

The Application of Game Theory to Forecasting Orders

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Abstract

The article deals with the effort to forecast the development of future sales over a period of several months. The ability to forecast is very important for a company in terms of being able to manage its working capital i.e. cash flow, materials, semi-products, work in progress, products and receivables, according to the forecast. Forecasting is often very difficult, particularly in a situation when a company enters a new market and has insufficient data over a substantial period of time, in particular when we consider the seasonality of a product or service. The article therefore analyses the possible application of game theory to the forecasting of orders.

Keywords: game theory, forecast, trade, working capital management, controlling

Introduction

Companies transform production factors (inputs) into the form of outputs, be it either products or services. The main goal of a company is to make profit, or to maximize shareholder value. It is for this reason that a company tries to perform the transformation as efficiently as possible. We understand efficiency in the same way as Synek & Kislingerová (2015), as the favourable ratio of input production factors to outputs. In other words a company tries to achieve “minimax” – to obtain the maximum output values by means of the minimum input values.

There are a lot of inputs that participate in the transformation of production factors. From the point of view of business economics these include executive and managerial work, materials and fixed assets. To transform these production factors we must state exactly what outputs they are to be transformed into, into what form, in what time, etc. This requires planning (Vochozka & Mulač, 2012).

The plan should determine the resources to be committed and how they should be gradually transformed into outputs. This implies that a company's plan should consist of numerous sub-plans e.g. a personnel plan with which to resolve recruitment issues and needs, professional exams, trades, and others; or a production plan crucial for material ordering, linked to a financial plan because the quantities of materials held directly affects the amount of available resources.

All the plans that a company prepares, with exception to some very specialized ones e.g. R&D, depend on an estimation of the development of sales. Realistic estimations over the long term are extremely difficult, if not impossible, to make because of the uncertainties within economies over a period of years. Short-term planning is different. A company can influence future short-term developments through its own behaviour. The requirements for accuracy in short-term plans are therefore much higher.

It is clear from the above that in the short term a company has to plan sales relatively accurately – it has to be able to forecast sales in order to purchase inventories, to address personnel demands (particularly where it concerns seasonal products or services) and cash-flow.

Although there is the requirement for very accurate planning, it is important to account for the fact that there is a certain level of probability when it comes to making forecasts. In some cases it may therefore be difficult to plan ahead. Planning involves decision making. If such decision making is considered to be a conflict situation, it is possible to apply game theory to the process.

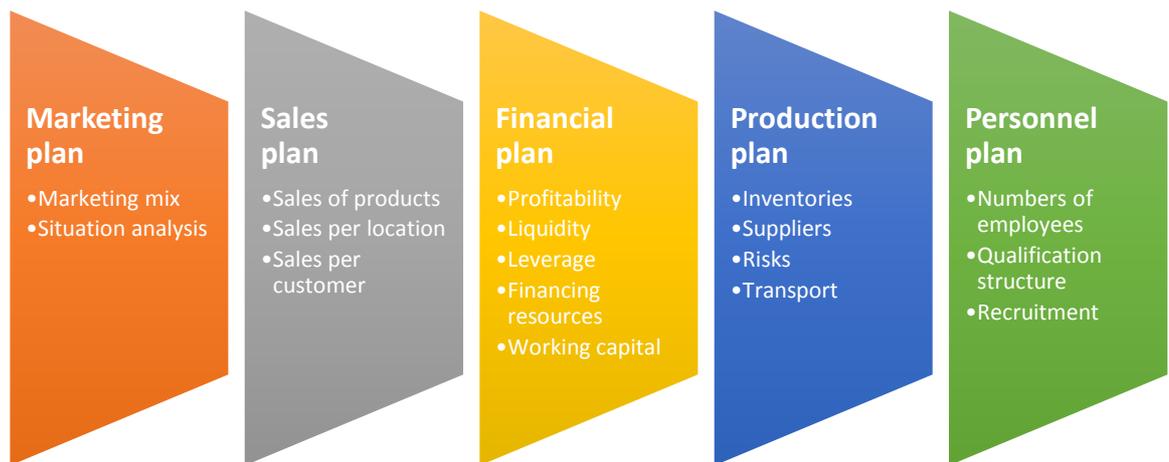
The aim of this article is to analyse the possibility of applying game theory to sales forecasting.

