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DEMAT: sustainability assessment of new flexibility-oriented business models in the machine tools industry

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New flexibility-oriented business models represent a novelty in business model research. They aim at optimising the management of manufacturing flexibility in turbulent environments through the offering of added-value services by system suppliers. However, they are currently defined at theoretical level and their economic sustainability for customers and suppliers has to be quantitatively demonstrated. In this paper, a methodology to assess the economic performance of flexibility-oriented business models based on probabilistic event-decision trees modelling is presented. The methodology was applied to a real industrial case and simulations were performed to identify win-win conditions that make business models sustainable for customer and supplier. Results allowed to understand the main variables, determining flexibility-oriented business models' success, and to constitute a reference for companies willing to innovate their business model in this direction.

Keywords: new business models; product service systems; manufacturing flexibility; production systems reconfigurability; business model financial assessment

1. Introduction

In the last decade, new service-oriented business models were indicated as a strategic factor to increase the competitiveness of manufacturing companies and, in particular, of machine tools suppliers (Chesbrough 2010; Shafer, Smith, and Linder 2005; Azarenko et al. 2009). However, business model innovation is a complicate process which presents significant cultural, strategic, operational, organisational and financial challenges (Gebauer, Fleisch, and Friedli 2005; Brax 2005). In particular, the capability to forecast and simulate the economic impact of innovative business models under different hypotheses is a fundamental prerequisite for their successful design and implementation (Malleret 2006). While several approaches for qualitative business models' configuration can be found in literature (such as Tukker 2004; Osterwalder, Pigneur, and Tucci 2005; Morris, Schindehutte, and Allen 2005; Teece 2010; Zott and Amit 2010; Tsvetkova and Gustafsson 2012), few researches were conducted on the quantitative economic assessment of alternative business models (Zott and Amit 2002; Copani et al. 2008; Copani and Marvulli 2010). In particular, the discussed approaches are based on discounted cash flow techniques, which are static in nature and, consequently, not appropriate for uncertain industrial environments.

In this paper a probabilistic method for the financial assessment of new flexibility-oriented business models in turbulent environments is proposed. The outline of the paper is as following. In Section 2, the state of the art on new business models and probabilistic methods for financial evaluation is discussed. In Section 3, the new flexibility-oriented business models' assessment methodology is presented. In Section 4, the results of the application of the model to a real industrial case are reported and critically discussed. In Section 5, conclusions of the paper are drawn, and in Section 6, progresses compared to the state of the art and future research perspectives are outlined.

2. State of the art

Two main relevant literature streams are addressed in this paper: the manufacturing business models' stream, with specific focus on business models determining the offering and utilisation of production systems, and the financial assessment methodologies' stream. State of the art of the two streams is summarised in Section 2.1 and Section 2.2.

2.1. New business models in the machine tools sector

Several taxonomies of innovative business models were proposed by scholars in the last decades. Urbani, Molinari-Tosatti, and Pasek (2002) presented a categorisation of new business models based on the dimensions 'ownership of equipment', 'location of production', 'equipment operation responsibility' and 'equipment maintenance responsibility'. Lay et al. (2003) added two additional categorisation dimensions for classifying and designing new business models: the 'mode of payment'

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and the ‘number of end-users’. Tukker (2004) classified the value proposition of service-oriented business models distinguishing between product-oriented product service systems (PSS), use-oriented PSS and result-oriented PSS. In order to define specific business models for the machine tools industry, Copani et al. (2007) proposed a set of business models adopted in other sectors and potentially suitable to machine builders: ‘Build – operate at end-user plant – own’, ‘Full operation concept’, ‘Equipment supplier turns into a part supplier’, ‘Supply park concept’, ‘Own and operate at end-user plant with final purchase option’ and ‘Multi-ownership for big and complex investments’. Biege et al. (2009) made an effort to summarise new business models for the machine tools sector referring to Tukker's scheme: ‘Availability guarantee’, ‘Solving end-user qualification deficits’, ‘Reconfigurable production systems’ and ‘Lean machine business concepts’ under product-oriented PSS; ‘Levelling irregular and temporary end-user capacity requirements’ under use-oriented PSS; and ‘Production service’ under result-oriented PSS.

Recently, Copani and Urgo (2012) proposed two new business model concepts conceived for the optimal management of manufacturing flexibility in turbulent contexts. The first business model, labelled *Reconfiguration-Guarantee Business Model*, foresees that system suppliers tailor the production system flexibility level on the forecasted end-users' demand in the short-medium term, without adding extra-flexibility whose future usage is uncertain. In addition, system suppliers identify possible reconfigurations that might be needed in future demand scenarios and, contractually, state conditions at which these reconfigurations might be available, having the end-users an option to activate the reconfigurations if required by the market. In this business model, system suppliers would sell reconfigurable machines with limited flexibility, renouncing higher initial incomes in favour of future uncertain cash flows that will depend on end-users' market demand. From a financial point of view, this new business model might appear pejorative for system suppliers. However, if end-users will recognise the advantage of this innovative value proposition, system suppliers will experience a market benefit thanks to the acquisition of new customers. In addition, system suppliers will establish long-term relationships with end-users, which will enable a better understanding of market needs and a privileged position to promptly satisfy the demand. The advantage for end-users will consist in a limited initial investment for extra-flexibility, whose future utilisation is uncertain, and in the postponement of eventual future reconfiguration costs. From a business model innovation point of view, this scenario is innovative because system suppliers will take a more end-user-centred approach, accepting a cash-flow risk linked to external customers' market conditions.

