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Technology Investment Decisions to Increase Company Value

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One of the main factors, influencing economic growth in today's global business environment is the penetration and implementation of new technologies in business. Scientific research and development of new technologies alone does not ensure total technological progress, because technological innovations without implementing and utilizing them, will not grant welfare, measured by financial – economic factors. At micro – company level, the importance of technology investment is defined as adopting of new technological equipment or innovative processes. This helps to reach higher activity results, market share and increase company market value at the same time. Aiming to develop effective new technology implementation process in a company, strategic importance is on defining investment environment and company hopes related with new technologies, which reflects the choice of the company for "technology leader" or "technology follower" position. This position is important aiming to invest in risky, but perspective-looking technological innovation or slowing investment process at the current moment by collecting information about market leaders' actions proving or disapproving the value of new technology on the market. In this situation company managers solve optimal investment timing problem for technological innovation adoption, combining it with company value maximization aims. These aims are formulated\ as generated cash flows, competitive advantage, activity effectiveness increase, market share enlargement finally evaluated as company value increase

Keywords: *technology adoption, company value increase, strategic investment decisions, optimal investment timing.*

Introduction

In agile business environment companies accept the importance of strategic technology investments more and more, aiming to enforce, sustain and expand their market position. For this objective implementation and seizing market opportunities, company's business strategy and technology strategy consolidation is necessary, as selection of optimal strategy effectiveness measures, at the same time. The selection of strategy effectiveness measures is of critical importance because of strategic technology investment decision value estimation, what can create or sometimes even destroy company value. Literature revised suggests different approaches and definitions of this value: J. Favaro & K. Favaro (1999) refer to economic value, Norvaišienė (2004) – investment value, Huisman & Kort (2003) – technology value. Scientific literature analyses this "value" mainly in strategic – managerial or mathematical – analytical context. In majority of these studies such technology investments are valuated as separate projects, which value (profitability, payback, risk & etc.) is calculated. Such viewpoint is directed towards investment effectiveness measurement, but separating technology investment project form total company activity, while importance of company business strategy and technological strategy is stressed as critical by Berry & Taggart (1998), Chester (1994), Francke (2003), Zahra, Sisodia & Matherne (1999), Bone & Saxon (1998), Burgelman & Rosenbloom (1997), Chiesa & Manzini (1998), Buckley (1998), Branscomb & Auerswald (2002). These authors recognized that technology strategy and its implementation process, though influencing the majority of business organizations, must be formulated in accordance with the needs of technology intensive companies.

Taking this viewpoint as formulating base for coming years' research of technology investment effectiveness measures, additional attention should be paid to the research aiming to develop the influence of strategic technology investment decisions on company value maximization. This should be implemented by selecting appropriate valuation measures, parameters defining technology market environment and consolidating business and technology strategies. Very often such kind of research faces a **scientific problem** of defining technology investment parameters, factors or conditions, that could help to define value created by selected strategic decision or effectiveness of such decision. This **problem** could be solved by creating company value maximization models, in accordance with uncertainty parameters changes mathematical definition, integrating those parameters with the state of the art managerial theories and strategic decions formatting processes. Additionally McTaggart, J., Kontes, P., & Mankins, M. (1994) noticed, that potential of the strategy can expressed as company's opportunities to act in economically attractive markets and improve their competitive position. J. Favaro & K. Favaro (1999) accentuated these main potential opportunities for the company:

- **Product / process advantage** (possibilities for differentiation to gain competitive advantage for company products and services, but such competitive advantage is gained only when customer accepts this product or process superior over competitive by quality, self-satisfaction or exploitation measures);
- **Economical activity advantage** (shorter production process terms, lower production costs, higher productivity, product and process innovations, reduction of process complexity);

Aiming to maximize company value strategic technology investment management becomes a selection and evaluation process of strategic alternatives. **The aim of**

this article – to identify the possibilities of mathematical technology adoption models integration with company value maximization of a managerial decisions process.

Research methods used to reach the aim of the article and to solve the scientific problem are – scientific literature review, the analysis of analytical and empirical studies and synthesis of fragmentary knowledge on the subject.

Strategic management aspects for technology investments

Company value creation is an integrated and complex process, but successful consolidation of strategic objectives with companies possibilities, can increase company value several times over relatively short period, by entering high profitability markets and leaving low profitability segments, where the company has losses. In business activities organizational context it is clear that in the absence of competition in target market segment, early penetration is handy to obtain competitive advantage. On the other hand, very often business organization has its internal links with financial or human resources, influencing technological investment process as an irreversible activity, often related with technological and market uncertainties.

Strategic management decisions in technology investments are associated with high risk, which is not always of a negative character. Brealey & Myers (1996) noted that aim of risk management is not a reduction of risk influence, but creation of additional value. Lister (1997) stressed that risk management has to identify only those risks that are important and making influence on decision value definition process in detail or overall context of company management. It only signifies that markets with high risk hide the largest value creation opportunities.