Theoretical-methodological part

Links between forecasts and other company plans

As previously mentioned, the forecasting of sales involves the exact determination of future sales. This is of importance to other company plans which are directly linked to sales. Figure 1 shows the system of individual plans. It is clear that a company must first analyse its market and select the appropriate marketing tools. By applying those tools the company seeks to fulfil its sales plan. The sales plan subsequently impacts on the financial, production and personnel plans which are closely linked to it. In some cases, the marketing function is so closely linked to the sales department that there is no clearly defined border between them.

Figure 1: Company plans and their links



Source: Havlíček (2011) – modified.

Whilst the marketing plan deals with market research, the marketing mix and the application thereof, the sales plan deals with concrete levels of sales both in quantitative and financial terms. This is why sales plans are usually divided into 3 categories according to:

- 1) territories;
- 2) products; and
- 3) customers.

The final plans must have the same values at the end in terms of the numbers of units, numbers of rendered services and sales revenues. The reason for the division of a plan into three categories with the same final results is the need for controlling, the task of which is to find mistakes in the planning.

If a plan were only drawn up according to territories, a mistake based for example on planned purchases from an untrustworthy company that might go bankrupt, might not be detected. The same principle applies to plans based on customers, whereby a mistake in the selection of a wrong market segment might not reveal how easily a competitor could substitute a service or a product on the local market. An example of a sales plans is given in Table 1.

Table 1: Example of Sales Plan for the First Four Months.

Line descriptions	January	February	March	April	Sum
Customer					
Retailers	525	473	496	521	2,015
Wholesalers	261	235	247	259	1,002
Direct sales	264	238	249	262	1,013
Sum	1,050	945	992	1,042	4,029
Product					
Wardrobe	210	189	198	208	806
Dining table	210	189	198	208	806
Bed	210	189	198	208	806
Office desk	210	189	198	208	806
Office chair	210	189	198	208	806
Sum	1,050	945	992	1,042	4,029
Territory					
Czech Republic	747	648	670	693	2,758
Austria	153	150	163	176	641
Other EU Members	150	147	160	173	630
Sum	1,050	945	992	1,042	4,029

Source: Authors

Table 1 shows that the company wants to sell the same quantities of the individual categories of products, whereby sales are primarily focused on retailers in the Czech Republic. We can also see that the company has taken seasonal fluctuations into account. If similar plans were drawn up for the other quarters an annual plan would be generated.

After completion of the annual plan, it is implemented. In doing so, it is of importance to take into consideration market uncertainties, as well as uncertainties within the macro and micro-economic environments in which the company operates. Examples include, a drop in sales because of an outbreak of flu, or because of the introduction of a new information system which employees are not able to use efficiently. Such circumstances, and the results thereof, are the reasons why monthly plans are adjusted and modified with only one goal in mind – the fulfilment of the annual plan. These corrections however have to be done several months in advance because of production planning needs, the particular time period being dependent on the complexity of the manufacturing process.

The forecasting of orders must therefore be managed through a system of regular meetings, on the basis of which the sales department determines the individual forecasts and the production department the purchase and manufacture of goods accordingly. An example of a scheme of forecast management is given in Table 2.

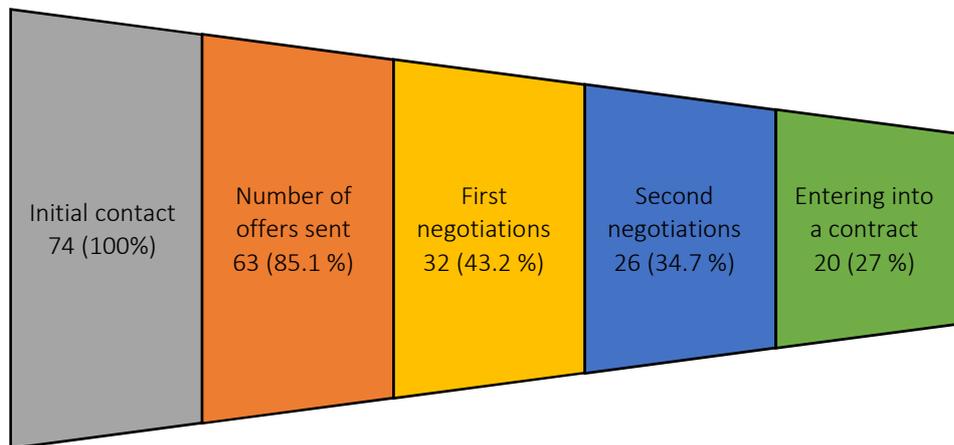
Table 2: Management of forecasts

	October	November	December	January	February	March	April	May	June	July	August	September	October	November
1	Yellow		Red											
2		Yellow		Red										
3			Yellow		Red									
4				Yellow		Red								
5					Yellow		Red							
6						Yellow		Red						
7							Yellow		Red					
8								Yellow		Red				
9									Yellow		Red			
10										Yellow		Red		
11											Yellow		Red	
12												Yellow		Red