The second business model, named *Capacity-Guarantee Business Model*, implies that system suppliers guarantee their end-users with the right production capacity and technology to manufacture what the market will require. Hence, system suppliers own the production system, maintain it, reconfigure it at own expenses (if and when needed) and manage the withdrawal. Customers do not have to take care of machinery ownership, maintenance and adaptation over time. They pay for capacity utilisation, within a minimum and maximum contractual range of capacity that parties agree at the beginning of the relationship. In this second business model, system suppliers will completely undertake the system life cycle management responsibility, including reconfigurations. They will be proactive in monitoring the demand and in deciding the optimal reconfigurations to implement. Compared to the current business model, the transformation required to system suppliers will be significant. In fact, they will have to turn their business from supplying production systems to managing production capacity. Also the financial and logistics implications are considerable, since it will be necessary to count on a wide stock of different machines. Such machines will be moved from a plant to another in order to implement reconfigurations and to build up production capacity for new customers. An important success factor for system suppliers will be the ability to enable a continuous machinery rotation, allowing to allocate machines to alternative manufacturing systems and to maximise their utilisation. As in the previous business model, system suppliers will experience a market benefit. In fact, from the one hand, it can be expected that such an innovative capacity-guarantee service would attract new end-users and, from the other hand, that the service would set a long-lasting relationship with them. In addition to market benefits, system suppliers might obtain also financial benefits, since they might compensate additional risks with higher profit margins incorporated in the price-per-capacity-use. For end-users, the advantage will be the possibility to focus on their core business, without being responsible for production capacity setup and management.

In order to assess the sustainability of these new promising flexibility-oriented business models and to demonstrate their real potential, a quantitative economic analysis is needed.

2.2. Business models’ financial assessment methodologies

The traditional method for the economic assessment of investment decisions in industrial contexts is the discounted cash flows method. It implies the calculation of financial indexes (such as net present value, pay back time and internal rate of return) that are based on discounted cash flows in a predetermined time period. The value of these indexes suggests the financial convenience of an investment or an industrial decision. The limit of this method is that it is static in nature, since cash flows value should be fixed at the beginning of the analysis. It does not allow to explicitly consider the impact of decisions that are usually taken in reality after that uncertain events happen (Damodoran 2007). Thus, in the case of uncertain contexts such as the ones for which flexibility-oriented business models are designed, probabilistic methods provide more reliable outputs.

Scenario analysis techniques, based on the definition of a best, base and worstcase, represent the evolution of discounted cash flows method to manage uncertainty (Hsia et al. 1994; Ahmed, Hardaker, and Carpenter 1996; Postma and Liebl 2005). However, scenario design is subjective and does not usually take into consideration the mutual dependency of variables, which results in extreme scenarios that are often non-realistic. Monte Carlo simulation is another option to introduce probability in input variables (Bottazzi et al. 1992; Sanchez, Ocaña, and Ruíz de Villa 1992; Nguyen and Bagajewicz 2008). However, its applicability is complex, due to the need of deep analysis and historical data to define statistical distributions, together with the difficulty of modelling distributions and variables correlations that change over time (Damodoran 2007). In recent manufacturing literature, Real Option Analysis (ROA) was proposed to assess different options of systems configuration in order to design systems with the optimal level of flexibility (Bengtsson 1999; Amico, Pasek, and Asl 2003; Amico et al. 2006). However, these approaches are derived from the financial theory, whose hypotheses appear limitative to embrace the complexity of the manufacturing context (Bengtsson 2001). Furthermore, their analytical level and their computational effort are generally out of range for industrial companies, especially for small and medium enterprises.

Among financial probabilistic methods, the event-decision tree methodology (Damodoran 2007) is a promising approach for the economic assessment of flexibility-oriented business models. This method is based on a tree model in which nodes are events or decisions that can be taken after events happen, thus when the uncertainty is solved or reduced. The tree embeds all the possible event-decision alternatives that can be forecasted with assigned occurrence probabilities. Discounted cash flows are associated to each branch of the tree, and 'folding back' the tree by choosing the decision routes that lead to optimal results in each phase and weighing the discounted cash flows with the occurrence probability in each branch, it is possible to estimate the overall present value of the business and its volatility. The advantage of the event-decision tree method is that it values the flexibility by stating that the best decisions are taken while information on events is available; it decomposes the assessment periods in smaller periods where a better risk estimation can be proposed (different discount rates might be chosen in different periods, accounting for the specific risks occurring in these periods); finally, it estimates the variability of returns (risk).

3. The event-decision tree model for flexibility-oriented business models' valuation

The event-decision tree method was applied in the DEMAT FP7 European project to assess the sustainability of new flexibility-oriented business models. The tree model was built considering, as event nodes, the different demand scenarios that can be forecasted and, as decision nodes, the initial decision on the business model to be applied, as well as the decisions on production system configuration and reconfiguration over the assessment period. Alternative technical system configurations and reconfigurations were an input coming from the results of a stochastic programming algorithm that was previously developed in order to identify suitable technical solutions optimising the system flexibility level. They consisted in the description of the optimal set of resources to be combined to address the manufacturing problem (e.g. number of machine tools, load and unload stations, carriers and pallets) and the related set of aggregated KPIs (e.g. energy and tool consumption, tool cutter and spindle bearing load, and surface finish quality). Such indicators were necessary for the calculation of cash flows.

In order to assess new business models under a customer–supplier perspective, two correlated event-decision trees were modelled: one for the end-user and other for the system supplier. To model a realistic industrial case, a production systems supplier and a manufacturer of components in the automotive sector were asked to provide a manufacturing scenario that they had experienced in the past. The scenario grounded on the orders of some products families that the manufacturer had acquired at the beginning of the assessment period, and on the forecast that he could have elaborated for the following years. A two-stage demand scenario was modelled. It consisted in an initial period of 4 years with a predictable demand, followed by a second period of 5 years with higher market uncertainty. This two-stage scenario can be considered of general validity in many production capacity investment decisions. The tree model, common to system supplier and end-user, is represented in Figure 1.

