EU and the announced multi-billion-dollar investment by car manufacturers in electro-mobility a rapid increase of share of electric cars in new car sales in the EU and possibly in the Czech Republic is expected by 2030.

In the following we will analyse the project that involves the production of electro vehicles whose share of growth in the car market is of the interest to the government. However, the need for a large initial investment in the project and the high production costs do not stimulate a sufficiently high demand to guarantee an adequate profitability to producers. The profitability increase is thus stimulated by means of a system of incentives. The implementation of various government incentives such as tax exemption, purchase subsidies, free parking and driving privileges should positively influence the impact on the growth in demand for electric cars.

Considering the uncertainty about the future supported demand that projects into vagueness about the future market prices and production volumes, it is rational to base further considerations on the intervals of these estimated input data. Furthermore, no relevant reason exists as to why a particular value within a given interval should be preferred (Hašková & Fiala, 2019). Therefore, we solve a problem of uncertainty on the input side of the assessment process with the profitability value on its output side as an uncertain parameter (Maciel et al., 2016).

For this purpose, the fuzzy linguistic method will be discussed and applied as an alternative to conventional budgeting technique based Internal Rate of Return (IRR). The theory will be aimed at the comparison of the standard managerial approach with the fuzzy approach. Both procedures will be applied in the problem solution the investors often face when deciding about investment in a subsidized production of electric vehicles. The solution reflects the uncertain input data of future demand that is the percentage of production margin. The benefits of the fuzzy method are discussed and justified.

1 Conventional approach to IRR evaluation

Internal Rate of Return (IRR) (see, e.g. Danielson, M. 2016) is an annual discount rate equalizing the initial capital expenditure with the present value of the cash flows generated by the project. IRR is simply quantifiable when the annual incomes generated by the initial investment are positive. The project can be recommended if its IRR is higher than the project´s discount rate (Patrick & French, 2016). In our case we define IRR by the formula:

$$\sum_{i=1}^{n} CF_i \,/(1 + IRR)^i = -CF_0 \qquad (1)$$

where **CF_0** = –(I + NW), in which I stands for capital investment and NW for net working capital expenditure, **CF_i** = R_i – VC_i – FC_i – T_i, i > 0, in which R_i stands for revenue from sales, VC_i for variable costs, FC_i for fixed costs and T_i for tax in each year i of the project run. The symbols I, NW, R_i, VC_i, FC_i and T_i, i = 1, 2, …, n, are input parameters of the task.

Formula (1) is relevant and unambiguously solvable only in the case where the numerators of all addends on the left side are non-negative (for details see Brealey et al., 2011). Let *IRR* be the required value of implicit output variable IRR of (1).

Let us suppose that some parameter *x* of any input variable is uncertain, i.e., only the interval $\langle x_{min}, x_{max}\rangle$ of all possible values of *x* can be estimated with no other relevant information available. Then, what value of this parameter should be inserted as a relevant input variable? The *principle of indifference* helps to resolve the question. It says that if there are more values where there is no relevant reason to prioritize one over another, the same probability of occurrence will be assigned for each (Pettigrew, 2014).

Let us regard the values on the interval $U = \langle x_{min}, x_{max}\rangle \subset R$ as values of the continuous random variable α given by constant probability density $f_\alpha(x) = 1 / (x_{max} - x_{min})$ on this interval and the statistically expected value $E[\alpha] = \int_U (x / (x_{max} - x_{min})) \cdot dx = (x_{max} + x_{min}) / 2$. Accordingly, in the conventional approach we replace the parameters I, NW, R_i, VC_i, FC_i, T_i with their expected values E[I], E[NW], $E[R_i]$, $E[VC_i]$, $E[FC_i]$, $E[T_i]$, i = 1,2,…,n, and the equations CF_0 = –(I + NW) and $CF_i = R_i - VC_i - FC_i - T_i$ with their expected forms $E[CF_0]$ = –(E[I] + E[NW]) and $E[CF_i] = E[R_i] - E[VC_i] - E[FC_i] - E[T_i]$. The statistically expected values $E[CF_0]$, $E[CF_i]$ and E[IRR] are inserted to the formula (1) the result of which is relation (2)

$$\sum_{i=1}^{n} E[CF_i] \,/(1 + E[IRR])^i = E[-CF_0] \qquad (2)$$

The value of E[IRR] from formula (2) can be calculated by an iterative method.

