Resources, Conservation and Recycling 97 (2015) 44–54

Contents lists available at ScienceDirect

Resources, Conservation and Recycling

journal homepage: www.elsevier.com/locate/resconrec

Leveraging intellectual property rights to encourage green product design and remanufacturing for sustainable waste management

Mark Krystofik[a], Jeffrey Wagner[b], Gabrielle Gaustad[a,*]

[a] Golisano Institute for Sustainability, Rochester Institute of Technology, United States
[b] Department of Economics, Rochester Institute of Technology, United States

ARTICLE INFO

Article history:
Received 3 July 2014
Received in revised form 11 February 2015
Accepted 14 February 2015
Available online 9 March 2015

Keywords:
Green design
Intellectual property rights
Patent
Remanufacturability
Remanufacturing
Sustainable waste management

ABSTRACT

There is increasing industrial and academic interest in remanufacturing as a more sustainable production process than those that utilize virgin or recycled materials, and therefore as a promising contributor to sustainable waste management plans. Yet, prevailing incentives are seemingly inadequate for achieving socially optimal rates of remanufacturing activity. The contribution of our paper is to combine the economics of green design literature with the concepts of "raising rivals' costs" and the economics of intellectual property rights. In so doing, we show that a regulator could raise social welfare by strengthening original manufacturer (OM) intellectual property rights in exchange for a decrease in physical product attributes built into products by OMs that inhibit remanufacturing. This result suggests that the structure of intellectual property rights should be considered a policy lever in sustainable waste management planning.

1. Introduction

There is increasing industrial and academic interest in remanufacturing as a more sustainable production process compared to those that utilize virgin materials or even recycled materials. There is also a growing sense that sustainable waste management practices must encompass the entire cradle-to-grave transformation of resources, with traditional landfilling ranked as the least desirable resource outcome (Morrissey and Browne, 2004; Mazzanti and Zoboli, 2009). The general purpose of this paper is to better understand why current market incentives do not seem strong enough to generate socially optimal rates of remanufacturing activity that could curb inefficient flows of single-use products to landfills and what, therefore, could be done to strengthen incentives. To achieve this goal, we propose combining literatures regarding green product design, "raising rivals' costs," and intellectual property rights. Our specific contribution is to show within such a framework that it is possible to raise social welfare and maintain the original manufacturer's profit by strengthening the original manufacturer's intellectual property rights in exchange for the original manufacturer decreasing physical product attributes built into its products that deter independent firms from remanufacturing the original manufacturer's product. This possibility arises since an original manufacturer may choose a level of remanufacturing deterring physical product attributes in its product that is greater than socially optimal. The firm is constrained by the regulator in selecting the level of intellectual property rights necessary to deter independent firms from entering the market with a remanufactured version of the firm's product. While granting stronger intellectual property rights might reduce social welfare, ceteris paribus, our model shows how the reduction in environmental impact from greater remanufacturing and less waste flowing to landfills can *raise* welfare by more than stronger intellectual property rights might *reduce* welfare.

Our paper proceeds as follows: Section 2 features our literature review and concludes with discussion of how our contribution extends the literature. In Section 3, we set forth the basic model, showing how an OM's decision concerning the degree of green design and the independent (aftermarket) remanufacturers' reaction to the degree of resulting remanufacturability can be modulated by the regulator's award of greater intellectual property right strength. We introduce representative functional forms and parameters in Section 4 so that the model can be solved and its properties illustrated. Comparative statics follow, showing how

* Corresponding author at: Golisano Institute for Sustainability, Rochester Institute of Technology, 190 Lomb Memorial Drive 81-2175, Rochester, NY 14623, United States. Tel.: +1 585 475 6089; fax: +1 585 475 7370.
E-mail address: gabrielle.gaustad@rit.edu (G. Gaustad).

http://dx.doi.org/10.1016/j.resconrec.2015.02.005
0921-3449/

different specifications for strengthening intellectual property rights might affect the firms' costs, firms' profits, and social welfare differentially. Section 5 concludes with discussion of the results and directions for future research.

2. Literature review

Remanufacturing involves recovering value from end-of-life products to manufacture like-new products. Since remanufacturing enables reused value-added components to see one or more additional use cycles, remanufacturing retains the embodied energy of reused components and is often environmentally preferential when compared to energy recovery, material recycling, or reusing components in products with less demanding specifications (i.e., downcycling) (Geyer et al., 2007; Gutowski et al., 2011).[1] Several studies aim to increase the engineering efficiency of dismantling and remanufacturing multiple cycle products (MCPs) as part of a more sustainable waste management strategy (see, e.g., Tian and Chen, 2014; Achillas et al., 2013; Tsiliyannis, 2012; Xanthopoulos and Iakovou, 2009). Extending lifespan via remanufacturing of MCPs reduces the overall flow of waste to landfills; may reduce the flow of electronic wastes in particular (since several remanufacturing initiatives are in the markets for small consumer electronics); and may also reduce greenhouse gas emissions.

