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Abstract

This article examines the potential market demand and economic welfare impacts of a potential food-borne illness outbreak in the US blackberry industry using an ex ante partial equilibrium demand-supply framework. Even though a food contamination event has not occurred for blackberries in the US, estimating the magnitude of economic losses from this incident (if it is to occur) is important information that can help guide food safety decisions of blackberry producers and industry stakeholders. Our numerical analysis suggest that total welfare loss from a food safety event in both the fresh and processed blackberry markets is around $16 million after 24 months. Blackberry producers, rather than consumers, are more adversely affected in terms of economic welfare losses, when a foodborne illness occurs. Given the extent of potential losses in the blackberry industry if an outbreak should occur, producer groups and the industry (as a whole) should consider further collective efforts to develop/implement novel interventions that can reduce the risk of an outbreak in the industry.

Keywords: Blackberry; Consumer surplus; Food safety event; Market demand; Producer surplus

JEL Classification: Q11; Q13

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1 Introduction

A food safety event, specifically outbreaks of foodborne illnesses, damages individual consumer health and negatively affects public perceptions of the food product involved. This consequently leads to a decrease in demand for the food product and financial losses to the industry. Analyzing the adverse economic impact of these food safety events is especially important in the fresh produce industry since a large proportion of foodborne illnesses in the US has been historically attributed to fruits and vegetables (Dewaal and Glassman, 2013; Painter et al. 2013; Sivapalasingam et al., 2004). For example, using data on foodborne illness outbreaks from 1998-2008, a recent study by Painter et al. (2013) revealed that 46% of outbreak-related foodborne illnesses in the US can be attributed to fresh produce.

The widely publicized spinach outbreak in 2006 and tomato outbreak in 2008 further highlights the importance of understanding the demand impacts of future food safety events and the potential magnitude of the financial or economic losses associated with it (Cuite and Hallman, 2009). Arnade, Calvin and Kuchler (2009) estimated that the 2006 foodborne illness outbreak of the deadly bacterium *Escherichia coli* (*E. coli*) O157:H7 linked to bagged spinach resulted in a $202 million reduction in total retail expenditures on this product within the first 68 weeks after warnings were announced. Another study by Palma et al. (2010) estimated that the outbreak caused short-term farm level losses to the US spinach industry of $8 million. A report by the Pew Charitable Trust (2008) on the 2008 *Salmonella* outbreak initially linked to tomatoes (but eventually traced to jalapeño and serrano peppers) suggest that the economic cost of the outbreak to the tomato industry in Florida was more than $100 million and in Georgia about $14 million. Palma et al. (2010) also indicate that the US tomato industry as a whole suffered about $25 million in losses due to the *Salmonella* outbreak.

The berry industry in particular also has not been spared of the adverse effects of food safety events. Richards and Patterson (1999) suggested that the strawberry industry incurred long run losses ranging from $84 to $273 million due to the negative publicity related to a series of *Cyclospora* outbreaks linked to strawberries in 1996-1997, even though one outbreak was eventually traced back to Guatemalan raspberries rather than strawberries. The trace back to the Guatemalan raspberry industry, however, cost Guatemalan producers around $10 million in exports to the US (Calvin, 2003). Worldwide, FAO (2008) indicated that berry fruit, including blackberry, raspberry, strawberry and blueberry, were the second-ranked produce commodity of concern in terms of potential microbiological hazard and impact.

Understanding the potential effects of an outbreak in the blackberry industry is important because this industry has grown to become one of the major non-citrus fruit crops in the US. Along with blueberries and tart cherries, blackberries have produced the largest increases in non-citrus crop value and grower price in recent years (Geisler and Morgan, 2012). In 2011, US blackberry production was valued at $43 million, up from $31 million in 2009 (Geisler and Morgan, 2012). Over half of US blackberry production is in the

Northwest, with Oregon as the predominant source of cultivated production. In 2012, 53.5 million pounds of blackberries were produced on 6,800 acres in Oregon (Table 1). Average blackberry yields in Oregon were 7,730 pounds in 2009, increasing slightly to 7,870 pounds per acre in 2012. Over 90% of blackberry production in Oregon is processed (frozen, freeze dried, pureed, canned, or juiced), although there has been strong increase in fresh blackberry utilization attributed to marketing the health benefits of this crop (Cook, 2011; Sobekova, 2012). Strong demand for blackberries is further evidenced by recent increases in grower prices for fresh and processed US fruit. Average grower price in 2012 for fresh and processed blackberry fruit were $2.11 and $0.76/lb pound, respectively; increasing from $1.35 and $0.56/lb, respectively, in 2009 (Table 1).