2 The fuzzy approach to IRR evaluation

In the fuzzy approach the interval $U = \langle x_{\min}, x_{\max} \rangle \subset$ R of all possible values of uncertain parameter x is interpreted as the support of a non-fuzzy subset $\underline{A} = \{(x, \mu_{\underline{A}}(x)) : x \in R\}$, $\mu_{\underline{A}}(x) = 1$ for $x \in U$, $\mu_{\underline{A}}(x) = 0$ otherwise, which is a fuzzy number (Běhounek & Cintula, 2006). In the case of certain parameter x, fuzzy number $\underline{A} = \{(x, \mu_{\underline{A}}(x))\}$ is the *singleton* with $x = x_{\min} = x_{\max}$ (for further details see Zadeh, 1975).

Within the fuzzy approach we change parameters I, NW, R_i, VC_i, FC_i, T_i for intervals $\langle I_{\min}, I_{\max} \rangle$, $\langle NW_{\min}, NW_{\max} \rangle$, $\langle R_{i\_min}, R_{i\_max} \rangle$, $\langle VC_{i\_min}, VC_{i\_max} \rangle$, $\langle FC_{i\_min}, FC_{i\_max} \rangle$, $\langle T_{i\_min}, T_{i\_max} \rangle$, i = 1, 2,…, n. Application of operations of algebra of intervals defined in Hašková (2017) enables to replace the equations $CF_0 = -(I + NW)$ and $CF_i = R_i - VC_i - FC_i - T_i$ with equations ($CF_{0min} = -(I_{max} + NW_{max})$; $CF_{0max} = -(I_{min} + NW_{min})$) and ($CF_{i\_min} = R_{i\_min} - VC_{i\_max} - FC_{i\_max} - T_{i\_max}$; $CF_{i\_max} = R_{i\_max} - VC_{i\_min} - FC_{i\_min} - T_{i\_min}$). The variables of interval limits $\langle CF_{0min}, CF_{0max} \rangle$, $\langle CF_{i\_min}, CF_{i\_max} \rangle$ and $\langle IRR_{min}, IRR_{max} \rangle$ are inserted in the formula (1), which then creates a pair of equations (3):

$$\begin{aligned} \sum_{i=1}^{n} CF_{i\_min} / (1 + IRR_{min})^{i} &= -CF_{0\_min} \\ \sum_{i=1}^{n} CF_{i\_max} / (1 + IRR_{max})^{i} &= -CF_{0\_max} \end{aligned} \tag{3}$$

The relations (3) represent a procedure for evaluating the values IRR_{min} and IRR_{max} of the output interval $\langle IRR_{min}, IRR_{max} \rangle$ that is possible to quantify by any iterative method. The calculation of a value from $\langle IRR_{min}, IRR_{max} \rangle$ is a technical procedure and therefore no rational reason exists to prefer one value over another. Whence, the output interval $Y = \langle IRR_{min}, IRR_{max} \rangle$ is the support of the fuzzy number $\underline{IRR} = \{(y, \mu_{\underline{IRR}}(y)) : y \in R\}$, $\mu_{\underline{IRR}}(y) = 1$ for $y \in Y$, $\mu_{\underline{IRR}}(y) = 0$ otherwise, in the form:

$$\begin{aligned} IRR &= \int_Y y \cdot \mu_{\underline{IRR}}(y) \cdot dy / \int_Y \mu_{\underline{IRR}}(y) \cdot dy = \\ &= (IRR_{max}^2 - IRR_{min}^2) / \left(2 \cdot (IRR_{max} - IRR_{min})\right) \\ &= (IRR_{max} + IRR_{min})/2 \end{aligned} \tag{4}$$

The value *IRR* is the *subjectively* expected value due to the fact that *IRR* calculated in this way is largely a result of the subjective experience and opinion of experts who state the intervals of possible values of uncertain parameters to the model.

3 An illustration of IRR analyses of electric car production

The case study illustrates how a state subsidy reflects in the profitability of investments in electric vehicle production in the situation of uncertainty of input data. The input parameters originate from the marketing research that took into account the actual subsidy policy and expected development of sales in the following decade. We analyse a newly built production of electric vehicles. The minimum profitability of the investment required by investors of this project is r = 12 %.

3.1 Project data

We consider a seven-year cycle project of production and sale of electric vehicles whose initial cost characteristics are captured in rows 1 and 3 of column 0; the operation cost characteristics are to be found in rows 4 and 5 of Tab. 1, Tab. 2 and Tab. 3.