Traditional company investment effectiveness measurement methods are based on discounted cash flows evaluation – current value of investment welfare. Current value or discounted value is one of the most simple and widely used methodologies, suitable to measure financial – economic value in the line of clearly defined and constantly processed businesses. Discounting parameter can be the indicator helping to evaluate risks and fluctuations in after-investment scenarios. Malkiel (1996) emphasized the importance of technology investment to company development, evaluating this process by discounted cash flows principles. Valuating technology investments Doscher & Hodges (1997) highlighted multistage investments necessary to develop skills of employees, necessity for additional education, experiments for matching new technologies to standards. These and many more studies reflected shortcomings of traditional discounted cash flow valuation methods, which are mainly based on cost/benefit investment principles, with clear post-investment scenarios – clearly defined future and constant business strategy. But these assumptions do not match modern managerial theories and business models, developed to conquer new markets, to present new agile business ideas and technologies, requesting by themselves active participation of companies managers in dynamic strategic decision implementation of dynamic process, quick reaction to non-constant market conditions, but seizing company value increasing opportunities. Option – pricing methodology presented by Black & Scholes (1973) develops wider view to dynamic business environment and uncertainty valuation for investment process. Rise of option – pricing theory was influenced by limitations evaluating strategic importance of technology investments and their non-financial value, which is hard to measure by quantitative instruments. It was the cause that option – pricing theory became as a tool for the valuation of traditional value creation sources and non-financial benefits in technological innovations. General strategy formation principles, that can be embodied in today's technology sector, were analyzed by Porter (1985), who developed a concept of competitive strategy and uncertainty interaction in accordance to influence of market indicators. Bassett (1996) presented conclusions about time-scale for company's strategic opportunities in technologies' sector. Current value of investment project as project effectiveness measure principles were presented in the studies of Brealey & Myers (1996), Malkiel (1996). Dixit & Pindyck (1994) analysed irreversible investment under uncertainty conditions mathematical models, related with option – pricing theory. Option pricing theories and their elements are discussed by Hull (1993), Kulatilaka, Balasubramanian & Storck (1996), Trigeorgis (1996). These studies are developed for strategic planning and management, taking options as capital investment management tool. Van der Heijden (1996) introduced scenario planning concept under uncertainty conditions.

These studies noticed only confirmed that technology industry companies face irreversible investment valuation needs under uncertain business environment. Management of such organizations has to measure effectiveness and amount of available information about technological change. Very often strategic technological investment decisions are delayed waiting for additional information on investment justification. But market pushes management from the other side – waiting for additional information is consuming time and possible revenues, that will never be recovered. In this case technology investment risk deals with risk to invest too early and risk to invest too late. Management problem to the company becomes balancing between waiting and increasing company value as much as it will be possible or to lose part of cash flows because of delayed investment under market uncertainty.

Optimal strategic technology investment timing models

New technology adoption (investment in new technologies) timing is one of the most important factors to ensure continuity of business, to keep market share and increase company's as market player's value in technology sector (in theoretical optimal investment timing studies term of 'technology adoption' goes in parallel with 'technology investment').

As far back as 1996 Organization for Economical Cooperation and Development presented results of research that revealed that technological development directly influenced *Total factor productivity* growth. This research also discovered that direct technology investments and technology adoptions makes bigger influence on this indicator in comparison to expenditures for scientific research and development (OECD, 1997). Studies aiming to define theoretical technology adoption timing concepts were introduced by Jensen (1982). Later these studies were renewed by different aspects of changes evaluation in mathematical models, that could help to simulate market processes, evaluate technological or revenue uncertainties.

Existing theoretical optimal technology adoption models can be classified according to different factors analyzed. In the majority of these studies as evaluation criteria 'technological uncertainty' was analyzed in the context of technology value, optimal investment timing or influence to company's competitive actions for further investment justification. In the later studies both technological uncertainty and strategic interaction in product markets (competitive aspect) were analysed for optimal investment timing problems.

Jensen (1982) was the first to analyze technology adoption under uncertain value of technology and possible revenues from technology investment to company. In his following studies (Jensen, 1988a; 1988b) the author stressed the importance of timely information for investment decision selection process in uncertain technological investments (technology value in these studies was related with technology success in the market, possible demand for new products and rising interest of new customers). Balcer & Lippman (1984) argued the importance of technological improvement, motivating constant technological development dynamics and its influence to new technology success in the market under technological uncertainties. Bhattacharya, Chatterjee & Samuelson (1986) analyzed company's situation choosing to adopt the technology, which profitability is not possible to evaluate at investment moment, and considering an alternative of investment delaying until the uncertainty will be lower or obtaining additional information. Study of Weiss (1994), presents company's hopes from technological investment as one of the most important factors for investment evaluation. These hopes are related with possible future technology which suits company's potential and opportunities the most, in comparison to current available technology. Kapur (1995) highlighted the importance of waiting and learning under revenue uncertainty environment, recommending to wait for the companies while competitors will adopt new technology and improve its value to the market. Farzin, Huisman & Kort (1998) emphasized value created by technology adoption investment for the company, compared technology adoption decisions by one-time and continuous investment influenced by technology improvements. This model is based on optimal adoption timing moment calculated with Bellman equation and using NPV method for comparison. The study mentioned was renewed by Doraszelski (2000) comments on NPV valuation line, arguing that value calculated by NPV method must be higher that compared by option pricing methods. Thijssen, Damme & Huisman (2000) analysed company's opportunities for uncertain profitability investment under situation of obtain stochastic information signals from market about possible investment profitability. Alvarez & Stenbacka (2001) in their study presented multi – stage technology adoption process, when company chooses continuous investment in technological innovations in order to sustain technology leader position in the market.

Jensen's study (1982) was built on the assumption that the company is not able to define the value of new technology, Bhattacharya, Chatterjee & Samuelson (1986) suggested three possible alternative solutions for the company under technological uncertainty: to invest in current technology with uncertain value, delay the investment or to wait for information about technology value from the market. Based on these three possibilities authors noticed that obtaining of costly information usually scaled company's decision to delay technology adoption. Jensen (1988a; 1988b) argued that costless information existence on the market stimulates the technology adoption, intellectual company potential growth but constructs more strict investment justification criterion slowing the process of investment decision selection, but increasing value of waiting. Thijssen, Damme & Huisman (2000) analyzed technology adoption timing when costless information arrives to the market according statistical Poison process. Controversially to Jensen (1982), Balcer & Lippman (1984) stated that value of existing new technology is clearly defined, but company is influenced by the uncertainty regarding future technological improvements. This draws the conclusion that the announcement of technology improvement will influence technology investment delay decision. Weiss (1994) defined two types of uncertainties in technology adoption process: arrival date of new technology and its value. The author states that company can obtain 'expensive' information regardless to technology improvement level, but forecasting significant technological improvements company is slowing investment processes in currently available technology. Similar thematic are studies of Dixit & Pindyck (1994), analyzing option pricing methodologies for irreversible technology investments, value of which is growing stochastically. Theoretic technology adoption studies also examined situations when one company delays its investment to technological innovation in order to observe actions of competitors and estimating their results, for investment decision justification. Company bearing this strategy always lets to step ahead a competitor and learns from its mistakes. At the same time this waiting is costly for the company, first off all because of lower financial benefit (lost market opportunities and discounted value of cash flows). This pushes company to overestimate technology investment. Vettas (1998) presented the situation when new technology investment decision selection is influenced not only by competition but also by cognition and value acceptance for potential customers. The author noted that customers facing uncertainty regarding new product quality, they lean to learn form other customers buying decisions for new product acquisition. But Vettas (1998) stresses that mutual company – customer learning process can slow down new technology exploitation.