These environmental benefits from remanufacturing may be complemented by economic benefits. For instance, Giuntini and Gaudette (2003) find that remanufactured products incur costs that are typically 40–65% less than costs incurred for new products, but only sell for 30–40% less than similar new products, indicating that there are incentives for both producers and consumers to engage in the remanufactured product market. And as Ferrer and Ayres (2000) suggest, developing a more robust remanufacturing sector can have positive economy-wide impacts in terms of raising the demand for labor and for all other goods. Geyer et al. (2007) note that Kodak's single-use camera core was designed with components with a durability level to endure six consumer use cycles. Since Kodak was able to effectively recover spent single-use cameras, remanufacturing proved to be more profitable than new production while providing environmental benefits. Maslennikova and Foley (2000) observe that Xerox continues to utilize a modular design strategy for most of its products that allows the firm to collect and profitably remanufacture products. Xerox was able to transform a potential disposal cost associated with 160,000 Xerox machines recovered from customers in Europe (in 1997) into a net savings of $80 million by reprocessing these machines (Maslennikova and Foley, 2000).[2]

Notwithstanding the engineering strides made in enhancing what is achievable in remanufacturing, and notwithstanding the economic opportunities that remanufacturing presents – and that some firms and consumers have captured – there remains a significant flow of remanufacturable materials heading to landfills each year. For instance, one industry report estimates that approximately 50% of more than 562 million computer printer cartridges consumed annually in the US are thrown away, most ending up in landfills (Kasuba, 2008).[3] As Tsiliyannis (2012) and others describe, there are still various obstacles to overcome in expanding remanufacturing networks more widely, some of which are economic in nature. Indeed, Cossu and Masi (2013) suggest that we will need to revisit the prevailing structure of economic incentives in waste management if we are to achieve significant reductions in waste production. Thus, the primary focus in our paper is upon recognizing and ameliorating the *economic* category of obstacles to remanufacturing as a strategy for reducing waste production. Several drivers of gaps between privately optimal and socially optimal consumer and firm decision-making regarding remanufacturability are considered in the literature. Several researchers focus upon the level of remanufacturability an original manufacturer (OM) selects to design into its products in various market structures. Ferguson (2010) notes that even though remanufacturing may be cost-efficient relative to producing a new product, most firms appear to either ignore or actively deter any remanufacturing and reuse of their product. Since OMs are not guaranteed that consumers will route discarded products to either recycling centers or the municipal waste stream, an unwanted product transferred by a consumer to an independent remanufacturer may re-enter the market as a differentiated product that competes with the OM's product. Hence, any actions an OM takes to improve the remanufacturability of its product may enable independent remanufacturers to free-ride on the OM's investment. Debo et al. (2005) consider an infinite time horizon model where a monopolist must select the product's remanufacturability level for a heterogeneous consumer market where the new product and remanufactured product are considered as differentiated products. They expand their model to consider competition from independent remanufacturers that collect the monopolist's product from period one and offer a remanufactured version in the next period. In this setting, increased competition in the remanufactured product market forces reduced prices for remanufactured product and for used remanufacturable product. This result then motivates the OM to reduce the product's remanufacturability, leading Debo et al. (2005, p. 1203) to suggest that "any legislator encouraging competition for remanufactured products should take into account that the level of remanufacturability of the new product will decrease with competition." Most recently, Bernard (2011) presents a model in which two OMs provide an interchangeable remanufacturable component part used in a durable product with an expected lifetime that exceeds the lifetime of the remanufacturable component. Hence, consumers that purchase the product will require at least one replacement component part before the durable product wears out. The OMs optimize profit within a four-stage game that starts with their production of an original component and the choice of a remanufacturing level and ends with competition in the aftermarket between the OMs and independent remanufacturers. Bernard finds that when the two OMs collude on the level of remanufacturability, the OMs internalize their free-riding ability by choosing the level of remanufacturability that maximizes joint profit. Even though collusion by the OMs does not eliminate independent remanufacturers' ability to free-ride on investments made in the level of remanufacturability embedded into the component part by the OMs, the collusive case has the OMs remanufacturing more components and lower quality independent remanufacturers producing less, resulting in an increase in both producer and consumer surplus. These results provide optimism that government policy instruments can help align strategic firm objectives with social welfare.

Identifying precisely where in the product life cycle government policy instruments should be optimally applied is also an active area of research focus. In particular, several researchers have looked into policy instruments that could be used to encourage upstream producers to design environmentally preferred products (i.e. "green design"), and encourage downstream consumers to recycle discarded products. Fullerton and Wu (1998) were the first to provide a

[1] See Geyer et al. (2007). See also Gutowski et al. (2011), as they provide a review of life cycle assessment studies with emphasis on energy savings. They find that remanufacturing usually outperforms new products in terms of energy savings, except when improvements in current models of durable energy consuming products have significantly reduced energy consumption during use compared with remanufactured versions of less efficient products, such as refrigerators.

[2] Maslennikova and Foley (2000, p. 228).

[3] Source: Kasuba (2008) "It's Not Easy Being Green" http://rechargermag.com/articles/2008/11/02/its-not-easy-being-green.aspx.