Most of the published works on produce outbreaks mentioned above are "ex post" studies that aim to quantify the economic impact of a food safety event *after* it has occurred (Belaya, Hansen, and Pinior, 2012). This ex post approach is feasible only if there is an actual widespread and well-publicized food safety event that affects a particular produce commodity. To the best of our knowledge, there have only been four documented minor food outbreaks linked specifically to blackberries in the US (as documented in the Foodborne Illness Outbreak Database website: http://outbreakdatabase.com). Hence, an ex post approach to quantify the market demand impact of a food safety event in the blackberry industry would not be an appropriate empirical method at this point.

However, there is still interest in an "ex ante" empirical estimate of the adverse demand impact if a widespread foodborne illness outbreak in the blackberry industry were to occur. Blackberry growers and other stakeholders are interested because information about the potential magnitude of losses can help guide their decisions and/or efforts with regards to possible interventions that could help reduce the probability and/or impact of a foodborne illness outbreak linked to blackberries (e.g., promotion of Good Agricultural Practices (GAPs), use of liability/recall insurance, establishing industry-initiated marketing orders). The objective of this article is to determine the potential market demand and economic welfare impact of a food safety event in the blackberry industry using an ex ante analytical approach. Specifically, we are interested in the consumer and producer surplus effects of a potential foodborne illness outbreak in the US blackberry industry.

The remainder of this article proceeds as follows. A conceptual framework is presented in the next section to theoretically describe the economic welfare effects of a food safety event. The numerical procedure, assumptions utilized, and data used are then described in the third section. This is followed by a discussion of the empirical results. Conclusions are presented in the final section.

2 Conceptual Framework

The economic impact of a food safety event for blackberries can be theoretically illustrated through a partial equilibrium demand-supply framework (Figure 1). Essentially, the framework models an "outbreak-induced" demand shift and evaluates the net welfare effects through the resulting changes in producer and consumer surplus. Recent studies that have used a similar framework for analyzing the impact of food safety events are: Woods et al. (2003) for strawberries; Paarlberg, Lee, and Seitzinger (2003) for livestock; and Brunke et al. (2004) for pistachios.

Since we are interested in the potential impact of a food safety event on the domestic blackberry market, our framework considers a single blackberry market (e.g., the US) in a closed economy setting. A closed economy assumption implies that commodity prices are determined within the country (or region of interest) and that the commodity is not typically traded. Other simplifying assumptions retained are: (1) supply and demand curves are assumed to be linear, (2) research-induced supply shifts are assumed parallel, (3) a static model is assumed (i.e., dynamics are put aside), and (4) competitive market clearing is imposed. Some of these assumptions are adjusted (i.e., relaxed/strengthened/changed) in the empirical implementation in order to facilitate the estimation of results.

In Figure 1, S_0 and D_0 represent the initial supply and demand curve for blackberries prior to the outbreak of a foodborne illness. Equilibrium price and quantity are P_0 and Q_0, respectively. Consumer surplus is represented by the triangle IaP_0, while producer surplus is represented by P_0aJ. Hence, the total economic surplus prior to an outbreak is the triangle IaJ.

When an outbreak occurs, demand for blackberries drops and shifts the demand curve from D_0 to D_1, resulting in a new equilibrium price and quantity of P_1 and Q_1. We assume that in the short-run blackberry producers cannot instantaneously reduce supply (and/or there is no instantaneous direct government regulation) that would shift the supply curve to the left (hence, it remains at S_0). In this scenario, the change in producer welfare (surplus) from the outbreak-induced demand shift is P_0abP_1 ($= P_0aJ - P_1bJ$) and the change in consumer welfare (surplus) is $IaP_0 - HbP_1$. Blackberry producers necessarily loose because they are selling less of the produce at a lower price. In general, the net change in consumer welfare can be positive or negative depending on the supply and demand elasticities and the nature of the outbreak-induced demand shift (i.e., consumers gain because of the lower price, but they can also lose because fewer blackberries are available in the market). But in Figure 1, with the assumed linear supply and demand curve plus the parallel shift, consumer welfare is negatively affected by the outbreak and the loss is represented as the area P_1bcd ($= IaP_0 - HbP_1$).