In Figure 1 notation, 'RG-BM' indicates *Reconfiguration-Guarantee Business Model*; 'CG-BM' indicates *Capacity-Guarantee Business Model*; 'Dn' is the demand scenario of the 'n' period; 'Rn' is the reconfiguration decision at the 'n' period; 'NORn' is the decision not to implement a system reconfiguration at the 'n' period. The upper and lower branches differ because in *Reconfiguration-Guarantee Business Model*, the end-user has the option to activate a system reconfiguration after the demand is known or forecasted. In *Capacity-Guarantee Business Model*, being system

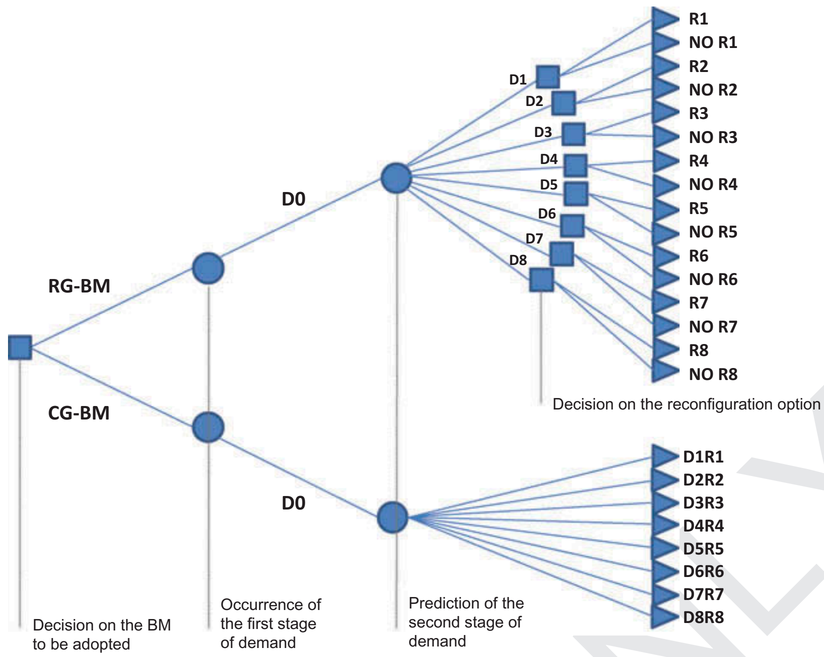

Figure 1. The event/decision tree model.

supplier responsible for all the system reconfigurations over time, it was hypothesised that the reconfigurations suggested by the stochastic programming algorithm would have always been implemented as the optimal decisions.

After having designed the decision tree, the discounted cash flows were calculated under the hypotheses of each branch (in terms of demand volume and manufacturing system configuration/reconfigurations). The discount rate was set taking into account the specific risks of each node. For example, in the lower branch referring to *Capacity-Guarantee Business Model*, higher discount rates were considered in order to account for the higher risk of such a business model compared to the first one.

To solve the tree, expected values (EVs) at end-nodes were calculated as the sum of discounted cash flows over the assessment period under the hypotheses of the different branches (EVn RG-BM or EVn CG-BM – 'n' stays for the scenario defined by the n-branch) (Figure 2).

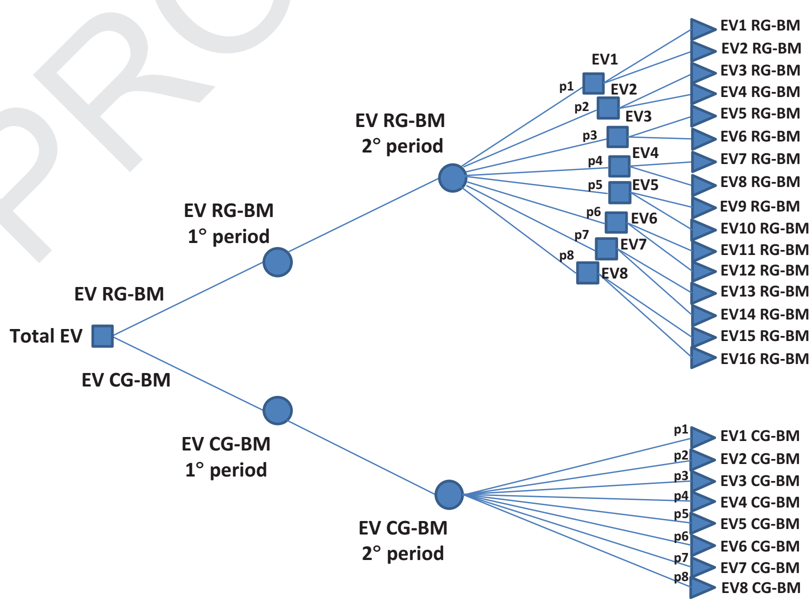

Figure 2. The DEMAT event/decision tree expected values.

Expected values were associated to each decision node by reporting the highest expected value, assuming that the decision-maker chooses each time the best possible option. The expected values at event nodes were calculated as the probability-weighted sum of the right branches expected values (EV RG-BM – m period or EV CG-BM – m period, where 'm' stays for first- or second-stage demand). As a result, the overall expected value for each of the two business models was calculated (EV RG-BM and EV CG-BM). This information, together with the volatility of business model expected value (the variance of expected values at the end nodes), was the fundamental indicators to assess business models' economic performance, considering the uncertainty embedded in the tree model.