Application of technology adoption models for investment decision selection

Farzin, Huisman &r Kort (1998) presented optimal technology timing model, which analyzed new technology coming and its value uncertainties. Authors made a simulation on assumptions that technology value rises over time (technology regress possibility was eliminated), and company collects the signals form market regarding technology improvements and innovations. Model is based on prediction that technology must be adopted as soon as its technology-efficiency parameter exceeds defined level. This parameter analysed in the study, looking from managerial perspective can be noted as qualitative technology parameter, valuating company technological potency to use current or measure future technology.

Farzin, Huisman & Kort (1998) formulated mathematical model based on option theory. It is one of the main studies focusing on technology value under uncertainty. Later this model was renewed and complemented with other aspects of mathematical analysis, but its still lacks integration with modern managerial theories and practical application. Based on this, further in the article there will be elaborated managerial decision making algorithm and its applicability possibilities tested, designed in order to measure increase of company value from managerial decision of investment taken. Parameters used to measure value increase (value maximization) over a certain period, are defined for perfect economy conditions, when there is assumption that company sells as much as it produces. Model also uses production function in defining technology efficiency parameter, that describes technological or manufacturing activity of the company, and only output elasticity "a" takes little into account economy behaviour processes – competition, marketing, activity effectiveness. These processes (such as technology change, prices, irreversible investment values and etc.) are explained in more details by other parameters used for mathematical modeling and interpreted for managerial decision algorithm design in Table 1.

Table 1

Parameters of the technology adoption model for investment decision selection

Sign	Description
Θ_0	Current technology-efficiency parameter (efficiency level), which value is defined by stochastic methods (from the company perspective, this parameter can be determined in absolute scale as current technology productivity parameter in the company, also it can be described as qualitative parameter describing influence of currently used technology for company results);
Θ^*	Technology-efficiency parameter of pursued by the company technology (it can be described as qualitative parameter, level of which can be defined as optimal technology – efficiency for the company to pursue, ensuring stability), parameter is calculated using mathematical expressions;
a	Constant output elasticity for the company with current technology, its reflects relation between resources and outcomes of the company;
λ	Parameter of the jump process governing the technology evolution. It also can be described as probability of new technology uprise (numerical value of which can be gained from historical tendencies of technology development analysis or by subjective valuation for future technology developments);
r	Discount rate used for current value determination in investment projects or company value calculations (usually this parameter is defined calculating weighted average cost of capital from balance sheet or investment project capital structure, or measuring opportunity costs for the company);
$\underline{u}$, $\bar{u}$	Lower and upper levels of technology – efficiency parameter jumps over defined period (usually one year), describing the smallest and the largest rise of technology efficiency;
I	Sunk cost investment sum, what is not irrecoverable in the case of wrong investment, this investment sum is describing specific investment related to appropriate technology adoption costs costs;
w	Unified cost to produce item (unified product) in case of new technology adoption (it is estimated by internal procedures in the company);
p	Unified price of the item (product) to sell the innovation on the market (it is estimated by internal procedures in the company);

Technology-efficiency parameter (Θ_0; Θ^*) used in the model is qualitative measurement factor, that according to the authors can be determined by subjective valuation. From the strategic technology importance to company's development, this parameter can be defined as a change of company's current and future technology efficiency, in the managerial terms of the main resource for business activities – in creating product, process or services for its customers. This resource is the main driver to create value in the company, at the same line with intellectual resources. This technology parameter can be mathematically expressed as coefficient which in product with other resources (materials, energy, labour and etc.) defines company's production function ($h(v;\Theta) = \Theta v^a$). Parameter "v" reflects variable company resources to create a product, "a" is constant output elasticity, defining total utilization of the technology for outcomes (this parameter fits into range 0<a<1, if a>1 company's activity effectiveness would be higher than 100 proc. What could draw the conclusion, that current technology in the company is utilized more than it is possible). Factor "λ" describes mathematical possibility for technology – efficiency parameter jump over period. This parameter rarely will reach value of "1", what would mean than on average every year new technology appears on the market. In this case technology uncertainty will be minimized and after company evaluation of technology conformity to its needs, company will make a decision for investment. Parameters "$\underline{u}$" and "$\bar{u}$" describes the largest and the smallest jump value of technology – efficiency parameter (lower and upper margin). These parameters define possible Θ increase when new technology or technology improvement appears on the market. If this jump does not allow company to reach desirable level of technology efficiency, company is tended to wait until the desirable level will be reached for investment advantage situation. Model also uses parameter "I" which describes sunk cost of investment, specific investment related to technology which company adopts and irreversibly meets specific expenditures. It also can be described as possible loss sum, which will not be regained from any other financial resources, compensating possible loss from failed investment. Parameters "w" and "p" define all possible costs (only direct costs related with new technology and company resources used to get the product, process or provide service) to produce a product with new technology and market price for this product.