Key:
■ Sale time
■ Time for forecast discussion
 Source: Authors

It is therefore up to the sales department to determine how many orders will be completed in the first 2 months. For this purpose probability rates, based on previous periods and the success rates (in percentage terms) of individual sales representatives in business negotiations, are used. Figure 2 is a schematic representation based on these success rates.

Figure 2: Scheme of the success rate of a sales representative



Source: Authors

Figure 2 shows that the sales process involves 5 phases. The initial contact is usually either personal, or electronic, and is followed up by an offer. In approximately 50% of cases the offer is of interest and triggers the first sales negotiations, whereby the terms and conditions are adjusted, discounts are discussed and other matters resolved. A lower percentage of those involved in first negotiations progress to a second round of negotiations on the basis of which a contract is entered into. From the point of view of

how many of the initial contacts (74 in total) resulted in a signed contract (20 in total), which is approximately 27 %, in reality depends on the specifics of the company.

The process illustrated in Figure 2 may take several weeks. At this stage, it is important to account for the fact that the delivery of the goods will be subject to some delay, dependent on the product specification. At the time the individual forecasts are being drawn up the company should know how many contracts have been, and will be, concluded. These statistics are usually calculated using ERP systems and a company does not have to deal with them. For such systems to be reliable and accurate they must build up an historic time line, over months and years, of contracts concluded.

If such a time line exists, it can help a company calculate with the highest possible probability how many deals of those already in progress it will close. This is done on the basis of how successful the company was in the past in converting initial contacts and achieving the set goal. If such a time line is absent the reliability percentage is lower. In such cases, companies can apply game theory to determine the first initial estimates for forecasts.

Game theory and probability

Game theory utilizes mathematics to describe real situations in decision making processes and then seeks the optimum i.e. the most advantageous, strategy within them. Numerous situations (games) are determined with the individuals playing a game having a limited number of strategies to achieve the payoff matrix. The payoff matrix is easy to calculate and represents the reward that a player gains in relation to a particular strategy subject to the responses of the other players. Nevertheless, other types of games (decision making situations) are not as clearly defined. It is for example possible to play against an unintelligent player (e.g. nature), who does not decide for the optimization of the payoff function, but who decides at random. For this reason Harsanyi (1967) chose, as the first to do so, to substitute incomplete information for complete but imperfect information. This entails assigning probabilities to the strategies of an unintelligent player. Games in which this is done are called Bayesian (Harsanyi, 1967). The imperfection of the information is based on the principle of probability, we know which situation may occur and with what probability, but we are not sure whether it will occur. By assigning probabilities it is then possible to construct a classical game in which it is possible to resolve the issue of the optimum strategy (Jackson, Tomás & Xu, 2012). In cases where the probability distribution is unknown, it is possible to apply a Laplace criterion which is based on a uniform probability distribution. Gross (2003) defines three additional criteria to the above:

- 1) Wald pessimistic criterion – the worst situation will occur;
- 2) Svagen criterion – the possible loss is minimized;
- 3) Hurwitz criterion – the decision maker's relation to the risk is taken into account.

The application of Bayes' criterion is advantageous for an entrepreneur under the condition that they can use at least some data to enable them to play this type of game (Beggs & Alan, 2015).

Bayesian criterion

In addition to the classical game as defined by a set of players, a set of strategies and their payoffs (Kalčevová, 2006), this game is complemented (Mañas, 1971) by:

- 1) a set of probabilities of the players $p = \{1, \dots, n\}$;
- 2) a set of payoff functions $f = \{(x_1; p_1), \dots, (x_i; p_n)\}$.

The principle of the Nash equilibrium (Nash, 1950) is retained in Bayesian games, so that:

$$x = \max_i \sum_{j=1}^n p_j \cdot m_{ij}$$

where:

- x - is the optimum strategy;
- p_j - probability that situation j occurs (the unintelligent player plays strategy j);
- m_{ij} - payoff for strategies i and j.