4. Industrial application of the assessment methodology

To test the feasibility and the potential of the described methodology, the manufacturer and the system supplier were asked to provide real data to run the model. Since the two companies had not adopted in reality the new business models, the system supplier made hypotheses on the pricing policy he was willing to practice for new business models' implementation (price of machines, reconfigurations, fee for capacity use, maintenance costs, residual value of machines at the end of the assessment period, etc.). As discount rate, the cost of capital was used for discounting cash flows in *Reconfiguration-Guarantee Business Model*. In *Capacity-Guarantee Business Model*, the discounted rate was increased by 2.5% to reflect the higher risk of this business model (the end-user might stop unexpectedly the contract, the system supplier might be unable to follow the changing demand through reconfigurations over time, etc.). The hypotheses made by the system supplier were quite conservative and anchored by his current way of doing business. In *Reconfiguration-Guarantee Business Model*, he imagined to maintain the same profits structure that he was currently adopting. Consequently, he did not imagine to lower the initial price of production system in order to make the new proposal attractive for end-users, nor to increase the price of future reconfiguration services to compensate revenues uncertainty. In *Capacity-Guarantee Business Model*, he designed the pricing policy in order to have a full return on investment at the very beginning of the contractual period, minimising the cash flow risk in the following periods. This resulted in significantly high price to be paid by the end-user for capacity use. Finally, system supplier hypothesised that machines had no residual value after the contractual period, because of their high customisation level, which does not allow to reuse machines in other contexts. This hypothesis reflected the system supplier's implicit idea to start new business models relying on current technology, without planning any type of adaptation to the specific needs of new business models (as suggested by Weissenberger and Biege 2010; Marvulli, Copani, and Biege 2009). The solved end-user and system supplier trees solved are represented in Figure 3.

The solution shows that *Capacity-Guarantee Business Model* would be the most convenient for system supplier. In fact, it would offer a better expected value with a lower volatility if compared to *Reconfiguration-Guarantee Business Model*. For the end-user, on the other hand, the optimal situation is not clearly identifiable. From the expected value point of view, in fact, the best choice would be *Reconfiguration-Guarantee Business Model*,

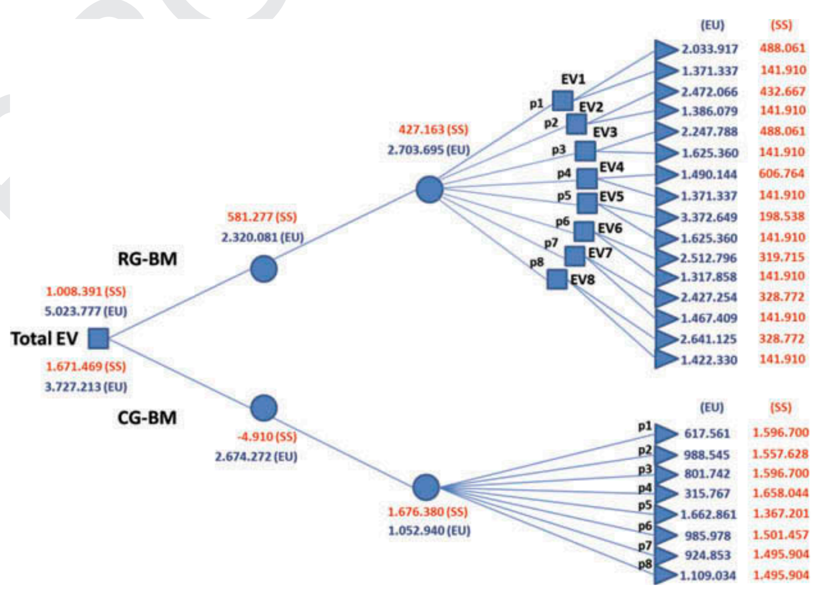

Figure 3. Customer and supplier solved tree with input data provided by the two parties (SS, system supplier; EU, end-user).

but the volatility of *Capacity-Guarantee Business Model* would be lower. This is because in *Reconfiguration-Guarantee Business Model* he might benefit of payment postponement without additional costs required by supplier to compensate revenues postponement. In this situation, the final decision would depend on the risk aversion of the end-user and on the value he assigns to flexibility. Thus, the numerical solution demonstrated that a clear win-win situation could not be identified under the hypotheses made by the two industrial actors. If the financial gap between *Reconfiguration-* and *Capacity-Guarantee Business Models* would be reduced, the latter could become more appealing also for the end-user. Based on these results, a set of simulations were performed in order to identify new business conditions that would enable win-win situations and that would improve the sustainability of the two business models both for end-user and system supplier.

4.1. New pricing strategy for reconfiguration-guarantee business model

The benefit of *Reconfiguration-Guarantee Business Model* for end-users consists in the opportunity to reduce the initial investment cost for extra-flexibility and to implement system reconfigurations only if they will be needed. However, system supplier might experience lower revenues due to the postponement of incomes that, in addition, become uncertain. The way to make this business model attractive for customers and financially sustainable for supplier is to decrease the initial system price and, at the same time, to increase the price of future reconfigurations in order to compensate the system supplier for revenues postponement and uncertainty. To identify a suitable pricing strategy, simulations were performed by reducing the initial system price of a percentage ranging from 5% to 10% and increasing reconfigurations price of 5% up to 25%. A reasonable compromise was reached with a 5% decrease of initial system price and a 25% increase of reconfiguration price (see Figure 4).

In this solution, the expected value of the business model is similar to the one in Figure 3, but its volatility is higher. Thus, it appears pejorative for system supplier compared to his initial hypotheses. However, beyond these indicators, the potential market increase generated by the new value proposition should also be considered as a variable determining the final decision.

