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Make-or-buy strategies for electric vehicle batteries—a simulation-based analysis

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ABSTRACT

The electrification of the powertrain leads to fundamental changes in the automotive value chain. Thereby, original equipment manufacturers (OEMs) have to decide which manufacturing steps to perform in-house and which parts to source from joint ventures or suppliers. This decision on the make-or-buy strategy is influenced by manifold uncertain parameters like technology evolution and market development. Moreover, it has considerable financial implications. We present a novel approach for the financial evaluation of strategic make-or-buy decisions for newly introduced components using the example of electric vehicle batteries. The approach is based on a Monte Carlo simulation with which the net present value of different make-or-buy strategies can be evaluated. In the model, we explicitly take into account (1) the impact of volume uncertainty on the economies of scale, (2) the financial consequences of a technology leap, (3) joint ventures as a form of quasi-integration, and (4) the option to change the position in the value chain over time. The application of the model for sample OEMs shows that make-or-buy strategies for electric vehicle batteries differ fundamentally from a financial point of view, depending not only on the degree of vertical integration but also on the size of the OEM.

1. Introduction

Due to restrictive emission regulations, increasing fuel prices, and changing customer behavior, an increasing electrification of the automotive powertrain can be observed. The implications of this electrification have been a common topic of research in different disciplines over the last years, focusing especially on the question of market development of electric vehicles. A broad spectrum of scientific models exists on this topic (Collantes, 2007; Struben and Sterman, 2008; Walther et al., 2010; van Bree et al., 2010; Friedrich, 2010; Eggers and Eggers, 2011; Zhang et al., 2011; Orbach and Fruchter, 2011; Fenwick and Daim, 2011; Kwon, 2012; Shafiei et al., 2012; Warth et al., 2013; Kieckhäfer et al., 2014). An area of research that has yet been largely neglected is that of future manufacturing strategies for the changing automotive value chain. Original equipment manufacturers (OEMs) have to react to the changing market circumstances and need to include electric vehicles in their portfolios (Kieckhäfer et al., 2012). As a consequence, OEMs also have to adapt their manufacturing strategy since vehicles with an electric powertrain differ fundamentally from conventional vehicles with an internal combustion engine (Berger, 2009). Components which currently account for a high share of value creation, like the combustion engine or the gearbox, are to be replaced with new components like the battery or the electric motor.

The battery is the single most important component that has to be considered in a manufacturing strategy since it determines the costs and driving characteristics of electric vehicles (Taniguchi, 2001). Before OEMs detail their manufacturing strategy for batteries, e.g., by planning the site locations and setup, they have to take a make-or-buy decision and decide which parts of the battery value chain they will focus on and which parts will be left to the suppliers. This decision determines the future OEM's position in the automotive value chain and has

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considerable financial implications. The battery manufacturing process requires high investments and the battery raw materials are of great value. As a result, batteries are the main driver of the currently high costs of electric vehicles, which are seen as a barrier of broad market penetration (Kalhammer et al., 2007). Thus, it is of great importance to evaluate the financial implications of the different make-or-buy strategies ex ante to offer electric vehicles at competitive prices.

In the evaluation of the financial implications, several challenges arise. Firstly, the battery manufacturing costs are driven by economies of scale, which are difficult to estimate due to the volume uncertainty caused by an uncertain market development of electric vehicles. Secondly, disruptive innovations in the battery technology lead to investment risks if a company has set the focus on the wrong technology. Thirdly, different forms of vertical integration can be applied by the OEMs, including partial integration and quasi-integration by means of a joint venture. Fourthly, the position of the OEM in the value chain can change over time, enabling a dynamic adaption according to the development of the electric vehicle volumes and battery technology.

Referring to these challenges, evaluating the financial implications of the battery make-or-buy decision is a highly complex task that comes along with several important questions, e.g., what impact does the uncertain development of the market for electric vehicles as well as of the battery technology have on the make-or-buy strategy? What are the critical financial success factors for the implementation of a make-or-buy strategy in the different phases of market development? What impact does the manufacturing volume of an OEM have on the make-or-buy strategy?