Framing sequence of strategic investment decision selection, to increase company value, critical attention must be paid to the decision nature, which is technology sector specific. This specific decision selection process should include initial valuation and analysis of possible outcomes in the total context of organization at the same time (Harris and Emmanuel, 2000). While King (1975) noticed that traditional financial management view to capital allocation is pretty narrow in company strategy implementation. Levy and Sarnat (1994), complementing these ideas stated, that financial management perspective in company does not have interrelate with organization strategy, because of the economic efficiency measurement for decisions taken. In today's economy such a view could be accepted if organization priority is built mainly on company value maximization, without competitive advantage, oneness, etc. valuation. Conformity of financial management and company strategy was analyzed in the studies of Mills (1994), Tomkins (1991), Ward (1993). Pike & Neale (1996) presented strategic decision formulation model with feedback from evaluation stage back to information search, collection and project estimation, for additional necessary resources demand estimation, what finally affects investment budget. According to the corresponding studies of financial management decision selection process for company value increase, Farzin, Huisman and Kort (1998) mathematical model can be arranged according to this sequence for managerial decision selection process design (Figure 1):

1. Analytical and/or subjective definition of (Θ_0,Θ^*, a, λ, r, $\bar{u}$, I, w, p) parameters;
2. Calculation of company's technology change value according formulas presented by Farzin, Huisman and Kort (1998):

$$V(\Theta)=\frac{\varphi\Theta^b}{r} \tag{1}$$

$$\Theta^{\frac{1}{1-a}}=\Theta^b;\quad b=\frac{1}{1-a}>1;\quad \varphi=\left(\frac{a}{w}\right)^{\frac{a}{1-a}}p^{\frac{1}{1-a}}(1-a) \tag{2}$$

3. Calculation of company value increase:

$$V^*=V(\Theta)-I \tag{3}$$

4. Analytical estimation of optimal technology adoption timing:

$$E[\Theta(t)]=\Theta_0+\frac{1}{2}(1-e^{-\lambda t})\lambda\bar{u}t \tag{4}$$

5. Evaluation of optimal for the company technology – efficiency parameter Θ^*:

$$\frac{\lambda\varphi}{\bar{u}r(b+1)}\left((\Theta^*+\bar{u})^{b+1}-(\Theta^*)^{b+1}\right)+Ir+\varphi(\Theta_0)^b-\frac{(r+\lambda)}{r}\varphi(\Theta^*)^b=0 \tag{5}$$

6. Recalculation of technology change value and company value increase according estimated value of Θ^*:

$$V(\Theta)=\frac{\varphi(\Theta^*)^b}{r} \tag{6}$$

$$(\Theta^*)^{\frac{1}{1-a}}=(\Theta^*)^b;\quad b=\frac{1}{1-a}>1;\quad \varphi=\left(\frac{a}{w}\right)^{\frac{a}{1-a}}p^{\frac{1}{1-a}}(1-a) \tag{7}$$

7. Recalculation of optimal technology investment timing according estimated value of Θ^*:

$$E[\Theta(t)]=\Theta_0+\frac{1}{2}(1-e^{-\lambda t})\lambda\bar{u}t \tag{8}$$

8. Comparison of V, Θ^*, t parameters according forecasted desired and calculated mathematically – optimal results;
9. Model feedback assessment for modelling optimal combination of parameters maximizing company value;
10. Construction of strategic technology investment decisions according evaluated parameters, in respect to primary parameters accuracy estimation, range of fluctuation of these parameters, formulation of presumptions for decision selection.

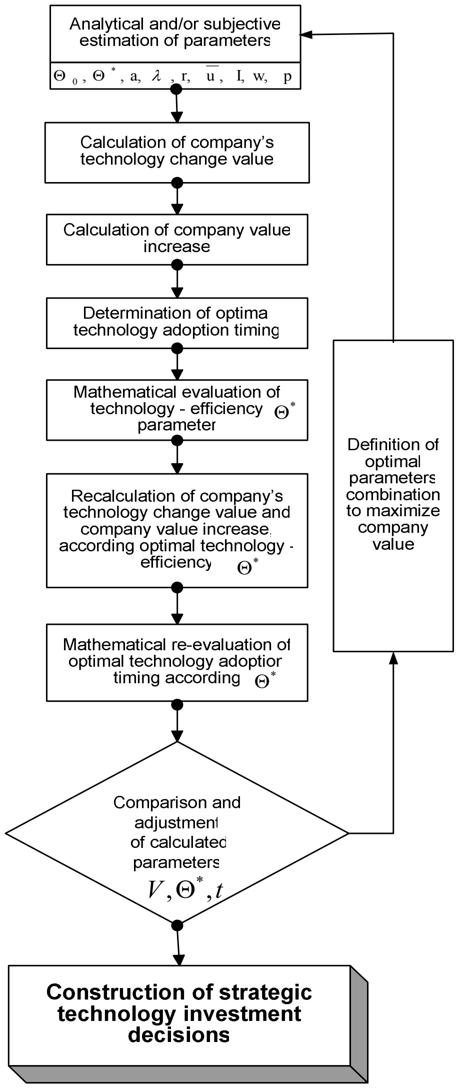

Figure 1. The process algorithm for strategic technology investment decisions selection

Interrelation of mathematical model parameters in the context of strategic technology investment management decisions and possible application of model in practise can be graphically analyzed, by selecting and modelling primary parameters and conditions for calculating. The obtained results can be presented graphically adding strategic managerial decision environment analysis.