4.2. New pricing strategy for capacity-guarantee business model

The pricing strategy hypothesised by the system supplier for *Capacity-Guarantee Business Model* resulted too unbalanced in his favour and, consequently, not attractive for the end-user. In order to identify win-win pricing areas, simulations were performed decreasing the fee for capacity use. This decrease was applied maintaining the same pricing architecture proposed initially by system supplier: the annual fee was calculated dividing in an equal way the initial system price and the maintenance price into the nine assessment periods and, after year four, summing to this quota the reconfiguration price, equally divided in the last 5 years. Accordingly, the first-stage annual renting price considered only the initial plant cost and maintenance, while the second one considered also the reconfiguration-related part. Compared to a flat pricing strategy

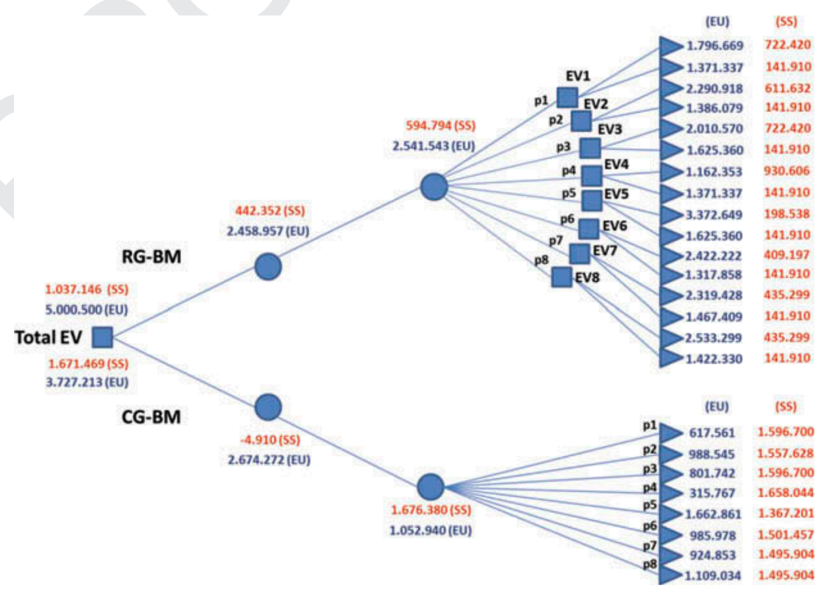

Figure 4. Customer and supplier solved tree with new pricing strategy for RG-BM (SS, system supplier; EU, end-user).

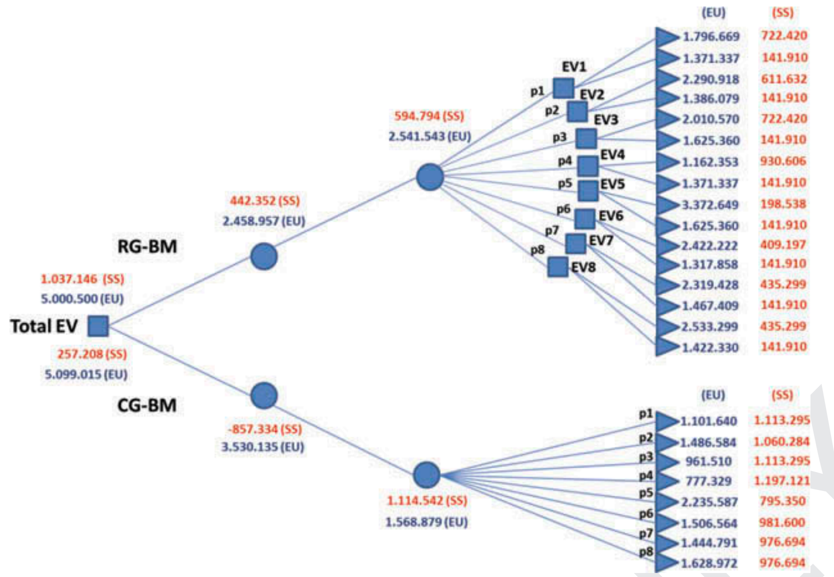

Figure 5. Customer and supplier solved tree with new reduced pricing strategy for CG-BM (SS, system supplier; EU, end-user).

(with equal fee in all periods), this pricing strategy might be attractive for end-users, since it lowers the capacity-use fee during the initial contractual period, when end-users usually experience high costs for product-process development and market introduction. Simulations were performed by reducing the capacity-use fee of a percentage ranging from 20% to 40% with respect to the level initially fixed by system supplier. Results for the simulation of a 20% reduction are shown in Figure 5.

Figure 5 shows that a 20% fee reduction makes *Capacity-Guarantee Business Model* more attractive for end-user than *Reconfiguration-Guarantee Business Model* (see Figure 4). However, such a reduction would make the *Capacity-Guarantee Business Model* not convenient anymore for the system supplier. Thus, simulations indicated that it is not possible to identify convenient solutions for both parties by leveraging only on the pricing variable with this revenues architecture.

With the intent of adopting a more innovative revenue architecture, system supplier might propose to be repaid through a fee that is directly linked to the end-user's business performances (e.g. to the end-users' revenues). With this solution, the riskiness of system supplier would increase, since he would participate directly to the end-users' market and operations risks. By his side, the end-user would make totally variable the production capacity costs. Simulations were performed by hypothesising a capacity-use fee varying from 5% to 10% of the end-user's annual revenues. The 10% pricing seemed to be a reasonable solution, but not an optimal one in terms of mutual convenience (see Figure 6).