Application

In the case below it is assumed that a sales representative has a forecast for the following two months and that they have to start to market a brand new product in a new territory. No previous statistics are available for making a reliable estimation. However, it is possible to utilize some statistics at least as an input for calculations. Under the circumstances, three situations may occur in which the product might sell well, less well and badly. These values thereby imply the probability with which the sales representative could complete the deals for which negotiations have already begun. In the case in question, it is assumed that the sales representative wants to set the forecast for orders at 240,000 and to initially address 50 potential customers. The sales representative would then decide how many potential customers to address to be able to comfortably ensure a turnover of 240,000 on the basis of 10,000 per contract. Table 3 shows with what probability the product will sell very well, well and badly. The table also shows the success rate that sales representatives would usually have in such situations (from 20 to 30%).

Table 3: Product success rate

	Bad product	Good product	Very good product
Success rate of entering into contract	20%	30%	40%
Probability of product success	30%	70%	30%

Source: Authors

If we assume that a sales representative intends to address a further 10 to 30 customers, it is possible, using the data above, to prepare a matrix with the payoffs for the individual situations. The payoff amounts on the basis of the data in Table 3 are calculated using the formula:

$$Z = -|p \cdot (S_r + S_d) - V_f|$$

where:

- Z - is the payoff amount;
- p - probability of entering into a contract;
- S_r - customers already addressed;

S_d - customers that are going to be addressed;
 V_f - forecast value (in this case 240,000).

The results are given in Table 4. The purpose of the absolute value and the negative sign is the fact that the sales representative has to set the exact offtake and not struggle for the maximum number of deals for the reason that the more stores they contact the more customers will not be satisfied over time. In opposite situations, materials or human resources would therefore remain unutilized. For simplicity, it is assumed that the costs related to the later satisfaction of a customer are equal to those of the non-utilization of resources. This cost is given by the difference from the forecast.

Table 4: Payoff matrix

Newly addressed	Bad product	Good product	Very good product
10	-120,000	-60,000	0
20	-100,000	-30,000	-40,000
30	-80,000	0	-80,000

Source: Authors

As stated, the situation involves a brand new product for which it is not possible to say whether it will sell well or badly. For this reason, the probability based on the historic experience of the company with launching new products is taken into account (the item "Probability of product success" in Table 3). The resulting payoff values are given in Table 5.

Table 5: Payoff matrix after taking probability into account

Newly addressed	Bad product	Good product	Very good product	Sum
10	-36,000	-42,000	0	-78,000
20	-30,000	-21,000	-12,000	-63,000
30	-24,000	0	-24,000	-48,000

Source: Authors

It is clear from the results in Table 5 that according to the Bayesian criterion the best strategy is to address a further 30 potential customers. This result was already implied from the results in Table 4 in which it was clear that the sales representative might achieve the required status in only two situations i.e. addressing 10 or 30 potential customers. If only 10 customers were addressed, the company would need to be sure that the new product would sell well. However, this variant had a lower probability, which implies that it would be more suitable to address 30 potential customers.

Conclusion

The forecasting of orders is very important from the point of view of servicing customers and the efficient use of production factors. It also enables efficient controlling which leads to the dynamism of the sales plan, which is based on the gradual modification of the individual monthly plans on the basis of the results of the previous months.

In most cases, where a longer time line exists, standard tools provided by various ERP systems can be applied. However, when a new product is launched or a new territory entered, the application of these tools might not be suitable because no relevant data is available. In such cases game theory may be applied to forecasting decisions, or in more accurate terms, the theory may help an entrepreneur to establish how many potential customers they should address to fulfil the forecast in full.

An entrepreneur might simply estimate the number of customers they should address. However, if they address fewer customers and find that the product does not sell as expected they may choose not to address further numbers of customers, which in turn may lead to the non-fulfilment of the forecast.

In contrast, if an entrepreneur addresses excessive numbers of customers, some customers may not be served on time, which in turn may have a negative impact on future deals with the customer. In addition, damage to the reputation and good name of the company is also likely to occur because individual customers may mention such information in non-formal discussions elsewhere. It is for this reason that it is important to deal with forecasts already in the first few months of launching a new product. Game theory provides an efficient tool for obtaining the inputs for decision making.

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