Tab. 1: Net cash flow estimate (in mil. EUR) from the production and sale of electric vehicles (conventional approach)

Year	0	1	2	3	4	5	6	7
1. Capital investment	75							
2. Revenue from sales		150	200	213.7	228.7	233.7	237.5	8
3. Production start-up investment	10						–8.5	
4. Variable costs		120	160	171	183	187	190	
5. Fixed costs		16	16.3	16.6	17	17.3	17.7	
6. Depreciation		15	15	15	15	15		
7. Profit before tax (2-3-4-5-6)	–10	–1	8.7	11.1	13.7	14.4	38.3	8
8. Tax 34 %	–3.4	–0.34	3	3.77	4.66	4.9	13	2.72
9. Net profit (7-8)	–6.6	–0.66	5.7	7.33	9.04	9.5	25.3	5.28
10. CF_i from operation (6+9)	–6.6	14.34	20.7	22.33	24.04	24.5	25.3	5.28
11. **E[CF_i]** (10-1)	**–81.6**	**14.34**	**20.7**	**22.33**	**24.04**	**24.5**	**25.3**	**5.28**

Source: own computation

The company takes into account the difficulty in making accurate estimates of cash flows given to uncertain development of purchase subsidy and demand. The historical experience in the automotive business suggests that if the project is not to be loss-making, the production margin x, where $x = (R – VC) / R$, with R stating for sales revenue and VC for variable costs, has to reach at least 15 %. It is also known that it is highly improbable to exceed the 25 % margin due to the competition in the sector. This knowledge actually defines the interval ⟨15 %, 25 %⟩ of possible production margins, within which there is no reason to prefer one value over another. The margin becomes the factor determining the limits of the interval of uncertain parameter R_i, for which it applies: $R_i = VC_i / (1 – x)$. Thus, $R_{i\_min} = VC_i / 0.85$, $R_{i\_max} = VC_i / 0.75$. The values R_{i_min} and R_{i_max} are recorded in the second row of Tab. 2 and Tab. 3.

3.2 Solution procedure

In the following we analyse the impact of uncertainty of the parameter R_i of input variable CF_i, i = 1, 2,…, n on the cash flows based on database in Tab. 1, Tab. 2 and Tab. 3, where the input data of three baseline scenario are entered (details of the cash flow budgeting can be tracked in Brealey et al., 2011 or Elkjaer, 2010).

The revenues from the sale of electro vehicles are given in the second row of the tables; they are estimated for the six years of the project run; the 7th year revenue stands for the income from the sale of dismantled machinery of a completely depreciated assembly line. Working capital expenditure in row 3 presents the amount to be gradually put into operation from external sources during the first financial cycle. This amount remains in stocks, receivables and product elaborations. It is gradually released at the shortening of the financial cycle and fully released after the termination of production. The negative tax in row 8 is a cash inflow resulting from a tax loss from a project, which is used to reduce the tax liability in another company production.

In Tab. 1 (section 4.1) the conventional approach is solved, and therefore, the values given in row 2 are the centres of the intervals $\langle R_{i\_min}, R_{i\_max}\rangle$. By inserting the values of the row 11 in the formula (2) we get the equation: $14.34 / (1 + E[IRR]) + 20.7 / (1 + E[IRR])^2 + 22.33 / (1 + E[IRR])^3 + 24.04 / (1 + E[IRR])^4 + 24.5 / (1 + E[IRR])^5 + 25.3 / (1 + E[IRR])^6 + 5.28 / (1 + E[IRR])^7 = 81.6$, the solution of which is E[IRR] = 0.15, i.e., 15 %.

In Tab. 2 and Tab. 3 we perform the fuzzy approach. Therefore, the values in row 2 of Tab. 2 are the values of R_{i_min}, and the values of Tab. 3 capture the R_{i_max} values.

Tab. 2: CF_{i_min} forecast from the production and sale of electric vehicles in mil. EUR (fuzzy method)

Year	0	1	2	3	4	5	6	7
1. Capital investment	75							
2. Revenue from sales (R_{i_min})		141.2	188.2	201.2	215.3	220	223.5	8
3. Production start-up investment	10						–8.5	
4. Variable costs		120	160	171	183	187	190	
5. Fixed costs		16	16.3	16.6	17	17.3	17.7	

6. Depreciation		15	15	15	15	15		
7. Profit before tax (2-3-4-5-6)	–10	–9.8	–3.1	–1.4	0.3	0.7	24.3	8
8. Tax 34 %	–3.4	–3.33	–1.05	–0.48	0.1	0.24	8.3	2.72
9. Net profit (7-8)	–6.6	–6.47	–2.05	–0.92	0.2	0.46	16	5.28
10. CF_{i_min} from operation (6+9)	–6.6	8.53	12.95	14.08	15.2	15.46	16	5.28
11. **CF_{i_min}** (10-1)	**–81.6**	**8.53**	**12.95**	**14.08**	**15.2**	**15.46**	**16**	**5.28**