For the system supplier, this variable pricing strategy would double the expected value compared to *Reconfiguration-Guarantee Business Model* (see Figure 4), which would compensate the augmented variability. From the end-user point of view, it would significantly decrease the expected value compared to *Reconfiguration-Guarantee Business Model* (see Figure 4). On the other hand, it would drastically reduce the volatility of the expected value, which would be an attractive situation for a risk-adverse end-user. However, this solution seemed to be still in favour of system supplier, since the expected value reduction of the *Capacity-Guarantee Business Model* was too pronounced for the end-user (almost €2 million). Thus, after simulations, it appeared clear that pricing cannot constitute the only tuning variable to determine new business models' sustainability. Other hypotheses on additional variables affecting cash flows should be done.

4.3. Reconfigurable machines

An important element that impacts on the final performance indicators is the residual value of machines at the end of the assessment period. If machines would have a residual value, this would increase the cumulated cash flow value and the financial performance of new business models. In previous simulations, such a value was set to zero, according to the hypothesis of the system supplier of not being able to reuse or resell machines because of their high customisation level and to logistics costs for layout dismantling and transportation. From a technology point of view, a positive residual value at the end of the assessment period (or when machines are removed from the production layout) could be obtained if machines would be more reconfigurable and readaptable to different

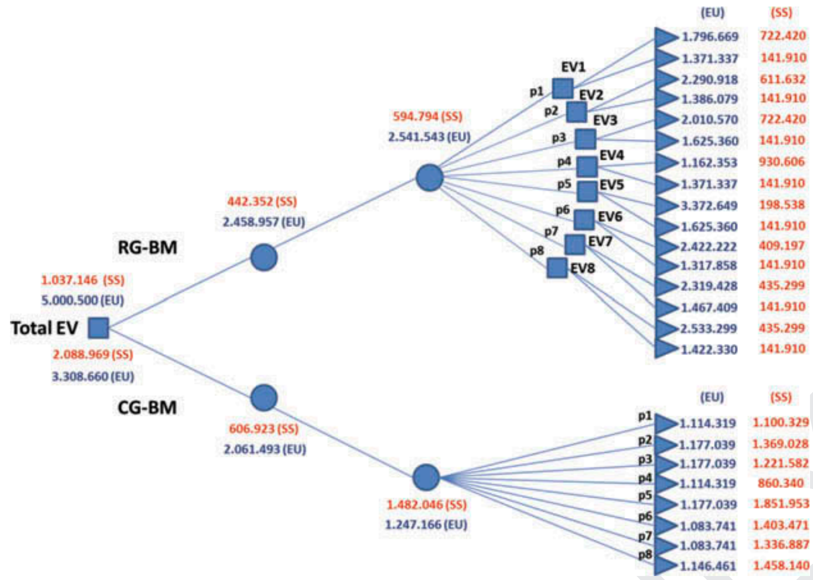

Figure 6. Customer and supplier solved tree with new variable pricing strategy for CG-BM (SS, system supplier; EU, end-user).

manufacturing requirements and layouts. This would result in the capability of system supplier to generate future earnings through dismissed machines, which could be reallocated to other customers after their initial use. The need of products technological adaptation to new business models is in line with past literature (Weissenberger and Biege 2010; Marvulli, Copani, and Biege 2009).

Simulations with different system residual values were performed assuming to link the capacity-use fee to customer's revenues, as described in Section 4.2. Residual values were hypothesised considering the expected value that such a production system is able to generate during a ~~10-year utilisation period~~. Residual value was set to different levels between k€500 and €1.5 million, while the capacity-use fee varied between 6% and 10% of end-user's revenues. A good compromise was reached with an 8% fee on customer's revenues and a residual value of €1.5 million (see Figure 7).

This alternative would make system supplier's profitability higher than in *Reconfiguration-Guarantee Business Model* (see Figure 4). For the end-user, it would limit the reduction of the expected value compared to

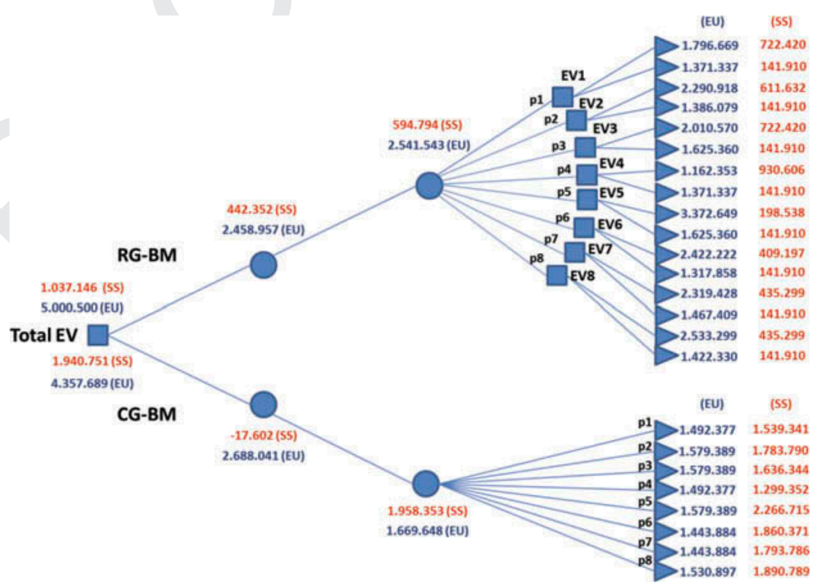

Figure 7. Customer and supplier solved tree with new variable pricing strategy and system residual value for CG-BM (SS, system supplier; EU, end-user).

