Making Sustainability Profitable: The impact of closed-loop supply chain design and regularity schemes on stakeholders

by

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in partial fulfillment of the
Doctor of Philosophy in Logistics and Supply Chain Management

Abstract

In this thesis, we develop a framework of helping firms to be financial rewarded for doing good to the environment. This issue is tackled from two aspects: First, companies need guidance to discover and unlock potential values of implements of sustainable corporate strategy. Secondly, effective environmental legislation become the prerequisite for it being successful. We focus on the extended producer responsibility on electrical and electronic equipments (EEEs) whose return streams have both a healthy secondary market for remanufactured products and a profit potential in recycling market for the original equipment manufacturers (OEMs). We also present a case study based on BSH Bosch und Siemens Hausgeräte GmbH - a leading producer of home appliances headquartered in Germany - for research validity purposes.

Our discussion starts from a cost-minimizing producer's viewpoint to study the impact of the uncertainties in the demand and return volumes as well as the quality of the returns on closed-loop supply chains (CLSCs), where remanufactured products are assumed to be perfect substitution of their new counterparts. Via a combination of optimization and simulation techniques, we discover that (i) the primary influential factor of uncertainty is demand which is marketing-related and (ii) reverse network configuration is robust, especially when return centers have sufficient capacity relative to return. We next study the impact of uncertainty on a profit-maximizing firm's closed-loop supply chain. The network setting is still the same, but now new and remanufactured products are clearly differentiable for consumers. The focus is to assist OEMs in the development of their remanufacturing strategy, with an outlook of pursuing the opportunities presented by the inherent uncertainties. We present a two-stage stochastic CLSC design model that incorporates the uncertainties in the market size, the return volume as well as the quality of the returns. Our analysis reveals that, while the reverse network configuration is rather robust, the extent of the firm's involvement in remanufacturing is quite sensitive to the cost associated with each product recovery option as well as the relative valuation of the remanufactured products by the customers. In the context of the BSH case, we find that among the sources of uncertainty, the market size has the most profound effect on the overall profitability, and it is desirable to build sufficient expansion flexibility in the forward network configuration. Last, we extend the analytical framework to include a regulator's perspective and provides insights on how regulators can offer incentives for better environmental outcomes in the context of take-back legislation. We focus on the possible improvement of the current regulatory structure by taking multiple environmental impacts into account. Three environmental measures are proposed, including raw material saving, energy con-

sumption and waste volume. These measures together cover the major environmental impacts of the life cycle of EEEs. We utilize Pareto analysis approach to generate a menu of efficient policies, as measured by economic surplus and the abovementioned environmental measures. We find that the recovery rate is the determinant of waste volume and raw material saving in take-back systems; whereas energy consumption is more relevant to the scale of economic surplus. Our analysis also reveals that, the objectives of minimizing waste and maximizing raw material saving play very similar role.

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