Lets assume that company's production function $h(v;\Theta)=\Theta v^a$ constant output elasticity is a = 0.4 (this parameter can be described as company's current technology potential utilization to generate outcomes or financial results; growing ration between resources used and outcomes obtained reflects more effective company activity, arranging current processes to catch market opportunities for company value increase. As a possible outcome of company activity can be named product, price for which is preliminary assessed to be p = 250 (in monetary units), average cost to produce an item in the company w = 100. Suppose current technology – efficiency in the company is estimated to at level Θ_0= 1, also parameter describing "technology jump" λ=1, it means that it is expected to meet on average 1 new technology or technology improvement every year. Technology value uncertainty is formulated with forecasted technology – efficiency possible change $\bar{u}$ = 0,2, what shows mostly presumable increased value of technology efficiency over year. Project discount rate or company capital cost are assumed to be 10 proc. – r = 0,1 (10 proc.), and sunk investment amount in case of investment fail is to be I = 2000. Solving equation 5 with defined parameters, optimal technology – efficiency is calculated Θ^*= 2,8526. Modelling of equation 8 allows to calculate optimal investment timing, what mathematically depicts time moment at which company should invest to change its current technology. For situation analysed analytical value of t is 18,525 years, and estimated company value increase 8606. There is always possible discussion regarding numerical values, but for model applicability graphical analysis of parameters interrelations should be used in the conjunction of managerial decisions selection process, determining value for investment justification.

Primary importance to the company applying this model is to identify current technology – efficiency parameter Θ_0, but it is only internal company technology potential estimation, which has also to influence desired level of Θ^* , regarding what company should execute investment decision selection process. Graphical analysis

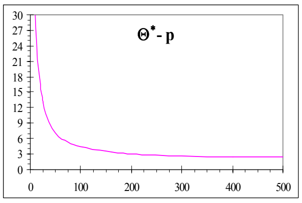

Figure 2. $\Theta^* -$ p relationship.

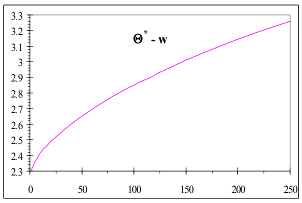

Figure 3. $\Theta^* -$ w relationship.

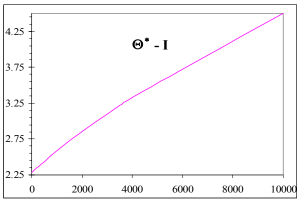

Figure 4. $\Theta^* -$ I relationship.

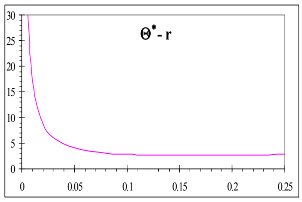

Figure 5. $\Theta^* -$ r relationship.

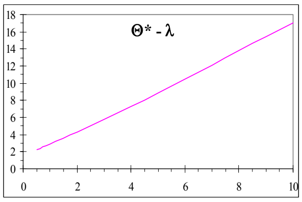

Figure 6. $\Theta^* - \lambda$ relationship.

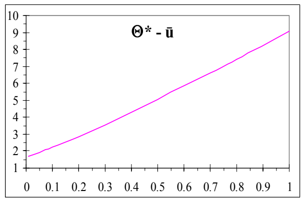

Figure 7. $\Theta^* - \bar{u}$ relationship.

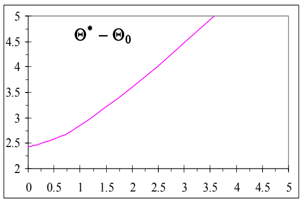

Figure 8. $\Theta^* - \Theta_0$ relationship.

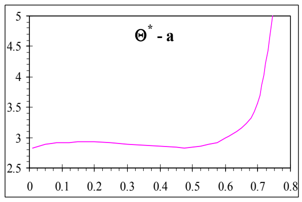

Figure 9. $\Theta^* -$ a relationship.

of model's parameters relationship depicts mathematical modelling tendencies, what has to be integrated with managerial decision forming. Graphs represent that lower level of Θ^* will accelerate company's decision to invest and adopt new technology, if the price of planned to

Table 2

Numerical relationship of technology adoption model parameters

No.	Parameters	Numerical values										
1	p	1	10	25	50	75	100	150	200	300	400	500
	Θ^*	298.1152	30.7851	13.0297	7.1822	5.2808	4.3592	3.4827	3.0774	2.7136	2.5562	2.4729
2	w	1	10	25	50	75	100	150	200	250	300	350
	Θ^*	2.3068	2.4127	2.5213	2.6542	2.7608	2.8526	3.0092	3.1427	3.2609	3.3680	3.4664
3	I	1	100	300	500	1000	1500	2000	2500	3000	3500	4000
	Θ^*	2.2771	2.3091	2.3723	2.4338	2.581	2.7201	2.8526	2.9793	3.1011	3.2186	3.3323
4	r	0.005	0.01	0.02	0.03	0.05	0.08	0.10	0.12	0.15	0.18	0.20
	Θ^*	33.4802	16.8827	8.6759	6.0195	4.0283	3.0878	2.8526	2.7393	2.6831	2.6962	2.7259
5	λ	0.5	1	2	3	4	5	6	7	8	9	10
	Θ^*	2.2207	2.8526	4.2564	5.7642	7.3256	8.9174	10.5279	12.1508	13.7822	15.4198	17.0621
6	ū	0.01	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1
	Θ^*	1.7132	1.9263	2.2149	2.8526	3.5494	4.2862	5.0503	5.8334	6.6302	7.4371	9.0721
7	Θ^0	0	0.1	0.5	1	2	3	4	5	6	8	10
	Θ^*	2.4338	2.4436	2.5731	2.8526	3.6047	4.4730	5.3919	6.3370	7.2972	9.2430	11.2076
8	a	0	0.01	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
	Θ^*		2.8299	2.8881	2.9220	2.9303	2.8961	2.8526	2.8475	2.9886	3.5698	7.0000