Reconfiguration-Guarantee Business Model (see Figure 4) and it would offer a low volatility of returns. Thus, it appeared clear that a sustainable design strategy to make sustainable the *Capacity-Guarantee Business Model is* to leverage at the same time on the pricing and on the production system residual value variables.

5. Conclusions

The present paper proposes a methodology based on event-decision trees for the assessment of the financial performances of new flexibility-oriented business models. The methodology was applied to a real industrial case of a production systems supplier and one of his customers in the automotive industry. Results showed that the hypotheses of system supplier for the application of the two new business models would not lead to win-win situations. They reflect the intention of system supplier to innovate the business model by continuing the traditional way of doing business in terms of risk undertaking, pricing strategies and machines technology. New business models, on the contrary, require a new logic of customer–supplier risk sharing and new balanced pricing strategies, allowing to remunerate additional risks undertaken by one party without generating unfavourable conditions for the other. The adopted methodology permitted to quantify these risks and to simulate the impacts of different hypotheses. For *Reconfiguration-Guarantee Business Model*, a suitable solution was identified by decreasing the initial production system price and by increasing the price for reconfigurations. In this scenario, the end-user would experience the advantage of reducing the initial investment cost and postponing reconfiguration costs, if necessary. System supplier can expect similar revenues compared to the traditional business model, but the uncertainty of returns would increase. As a counterpart, system supplier would benefit of a market increase due to the new value proposition. For *Capacity-Guarantee Business Model*, no real win-win situations could be identified simulating different profit levels and pricing strategies of the system supplier. To reach customer–supplier convenience, it was necessary to hypothesise a positive residual value of the production system at the end of the contractual period, which is possible in reality if machines are equipped with reconfigurable technologies allowing to reuse them in different contexts. From a theoretical point of view, this is in line with theory indicating that when designing new business models, products technology should change according to new business models' requirements.

Simulations showed that no unique solution exists for the sustainability of new business models. A suitable negotiation area can be identified with the support of the presented methodology, inside which end-user and system supplier should identify an acceptable solution that will depend on their priorities and contingent situation (for example, the availability of funds for initial system investment or their risk aversion).

6. Advances and future research

Compared to traditional discounted cash flow methods, the methodology proposed in this paper allowed to embed the effect of uncertainty (risk) in the forecasted economic results at business model level, providing a more reliable output. Compared to real options techniques, it offered a more intuitive framework to industrial users in which they can consciously embed the industrial hypotheses and technical requirements at the basis of their industrial scenarios. The computational effort and the theoretical complexity of the model resulted to be affordable for the companies that participated to the testing, indicating that the approach is potentially adoptable in practice, also by small and medium enterprises.

In order to confirm and generalise the results of this paper, future research should test the potential of the event-decision tree approach for business model assessment against real outcomes of business innovation decisions. In this paper, in fact, the testing relied on theoretical hypotheses of industrial companies that imagined to implement new flexibility-oriented business models, without having done it in reality. Consequently, outcomes to evaluate the quality of the output of the model compared to the real effects of choices were not available. Furthermore, the model presented in this paper evaluates the potential of different business models considering reconfiguration solutions as an input coming from a previous step of system technical design based on stochastic programming. From a system design perspective, a promising avenue will be to integrate technical system design and business model design in a unique probabilistic optimisation model based on a common event-decision tree.

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References

Ahmed, P. K., G. Hardaker, and M. Carpenter. 1996. "Integrated Flexibility-Key to Competition in a Turbulent Environment." *Long Range Planning* 29 (4): 562–571. doi:10.1016/0024-6301(96)00048-9.

Amico, M., F. Asl, Z. J. Pasek, and G. Perrone. 2006. "Real Options: An Application to RMS Investment Evaluation." *Journal of Reconfigurable Manufacturing Systems and*

Transformable Factories 675–693. doi:10.1007/3-540-29397-3_34.

Amico, M., Z. J. Pasek, and F. Asl 2003. “A New Methodology to Evaluate the Real Option of an Investment Using Binomial Trees and Monte Carlo Simulation.” *Proceedings of the 2003 Winter Simulation Conference* 1: 351–359, December 7–10, 2003, doi:10.1109/WSC.2003.1261443.

Azarenko, A., R. Roy, E. Shehab, and A. Tiwari. 2009. “Technical Product-Service-Systems: Some Implications for the Machine Tool Industry.” *Journal of Manufacturing Technology Management* 20 (5): 700–722. doi:10.1108/17410380910961064.

Bengtsson, J. 1999. “The Value of Manufacturing Flexibility: Real Options in Practice.” In *Proceedings of the 3rd Annual Real Options Conference*, 1999.

Bengtsson, J. 2001. “Manufacturing Flexibility and Real Options: A Review.” *International Journal of Production Economics*, December 2001 74(1–3), 213–224. 10.1016/S0925-5273(01)00128-1.

Biege, S., G. Copani, G. Lay, S. Marvulli, and M. Schroeter 2009. “Innovative Service-Based Business Concepts for the Machine Tool Building Industry.” In *Proceedings of the 1st CIRP Industrial Product-Service Systems (IPS2) Conference*, 173. Cranfield University, April 1–2,2009.

Bottazzi, A., A. Dubi, A. Gandini, A. Goldfeld, R. Righini, and H. Simonot 1992. “Improving the Preventive Maintenance of a Bus Yard by a Monte Carlo Simulation Method.” In *Proceedings of the European Safety and Reliability Conference*, *Copenhagen*, Denmark, June 9–12, 1992.

Brax, S. 2005. “A Manufacturer Becoming Service Provider – Challenges and a Paradox.” *Managing Service Quality* 15 (2): 142–155. doi:10.1108/09604520510585334.

