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Decision Support

Converting retail food waste into by-product

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ABSTRACT

By-product synergy (BPS) is a form of joint production that uses the waste stream from one (primary) process as useful input into another (secondary) process. The synergy is derived from avoiding waste disposal cost in the primary process and virgin raw material cost in the secondary process. BPS increases profit and can have a positive environmental impact by reducing waste. We investigate how BPS can mitigate food waste in a retail grocer setting, and how it interacts with other mechanisms for reducing waste (i.e., waste disposal fee and tax credit for food donation). In the retail setting, waste is generated because of demand uncertainty – the retailer stocks inventory without knowing demand and excess units become waste. We derive the retailer's optimal order policy under BPS and the order policy for a more practical hybrid implementation of BPS, and compare these BPS implementations to the benchmark case where the retailer only sells fresh produce ("Fresh Only"). We show that the benefit of BPS increases in primary demand uncertainty, but decreases in secondary demand uncertainty. We find that BPS can reduce waste when secondary demand uncertainty and the net tax benefit from donation are low, but can increase waste if increased secondary demand uncertainty drives up safety stock. Our results suggest that under BPS, the threshold net tax benefit required to induce donation increases because BPS competes with donation for excess primary units. We find that the tax credit and disposal fee are substitute mechanisms for inducing food donation.

The process of selling in a retail setting naturally produces waste in the form of excess inventory. In particular, for retail grocers who face uncertain demand, selling perishable fresh food items creates a waste stream of unsold products that is economically, socially, and environmentally undesirable. In this paper, we examine how a retail grocer can productively use this waste stream as an input ingredient for a prepared food product. The practice of converting a waste stream into a useful by-product is often referred to as "by-product synergy" (BPS), a term we will use throughout this paper (U.S. Business Council for Sustainable Development, 2011).

In a BPS operation, the waste stream that is generated by one process (the primary process) can be used as input into another process (the secondary process). There are many examples of BPS in industries ranging from agriculture to manufacturing. For example, manure from livestock can be used as fertilizer, waste water and waste heat can be used to cool or heat facilities, and the steel slag waste stream from steel production can be used to make Portland Cement (National Slag Association, 2011). In BPS, the more output produced by the primary process, the more input is available for the secondary process – this relationship is the crux of the synergy in BPS. The primary process "feeds" the secondary process with its waste stream, and the secondary process "consumes" the waste stream of the primary process. Thus, virgin raw material cost is avoided in the secondary process and waste disposal cost is avoided in the primary process. The avoidance of these costs can increase profit and provide social and environmental benefits. The U.S. Business Council for Sustainable Development has organized regional programs in Chicago IL, Houston TX, Kansas City KS, Columbus Ohio, Mobile AL, and Seattle WA to promote industrial BPS exchanges (U.S. Business Council for Sustainable Development, 2011).

In this paper, we study BPS implementation in a retail setting – in particular, the retail grocer setting. The retail grocer selling process is challenging because demand is uncertain and the product is perishable. Grocery stores typically carry more food than they expect to sell and end up selling. Therefore, a waste stream of excess inventory is generated as a natural part of the retail process. The excess inventory is costly to dispose and wasteful from a natural resource perspective. A recent United Nations Environment Programme (UNEP) report found that "one out of every

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four food calories produced for humans is not being consumed" (Lipinski et al., 2013). One study estimates that the U.S. retail and wholesale sectors generated 3.8 billion pounds of food waste in 2011 (Business for Social Responsibility, 2013).[1] Wasted food negatively affects firm profits and the environment (e.g., in the form of methane emissions from landfill, carbon emissions throughout the supply chain, unnecessary conversion of natural ecosystems into farmland, etc.).

There are many ways to reduce food waste in the retail setting. An obvious way is to stock less. However, stocking less leads to lower service levels and also potentially lower profit. Excess food can also be sent to reclamation centers. This channel is typically used for packaged and canned food because handling (e.g., temperature control) and logistics (timeliness) are more difficult and costly for fresh food (Arumugam, 2012). The retailer can also use pricing to increase sales, however, in the case of fresh food, the value of the item decreases considerably over time, thus the retailer must lower prices – sometimes significantly – to sell more product. Some grocers, particularly high-end ones, may be reluctant to sell low quality fresh produce because not only do they have low margin, but discounting lower quality food conflicts with the strategic positioning of the retailer.