develop new product will be relatively high (Table 2, Figure 2), but lower costs of resources incurred to produce it (Table 2, Figure 3). Lower estimated sunk investment costs will also accelerate investment decision (Table 2, Figure 4), but high capital costs or investment discount rate will decrease current value of investment benefit and at the same time influence delaying decision (Table 2, Figure 5). Modern financial management is also taking into account business opportunities costs, corresponding to planned profit or cash flows, estimated from new and progressive new technologies. Planned results of the company will be higher in economic terms, if market price for planned new product will be high and resources or costs used for product production will be low, and low investment costs at the same time. Estimating discount rate, if it is high, investment project payback is longer, lower current value of investment generated cash flows, what is also evaluated with risk factor. These factors reduce strategic technology investment decision value, as restrictedly growing discount rate will reflect in to low level of Θ^* parameter, which in marginal situation can reach 0 range. In traditional investment project effectiveness calculation methods, estimating project NPV, high discount rate reduce current value of cash flows, and investment attractiveness at the same time, but looking at strategic decision selection context, there is possibility for optimal situation when rather high discount rate will reflect "acceptably" technology efficiency Θ^* level, that will force company to invest. Θ^* relationship with other technological development parameters λ, and $\bar{u}$ should be analyzed (Table 2, Figure 6 and Figure 7). Graphs clearly present situation that lower level λ (probability of new technology uprise in the market over planned period) will result in a lower Θ^* , what will speed investment process, or the same result for decision making will be obtained if planned technology efficiency jump $\bar{u}$ will be relatively small. Explanation of these effects is evident, because mostly probable technology improvement will be defined as ($\frac{1}{2}\bar{u}$), and lower probability for technology appearance on the market during period estimated only increase waiting and business opportunities costs, because waiting period for technological innovation increases. It will also result in a lower value of strategic decision and lower level of Θ^* at the same time. Constructing of the model and integrating it with managerial decisions shows that lower probability of new technology appearance on the market and pretty low level of Θ^* can accelerate investment selection process. Looking form the other perspective, if there is high probability of technology improvement on the market or new technology, this fact will influence company to delay investment decision for expecting new and more improved technology instead of investing to obsolescent technology. This analysis draws several conclusions: (1) technological innovations for which technology efficiency jump is forecasted relatively small, likely to be adopted more intensively in comparison to those technologies for which technology development is rapid; (2) innovations for which technology improvement probability and frequency is high will be adopted slow.

Considering company's current technology efficiency level, low Θ_0, will influence lower level of desired Θ^* parameter, and accelerate investment decision selection (Table 2, Figure 8). It is explained from opposing argument, if company currently holds the technology for which estimated level of Θ_0 is relatively high, changing this technology will evaluate higher business opportunity costs and requirements for higher level of desired technology efficiency. This argument can be explained that under ideal economical conditions, companies with relatively high technologies will not be interested to change them.

Corresponding to company production functions elasticity parameter "a" relationship with technology efficiency Θ^* (*a* – can also be named as parameter defining effectiveness of company activities), it can be noted that this parameter is not dependent on technological development, because at marginal case in model when a→1, Θ^* parameter numerical value goes to infinity (Table 2, Figure 9). It means that in this situation company does not faces optimal technology investment selection problem, because having situation when numerical value a=1, company production function is $h(v;\Theta) = \Theta v$, what show that all resources used in a company will be directly used for a product, utilizing full technology potential. In this situation there will not be necessity to change effective technology, because calculated value of technology investment (equation 5) "V" in this situation will be equal to 0, if $p\Theta < w$ or equal to infinity if $p\Theta > w$. in the firs case (V = 0) desired level of $\Theta^* \geq p/w$ will depict situation that company is beside the purpose to make business. In other case, when $V \to \infty$, company's profit will grow to infinity too, and at the same time $\Theta^* \to \infty$, depicting unnecessary technology change. But graph also reflects that in the situation when 0<a<1, Θ^* – a relationship is not monotonic and unidirectional. For relatively high values of "a", level of technology efficiency Θ^* also rapidly increases. For relatively small values of "a" there is a situation when Θ^* increases, what can be explained that small effectiveness of company's resources used will tend to change technology for higher efficiency level technology. It may look uncommon, but companies with low output elasticity are pretty slow for technology innovation investments, usually these companies tend to be technology followers.

Conclusions

1. Technology investment importance is widely appreciable as on of the main factors for company competitiveness in today's global business environment, but studies, research analysed and results presented reflect dominating qualitative technology benefit measurement parameters: competitive advantage, leadership in the market, intellectual and technology potential in a broad sense. Valuating technology importance researchers argue, that it is necessary to integrate company general strategy with company's technology strategy. This results in a conclusion

that technology investment is of strategic importance to company in company budget forming and investment management sense.

2. Models attempting to evaluate optimal new technology adoption investments in the company can be distributed into two groups: dealing with technology and its value uncertainties, and dealing with planned revenue uncertainties. These two groups were integrated and evaluated in other models, that influenced this research field expansion in the last decade of 20th century but mainly in mathematical modelling field, explanation, integration and managerial applicability was the weakest point, necessary for further research, what forms the aim of the article.
3. One of the first studies for optimal technology timing valuation related with investment value determination from this technology investment decision were presented by Farzin, Huisman & Kort (1998) and later complemented or used for other research in this field. Adopting this model for managerial decisions' selection in technology investment, mathematical parameters of the model can be differed to 3 different strategic managerial decisions influencing groups: depicting market conditions and business environment (p, w, I, r), reflecting technology development (λ, $\bar{u}, \underline{u}$) and determining current situation in company with currently used technology (Θ0, a).
4. The model of the mentioned authors was integrated with managerial decision environment for wider model applicability in strategic technology investment decision selection process for company value maximization. Constructed algorithm (Fig. 1) depicts feedback connection possibility for clarifying the decision.
5. Testing of this algorithm and modelling of parameters allowed to draw interrelation of mathematical laws presented by Farzin, Huisman & Kort (1998) and possible market processes what has to be taken into account for investment managerial judgement. Performed analysis identifies that model corresponds to market change processes and is valuable as a tool for strategic technology investment decision selection.
6. The shortcomings of the model are: it is based on economically ideal market conditions; technology adoption case analysed gave the results – optimal investment timing 18,525 years. This in practise (according to global technology change) can be interpreted as time for new technology platform development but not as technology improvement (as stated by mentioned authors); value created and calculated in the model. When the company has a wide portfolio of products could be treated as company value increase over analyzed period but only from one investment project for certain product, for which production technology investment is to be analyzed.
7. Further research in this field should be oriented to the identification of financial evaluation tools supplementing current model parameters, defining current and future state of the company: technology-efficiency parameter (Θ_0, Θ^*), output elasticity (a), discount rate (r) and investment (I) for financial management decision applicability.