To answer such questions, we develop a simulation model for the analysis of the financial implications of different OEM battery make-or-buy strategies. Based on real-world data, the model is applied to case studies considering OEMs with varying manufacturing volumes. From this, we derive recommendations for different types of OEMs regarding their make-or-buy decision for electric vehicle batteries. In the model, the net present value of a make-or-buy strategy for a specific type of OEM is derived based on a Monte Carlo simulation. The model allows us to evaluate the financial implications of dynamic make-or-buy strategies for electric vehicle batteries in the face of existing uncertainties. To this end, we explicitly incorporate (1) the impact of volume uncertainty on the economies of scales, (2) the financial consequences of a technology leap, (3) joint ventures as a form of quasi-integration, and (4) the option to change the position in the value chain over time into the model. This way, we also generally contribute to the field of make-or-buy decisions.

The paper is structured as follows. In Section 2, we detail the battery value chain, possible strategies of OEMs, and the existing uncertainties which affect the financial implications of a strategy. Based on this, we summarize the requirements of a model for the evaluation of the financial implications of a manufacturer's make-or-buy decision for electric vehicle batteries. We then give a brief literature review in Section 3 and argue that a novel approach is needed. In Section 4, we present the structure of our simulation model. This model is applied to a case study in Section 5 for sample OEMs and recommendations regarding the future OEM's strategic position in the electric vehicle battery value chain are given. Finally, we draw a conclusion and show possible future directions for research in Section 6.

2. Decision situation

The value chain of electric vehicle batteries consists of two main steps: cell manufacturing and battery packaging (Fig. 1). Each of the steps demands specific competences (Lamm et al., 2009; Parrish et al., 2011). Cell manufacturing, which is comparable to the manufacturing of solar modules and flat screens, requires sophisticated technological skills regarding the control of the precise electro-chemical processes. OEMs do not yet possess the necessary competences for this manufacturing step. In contrast, battery packaging is an assembling process of prefabricated parts, which is comparable to current processes in the automotive industry. Besides the required competences, the two manufacturing steps also differ from a financial point of view (Nelson et al., 2009). Cell manufacturing requires considerable investments in highly automated manufacturing facilities and contributes a high share of the value added. In contrast, different degrees of automation and therefore investments are possible in battery packaging. The costs in both manufacturing steps are reduced by economies of scale in the medium to long term. This reduction is caused by various effects like the degression of fixed costs due to higher capacity utilization and learning effects.

Several alternatives for an engagement in the battery value chain exist for OEMs. We have conducted a comprehensive empirical analysis on the currently pursued make-or-buy strategies of major OEMs (Huth et al., 2013a). This analysis shows that some OEMs are engaged in both main manufacturing steps (full integrator, Fig. 2), while others focus on battery packaging (packager) or source complete battery packs from suppliers (purchaser). An engagement of the OEMs can thereby occur in two different ways. On the one hand, OEMs can start the manufacturing on their own, which is common for battery packaging. On the other hand, OEMs can found joint ventures with specialized companies from the electrical or chemical industry to share the risk and necessary competences. The latter type of engagement is particularly common for cell manufacturing. In addition, several OEMs source cells as well as packs from suppliers although they are active in the battery value chain (waiting integrator). The reasons for this partial integration lie, amongst others, in possible cost advantages of suppliers and the access to a broad spectrum of battery technologies. Furthermore, our analysis shows that the OEMs can change their position in the value chain during the market development of electric vehicles. While some OEMs have increased their engagement in the value chain over time, e.g., by entering the battery packaging process, others have decreased their value share by selling their part of a joint venture for cell manufacturing.

One of the reasons for the dynamic nature of the strategies is the uncertain manufacturing circumstances. Several uncertainties exist on the young market of electric vehicles. So far, it is unclear how quickly the market for electric vehicles will develop, as the broad spectrum of experts' forecasts shows (Fig. 3a). Therefore, the impact of the economies of scale, which are necessary for an economic manufacturing of batteries, is hard to predict. For example, the market development affects the degree of capacity utilization and the cost reduction due to