We examine how a grocery store can reduce food waste by implementing by-product synergy – in particular, we focus on the use of excess fresh produce to make prepared food items. For example, Whole Foods culls produce from its fresh produce department to use as input for its prepared food department – cabbage can be used to make cole slaw, avocados to make guacamole, apples to make apple pie, etc. (Whole Food's Market, 2012). Tesco also makes smoothies using excess fruit (Little, 2014). An advantage of BPS over simply lowering the fresh produce price is that the prepared food item can be positioned as a high quality product that can have a high margin. Also, the potential economic and environmental impact of BPS in this setting can be significant. In 2010, the estimated fresh food loss at the retail level was 4.4 billion pounds of fresh fruit worth 4.2 billion dollars, 5.2 billion pounds of fresh vegetables worth 6.9 billion dollars, and 2.7 billion pounds of meat, poultry, and fish worth 8.8 billion dollars (Buzby, Wells, & Hyman, 2014). A study of 612 retail outlets in Austria showed that the food loss rate of fresh fruits and vegetables was 4.19% (by mass) and 4.25% (by value) (Lebersorger & Schneider, 2014).

Food waste has also caught the attention of regulators. In France, a law was passed that prohibits supermarkets from throwing away unsold food. A food waste bill with similar provisions to the French law was proposed in the United Kingdom in September 2015, and there is movement to extend the law to other countries in the European Union (Chrisafis, 2016). The increased scrutiny on food waste may increase the appeal of BPS to supermarkets as it gives them an opportunity to sell fresh food in a high-margin secondary market before resorting to donation.

We investigate how the use of excess fresh produce inventory (i.e., the waste stream of the primary retail selling process) as an ingredient for the prepared food (secondary) process affects the retailer's order policy and profit, and the subsequent environmental and social impact. In particular, we are interested in how BPS in the retail grocer setting affects the amount of food waste. The retailer faces demand uncertainty for both products. We characterize the profit-maximizing BPS order policy of the retailer. We also analyze a hybrid approach to BPS that still increases retailer profit, but can be more straightforward to implement as it preserves the autonomy of different departments that may be making decisions. Moreover, we show that "hybrid-BPS" generates less food waste than "optimal-BPS".

We compare the retailer's performance metrics under optimal- and hybrid-BPS to a benchmark "Fresh Only" setting where the retailer only operates a fresh produce department without the BPS option for excess inventory. Because BPS gives the retailer multiple opportunities to profit from each unit of inventory, the retailer optimally increases her fresh produce order, thereby increasing her profit. We show that the benefit of BPS increases in primary demand uncertainty, but decreases in secondary demand uncertainty.

We also examine how two regulatory mechanisms, waste disposal fee and tax credit for food donation, affect the retailer's operating policy, and show the subsequent impact on food waste. Disposal fees are typically charged on a per unit weight basis (e.g., landfill tip fees). If the retailer donates excess fresh produce inventory, she can receive a tax credit that increases the salvage value of the excess inventory. Food waste is reduced and moreover, social value is created by providing healthy fresh food to food insecure individuals. However, in order to set up an inventory donation program, the retailer incurs fixed (e.g., administrative) and variable (e.g., handling and labor) costs.

We find that waste disposal fee and tax credit are substitute mechanisms for inducing donation. The higher the disposal fee, the lower the tax credit required to induce the retailer to donate. Moreover, in the BPS setting, our findings suggest that the threshold tax credit required for donation is higher than under Fresh Only. Under BPS, some primary excess units are used productively in the secondary process, thereby reducing the quantity available for donation. Therefore, the retailer does not find it worthwhile to donate excess units unless the tax benefit is higher. Thus, BPS has a negative impact on donation. We also explore how primary and secondary demand correlation, secondary product pricing, and fresh produce extended shelf life affect the BPS order policy and performance metrics.

We characterize how BPS decreases or increases expected total waste depending on demand characteristics and regulatory mechanisms used to reduce food waste. There are two sources of waste in the BPS setting: the primary and secondary processes. Nonetheless, we find that if the tax benefit for donation and secondary demand uncertainty are low enough, BPS can decrease expected total waste – even though two products are offered compared to only one under Fresh Only.

Literature review. This paper contributes to an emerging body of work in operations management that studies the joint production of multiple products in one operation (see Lee 2016 for a review). Chen, Tomlin, and Wang (2013) introduce the characterization of joint production operations as producing either horizontally or vertically differentiated products and provide a comprehensive review of joint production literature. In vertically differentiated joint production operations, products vary along the quality dimension. Higher quality parts typically command higher prices, but products of differing quality can be substituted for each other. Earlier work focused on production optimization and inventory allocation among the various quality classifications (cf. Bitran & Dasu 1992; Bitran & Gilbert 1994; Bitran & Leong 1992; Hsu & Bassok 1999). Tomlin and Wang (2008) incorporate pricing into the joint production analysis, and Chen et al. (2013) show how the product line design (of jointly produced products) is influenced by production cost and output variability. Horizontally differentiated joint production operations produce products that are sold into different markets – the products do not compete and cannot substitute for each other (e.g., joint production of palm oil and palm kernel). Research in operations management that study horizontally differentiated joint production include Dong, Kouvelis, and Wu (2014) (operational flexibility in oil refining), Boyabatli (2014) (procurement

[1] Food waste is food that was intended for human consumption, but was not consumed by people.

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