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Rytis Krušinskas, Asta Vasiliauskaitė

Investavimo į naujas technologijas sprendimų priėmimas įmonės vertei didinti

Santrauka

Vienas pagrindinių ekonomikos plėtrą sąlygojančių veiksnių yra naujos technologijos. Moksliniai tyrimai ir technologinė eksperimentinė plėtra neužtikrina visuotinio technologijų sąlygotos pažangos, kadangi neįdiegtos technologinės nesuteikia laukiamos, finansiniais ir ekonominiais rodikliais vertinamos, naudos. Technologinių investicijų klausimus įmonių vadovams tenka spręsti kiekvienoje su technologijų sektoriumi susijusioje įmonėje, kur vertinant investicijų poveikį įmonei reikia prognozuoti būsimą technologijų vystymąsi, įmonės technologijų įdiegimo spartą, numatyti įmonės kaip rinkos dalyvės būsimą strategiją konkurencinėje kovoje. Sparčiai besivystančioje verslo aplinkoje šios problemos gali būti įvardijamos kaip optimalus technologinių investicijų valdymas, maksimizuojant įmonės vertę prognozuojamu periodu. Technologijų, kaip įmonės strateginės svarbos verslo vykdymo įrankio, svarbą pabrėžė Berry ir Taggart (1998), Francke (2003), Zahra, Sisodia ir Matherne (1999), Bone ir Saxon (1998), Burgelman ir Rosenbloom (1997), Chiesa ir Manzini (1998), Buckley (1998), Branscomb ir Auerswald (2002), akcentavę kritinę įmonės bendrosios ir technologijų strategijos sąveikos svarbą. Daugelis darbų pabrėžia technologijų svarbą, sukuriamą konkurencinį pranašumą, inovatyvių produktų kūrimo galimybes išnaudojant naujų technologijų potencialą, tačiau šiuose darbuose pasigendama skaitinio technologinių investicijų efektyvumo vertinimo matų, susijusių su įmonės finansine nauda. Dixit ir Pindyck (1994), Hull (1993), Kulatilaka, Balasubramanian ir Storck (1996), Trigeorgis (1996), Van der Heijden (1996) ir kt. darbai patvirtino jog technologijų sektoriuje pramonės įmonės susiduria su neišvengiamų investicijų į technologijų atnaujinimą poreikiu, kurio vertinimas ir planavimas prognozuojant būsimą finansinę naudą moksliniu požiūriu dar yra neišspręsta problema.

Esami technologijų adaptavimo teoriniai modeliai gali būti klasifikuojami atsižvelgiant į skirtingus mokslinėse studijose analizuotus veiksnius, kuriais remiantis šios studijos ir buvo atliekamos. Daugelyje šių modelių kaip vertinimo veiksniai buvo pasirinkti neapibrėžtumai, susiję su naujų technologijų verte ir jų atsiradimo laiko momentu, taip pat analizuota šių technologijų įtaka įmonių konkurencinei strategijai – modeliuose buvo nagrinėjama situacija, kurioje buvo vertinami arba nevertinami konkurentų veiksmai atsižvelgiant į įmonės pasirinkimą vykdyti technologines investicijas. Taip pat buvo rengiami moksliniai darbai kuriuose analizuoti abu veiksniai: technologijų neapibrėžtumas ir konkurencinis aspektas, kaip strateginė sąveika produktų rinkoje. Mokslinės studijos, siekiančios nustatyti teorinius optimalaus technologijų adaptavimo laiko momentus, pradėtos vykdyti dar 1982 metais (Jensen, 1982). Šios studijos vėliau papildytos įvairiais aspektais, kurie padėdavo atlikti galimų rinkos kaitos procesų simuliaciją, imituoti konkurencinę aplinką, vertinti technologinius ar pajamų gavimo neapibrėžtumus. Balcer ir Lippman (1984) vieni pirmųjų iškėlė patobulintos technologijos adaptavimo svarbą, akcentuodami nuolatinio technologijų tobulinimo proceso dinamiškumą ir jų įtaką technologijų sėkmei rinkoje, taip pat analizuodami šiame procese atsirandančius technologinius neapibrėžtumus. Bhattacharya, Chatterjee ir Samuelson (1986) nagrinėjo įmonės situaciją pasirenkant adaptuoti technologiją, kurios pelningumo įvertinti neįmanoma galimo investavimo momentu ir svarstant: ar atidėti šį sprendimą, kol neapibrėžtumas sumažės, ar įsigyti informaciją apie šią technologiją. Weiss (1994) savo darbe, kaip svarbiausią veiksnį, darantį įtaką, įmonės priimamam sprendimui adaptuoti technologiją, įvardija viltis, siejamas su naujai atsirasiančiais, geriausios šiuo metu rinkoje esančios technologijos, patobulinimais, ir analizuoja situaciją, kai įmonė tikisi, jog naujai atsirasianti technologija bus labiausiai jai tinkamiausia ir teikianti didžiausią naudą. Kapur (1995) akcentuoja laukimo ir „mokymosi" svarbą, kai planuojamomis būsimų pajamų neapibrėžtumo sąlygomis įmonėms rekomenduojama palaukti, kol konkuruojančios įmonės įsidiegs esamą technologiją, o jas stebint ir įgyjant patirtį bus galima efektyviai investuoti. Thijssen, Damme ir Huisman (2000) analizavo įmonės galimybes investuoti į neapibrėžto pelningumo technologiją situacijoje, kai tik per tam tikrą laiką – stochastiškai yra gaunami signalai apie šio investicinio proceso būsimą pelningumą. Alvarez ir Stenbacka (2001) savo darbe matematiškai nagrinėjo keleto pakopų technologijų adaptavimo procesą, kada įmonė nuolatos investuoja į savo technologiją, ją atnaujindama ir siekdama išlikti technologijų lyderiu savo rinkos segmente.