Source: own computation

Tab. 3: CF_{i_max} forecast from the production and sale of electric vehicles in mil. EUR (fuzzy method)

Year	0	1	2	3	4	5	6	7
1. Capital investment	75							
2. Revenue from sales (R_{i_max})		160	213.3	228	244	249.3	253.3	8
3. Production start-up investment	10						–8.5	
4. Variable costs		120	160	171	183	187	190	
5. Fixed costs		16	16.3	16.6	17	17.3	17.7	
6. Depreciation		15	15	15	15	15		
7. Profit before tax (2-3-4-5-6)	–10	9	22	25.4	29	30	54.1	8
8. Tax 34 %	–3.4	3.06	7.48	8.64	9.86	10.2	18.4	2.72
9. Net profit (7-8)	–6.6	5.94	14.52	16.76	19.14	19.8	35.7	5.28
10. CF_{i_max} from operation (6+9)	–6.6	20.94	29.52	31.76	34.14	34.8	35.7	5.28
11. **CF_{i_max}** (10-1)	**–81.6**	**20.94**	**29.52**	**31.76**	**34.14**	**34.8**	**35.7**	**5.28**

Source: own computation

After insertion of the values of the row 11 of Tab. 2 and Tab. 3 into relations (3) we get:

$$8.53 / (1 + IRR_{min}) + 12\ 95 / (1 + IRR_{min})^2 + 14.08 / (1 + IRR_{min})^3 + 15.2 / (1 + IRR_{min})^4 + 15.46 / (1 + IRR_{min})^5 + 16 / (1 + IRR_{min})^6 + 5.28 / (1 + IRR_{min})^7 = 81.6$$

and

$$20.94 / (1 + IRR_{max}) + 29.52 / (1 + IRR_{max})^2 + 31.76 / (1 + IRR_{max})^3 + 34.14 / (1 + IRR_{max})^4 + 34.8 / (1 + IRR_{max})^5 + 35.7 / (1 + IRR_{max})^6 + 5.28 / (1 + IRR_{max})^7 = 81.6,$$

from which IRR_{min} = 0.02, i.e., 2 % and IRR_{max} = 0.28, i.e., 28 %; the subjectively expected value *IRR* = (2 % + 28 %) / 2 = 15 %.

4 Result discussion

The statistically expected value E[IRR] of the project's return rate corresponds to its subjectively expected value of *IRR*. In general, this may not be the rule. The calculated value exceeds the required rate of return (r = 12 %) by 3 %, which supports the adoption of the project.

The fuzzy interval of the solution offers additional information: possible yields can be expected in the range from 2 % to 28 %; the probability that the required 12 % project profitability will not be achieved is 100 · 10 / 26 = 38 %; this figure can discourage an investor with a negative attitude towards risk; let us suppose that a risk-averse investor is willing to accept the maximum level of 30 % probability that the project will not reach investors´ requirement of 12 % profitability ; in that case the left value of the interval should not be lower than 5.3 %.

It follows then that the fuzzy approach informs us, for example, that a 20 % capital investment subsidy, which would reduce the initial investment from 75 to 60 mil. EUR increases the minimum possible yield of return to 8 %. Such a subsidy policy tends to encourage investors to implement the project. From the microeconomic analyses point of view, the electric vehicle market supply curve would shift to the right, which is in the same direction as the government-supported purchases (in order to increase consumption) shift the market demand curve.

Summary and conclusion

The trend of reduction of CO_2 makes the producers to behave strategically and to redirect their production towards greener products. In the last decade this trend significantly projected into the growth of the production and purchase of electric vehicles at the expense of vehicles with combustion engines. This strategy is actively supported by governments through subsidy interventions in order to encourage the production and sale. From the managerial point of view the uncertainty about the initial investment in the production, the future market price and the demanded amount exists, which enables to assess the project only within intervals of the possible values.

The uncertainty of data on the input side of the evaluation process results in the searched output that is uncertain as well. This situation is solved by means of the fuzzy approach based on the algebra of intervals. As shown this method proved to be a suitable tool for answering the question, whether the system of subsidies offered by the government is adequate and promotes desirable market growth. Compared to the conventional method to IRR evaluation the fuzzy approach provides above-standard information useful for decision makers.

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