Chesbrough, H. 2010. “Business Model Innovation: Opportunities and Barriers.” *Long Range Planning* 43 (2–3): 354–363. doi:10.1016/j.lrp.2009.07.010.

Copani, G., and S. Marvulli 2010. “Business Model Life Cycle Evaluation: Two Successful Case Studies in the Machine Tool Sector.” In *Proceedings of the 17th CIRP International Conference on Life Cycle Engineering*, Heifei, May 19–21, 2010.

Copani, G., S. Marvulli, C. Colombo, and L. Molinari Tosatti 2008. “An LCC-LCA Methodology to Design Manufacturing Systems under a Business Model Perspective” In *Proceedings of the 6th CIRP International Conference on Intelligent Computation in Manufacturing Engineering (CIRP ICME ’08)*, Naples, 23–25 July, 2008.

Copani, G., L. Molinari Tosatti, G. Lay, M. Schroeter, and R. Bueno 2007. “New Business Models Diffusion and Trends in European Machine Tool Industry.” In *Proceedings of the 40th CIRP International Manufacturing Systems Seminar*, Liverpool, June 2007.

Copani, G., and M. Urgo 2012. “New Business Models and Configuration Approaches for Focused-Flexibility Manufacturing Systems.” In *Proceedings of the 1st CIRP Global Web Conference: Interdisciplinary Research in Production Engineering*, Procedia CIRP, Elsevier 2012.

Damodoran, A. 2007. *Strategic Risk Taking: A Framework for Risk Management*. 2007. Upper Saddle River, NJ: Pearson Prentice Hall.

Gebauer, H., E. Fleisch, and T. Friedli. 2005. “Overcoming the Service Paradox in Manufacturing Companies.” *European Management Journal* 23 (1): 14–26. doi:10.1016/j.emj.2004.12.006.

Hsia, P., J. Samuel, J. Gao, D. Kung, Y. Toyoshima, and C. Chen. 1994. “Formal Approach to Scenario Analysis.” *IEEE Software* 11 (2): 33–41. doi:10.1109/52.268953.

Lay, G., H. Meier, J. Schramm, and A. Werding. 2003. “Betreiben Statt Verkaufen – Stand Und Perspektiven Neuer Geschäftsmodelle Für Den Maschinen-Und Anlagenbau.” *Industrie-Management* 19 (4): 9–14.

Malleret, V. 2006. “Value Creation through Service Offers.” *European Management Journal* 24 (1): 106–116. doi:10.1016/j.emj.2005.12.012.

Marvulli, S., G. Copani, and S. Biege 2009. “A Knowledge Base of Technical Guidelines for Machines Configuration in Innovative Business Environments.” In *Proceedings of the 16th International conference on Life Cycle Engineering*. El Cairo, May 4–6 2009.

Morris, M., M. Schindehutte, and J. Allen. 2005. “The Entrepreneur’s Business Model: Toward a Unified Perspective.” *Journal of Business Research* 58 (6): 726–735.

Nguyen, D., and M. Bagajewicz 2008. “Optimization of Preventive Maintenance Scheduling in Processing Plants.” *Proceedings of the 18th European Symposium on Computer Aided Process Engineering* 25: 319–324

Osterwalder, A., Y. Pigneur, and C. L. Tucci. 2005. *Clarifying Business Models: Origins, Present, and Future of the Concept*. Communications of Association for Information Systems.

Postma, T. J., and F. Liebl. 2005. “How to Improve Scenario Analysis as a Strategic Management Tool?” *Technological Forecasting and Social Change* 72 (2): 161–173. doi:10.1016/j.techfore.2003.11.005.

Sanchez, A., J. Ocaña, and C. Ruíz de Villa 1992. “An Environment for Monte Carlo Simulation Studies (EMSS)” In *Proceedings of the 10th Symposium on Computational Statistics (COMPSTAT)*. Neuchâtel (CH) August 1992

Shafer, S. M., H. J. Smith, and J. C. Linder. 2005. “The Power of Business Models.” *Business Horizons* 48 (3): 199–207. doi:10.1016/j.bushor.2004.10.014.

Teece, D. J. 2010. “Business Models, Business Strategy and Innovation.” *Long Range Planning* 43 (2–3): 172–194. doi:10.1016/j.lrp.2009.07.003.

Tsvetkova, A., and M. Gustafsson. 2012. “Business Models for Industrial Ecosystems: A Modular Approach.” *Journal of Cleaner Production* 29–30: 246–254. doi:10.1016/j.jclepro.2012.01.017.

Tukker, A. 2004. “Eight Types of Product-Service System: Eight Ways to Sustainability? Experiences from Suspronet.” *Journal of Business Strategy and the Environment* 13 (4): 246–260. doi:10.1002/bse.414.

Urbani, A., L. Molinari-Tosatti, and Z. Pasek 2002. “Manufacturing Practices in Dynamic Markets: Reconfigurability to Enable a Service-Based Manufacturing Capacity Supply” In *Proceedings of the International Mechanical Engineering Congress and Exposition (IMECE 2002: ASME)*, New Orleans , November 17–22 2002

Weissenberger, M., and S. Biege. 2010. “Design for Industrial Product-Services Combinations-A Literature Review.” *Journal of Applied Management and Entrepreneurship* 15 (3): 34–49.

Zott, C., and R. Amit 2002. “Measuring the Performance Implications of Business Model Design: Evidence from Emerging Growth Public Firms” Insead R&D Working Paper.

Zott, C., and R. Amit. 2010. “Business Model Design: An Activity System Perspective.” *Long Range Planning* 43 (2–3): 216–226. doi:10.1016/j.lrp.2009.07.004.