Remdamiesi šiomis studijomis, Farzin, Huisman ir Kort (1998) analizavo dėl technologijų adaptavimo poveikio sukuriamą vertę įmonei. Šių autorių parengtas matematinis modelis laikomas vienu pagrindinių tyrimų, atliktų siekiant nustatyti technologijos vertę neapibrėžtumo sąlygomis, tačiau šio modelio taikomumas modelyje apibrėžiamos technologijų vertės – technologijų efektyvumo parametro nustatymo ir jo finansinio vertinimo atžvilgiu yra ribotas. Tai parodo straipsnyje pateikiamas sudarytas įmonės vertės maksimizavimo sprendimų algoritmas ir jo taikymo galimybių įvertinimas. Parametrai, naudojami įmonės vertės prieaugiui nustatyti, įmonės

vertei maksimizuoti per nagrinėjamą laikotarpį – yra apibūdinami idealiomis ekonominėmis sąlygomis, kai daroma prielaida jog parduodama tiek, kiek pagaminama. Naudojama veiklos produktyvumo funkcija, kaip kokybinis technologijos vertę nusakantis parametras, vertina tik technologinę ar gamybinę įmonės atžvilgiu veiklą, tačiau neatsižvelgia į ekonominės elgsenos procesus – konkurenciją, marketingo, veiklos organizavimo rinkoje procesus.

Modelyje naudojamas technologijos efektyvumo parametras (Θ_0; Θ^*) yra kokybinio vertinimo matas, kuriam nustatyti modelio autoriai rekomenduoja subjektyvų vertinimą. Atsižvelgiant į technologijų strateginę svarbą įmonės gyvavimo kontekste, šis parametras galėtų būti išreiškiamas kaip įmonės turimos ir siekiamos technologijos efektyvumo kokybinis pokytis, vertinantis įmonės turimos technologijos kaip pagrindinio resurso indėlį kuriant įmonės veiklos rezultatą – produktą, paslaugą, procesą. Dydis „v" atspindi įmonės veikloje naudojamus resursus, o dydis „a" – veiklos, vykdomos su turima technologija, rezultatų elastingumą, apibūdinantį turimos technologijos kokybinio panaudojimo rezultatų kūrimui laipsnį (šis dydis turi tenkinti sąlygą $0<a<1$; esant $a>1$, įmonės veiklos efektyvumas būtų aukštesnis nei 100 proc., ir tai patvirtintų, jog įmonėje turima technologija naudojama daugiau nei įmanoma). Dydis „λ" matematiškai nusako tikimybę, jog per tam tikrą laikotarpį įvyks technologinio efektyvumo pokyčio šuolis. Šis dydis technologijos neapibrėžtumo sąlygomis retai pasieks „1", kadangi, esant tokiai matematinei reikšmei, tai parodytų, jog technologinis neapibrėžtumas neegzistuoja, ir įmonė žino, kad technologijos patobulinimas rinkoje atsiras; įvertinusi, jog rinkoje esanti technologija atitinka jos lūkesčius, įmonė bus linkusi investuoti į šią technologiją. Dydžiai „$\underline{u}$"ir „$\overline{u}$" apibūdina labiausiai tikėtiną technologijos efektyvumo parametro didžiausią ir mažiausią pokytį (apatinę ir viršutinę ribą). Šie parametrai nurodo tikėtiną Θ, prieaugį atsiradus technologiniam patobulinimui. Jeigu šis prieaugis neleidžia pasiekti norimo technologijos efektyvumo parametro dydžio, įmonės vadovai toliau laukia, kol rinkoje atsiras tam tikras kiekis technologijos patobulinimo atvejų, kurie leis suformuoti investavimo momentui palankią aplinką. Modelyje esantis parametras „I" apibūdina investicijų sumą, kuri, investavus į naują technologiją, neatsiperka, t.y. įmonės galimo nuostolio suma, kuri nebus padengta iš kitų įmonės finansinių resursų, kurie galėtų kompensuoti galimus investicijų praradimus. Dydžiai „w" ir „p" atspindi galimus įmonės naujojo produkto, pagaminto įdiegus naują technologiją, sąnaudas ir prognozuojamą produkto kainą rinkoje. Dydis „w" vertina tik tiesiogines sąnaudas, susijusias su naudojama technologija ir įmonės resursais produkto gamybai ar paslaugai teikti.

Modelio parametrų tarpusavio priklausomybės ir atitikties įmonės vadybinių sprendimų aplinkai tyrimas galimam praktiniam modelio taikymui nustatyti, parodė, kad modelio parametrų kitimas gali būti apibrėžiamas ir komentuojamas rinkoje vykstančiais procesais ir įmonės strateginio valdymo aspektais, tačiau juos plėtojant praktinio taikymo srityje bei apibrėžiant finansinio vertinimo matus, kas padėtų nustatyti technologinių investicijų vertę įmonei. Šis Farzin, Huisman ir Kort (1998) modelis yra orientuotas į idealios ekonominės aplinkos sąlygas; modelyje vertinamas technologijos patobulinimas – inovacijos, tačiau gautas sprendinys, vertinantis optimalų investavimui laiką (18,525 metai), labiau tinka naujai technologinei platformai atsirasti; modelyje nustatoma dėl investavimo sukuriama vertė platų produktų spektrą turinčioje įmonėje turėtų būti traktuojama kaip įmonės vertės prieaugis per nagrinėjamą laikotarpį iš vieno vykdomo projekto ar kuriant naują produktą, kuriam reikia įsigyti naują technologiją.

Raktažodžiai: technologijų adaptavimas, įmonės vertės maksimizavimas, strateginiai investavimo sprendimai, optimalus investavimo laikas.

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