The total welfare loss due to a food safety event in the blackberry industry is the sum of the changes in producer and consumer surplus – $IabH$ (which is also equal to $mKabP_1$ due to the linear curves and parallel shift assumptions). The area $IabH$ can be viewed as the sum of two parts: (i) the lost surplus due to the outbreak at the new equilibrium quantity (i.e., the area $IkbH$), and (ii) the deadweight loss due to the outbreak (i.e., the area kab which represents the total value of the reduction in consumption – Q_1kaQ_0 – less the production cost saved – Q_1baQ_0). Alternatively, the total welfare reduction due to the outbreak can also be interpreted as the consumer surplus loss (area $mkaP_0$) and the producer surplus loss (area P_0abP_1).

Figure 1 represents the initial market demand impact of the food safety event and essentially presents a static snapshot of the total welfare loss at this point in time. However, after this initial shock in the market and as time goes by, consumers may gain confidence in the safety of the product and begin purchasing it again. For example, in the case of the 2006 spinach outbreak, Arnade, Calvin and Kuchler (2009k) point out that the biggest percentage reduction in bagged spinach expenditures (-63%) occurred 3 weeks after the outbreak. But at week 26 the percentage difference was only at -17% and at week 68 it further fell to -10%. Hence, consumers gained confidence in the safety of bagged spinach such that after 68 weeks the amount of purchases after the outbreak was only 10% lower than the expected level had the outbreak not occur. The initial maximum reduction in purchases due to an outbreak, and the consequent welfare loss, can be viewed as the static picture in Figure 1. As weeks go by, the observed dynamics of consumer purchases after an outbreak suggest that the demand curve D_1 will slowly shift to the right week by week (moving towards the original demand curve D_0). In the case of the spinach outbreak, the demand curve did not actually go back to the original level after 68 weeks since there is still a 10% difference. These dynamics suggest that the welfare effects of an outbreak should be calculated for each time period after an outbreak (i.e., month-by-month, in our case) because the demand curve shifts back toward the original levels over time. The sum of the changes in welfare over each time period (for a set period of time, say 24 months) can then represent the total welfare effect of the food safety event.

3 Empirical Approach and Data

3.1 Numerical Calculation Approach

The conceptual framework above can be empirically implemented using a numerical calculation approach. Essentially, we algebraically represent the closed economy economic surplus analysis in Figure 1 to derive equations necessary to numerically calculate the welfare changes from an outbreak-induced demand shift in the blackberry industry. We start with supply (1) and demand (2) equations that are a function of slope and intercept parameters, and treating the outbreak-induced demand shift as an intercept change:

$$Q_S = \alpha + \beta P \tag{1}$$

$$Q_D = \gamma - \delta(P + k) = (\gamma - \delta k) - \delta P \tag{2}$$

where k is the demand shift down (or to the left) due to the outbreak (from D_0 to D_1). In Figure 1, $k = P_0 - d$, and the proportional demand shift relative to the initial equilibrium price is $K = \frac{k}{P_0} = \frac{P_0 - d}{P_0}$.

Setting the equilibrium market condition $Q_S = Q_D = Q$ gives the equilibrium price $P = \frac{\gamma - \alpha - \delta k}{\beta + \delta}$. If $k = 0$ (i.e., the pre-outbreak condition), then $P_0 = \frac{\gamma - \alpha}{\beta + \delta}$. With the outbreak, $k = KP_0$ such that $P_1 = \frac{\gamma - \alpha - \delta K P_0}{\beta + \delta}$. The outbreak-induced change in price would then be $P_1 - P_0 = \frac{\delta K P_0}{\beta + \delta}$. The relative change in price (with respect to P_0) can then be expressed as $-\frac{P_1 - P_0}{P_0} = \frac{\delta K}{\beta + \delta}$. We can then convert the slope parameters in the relative price change equation to elasticities (i.e., multiplying through the numerator and denominator by $\frac{P_0}{Q_0}$) and get the following:

$$-\frac{P_1 - P_0}{P_0} = -\frac{\eta K}{\varepsilon + \eta} = Z, \tag{3}$$

where η is the demand elasticity and ε is the supply elasticity.

In Figure 1, the change in producer surplus is $\Delta PS = P_0 abP_1 = P_0 agP_1 - abg$, where $P_0 agP_1$ is a rectangle and abg is a triangle. Therefore, the change in producer surplus can be expressed as $\Delta PS = (P_0 - P_1) Q_0 - 0.5 (P_0 - P_1)(Q_0 - Q_1)$ or $\Delta PS = (P_0 - P_1) Q_0 \left[1 + 0.5 \left(\frac{Q_1 - Q_0}{Q_0}\right)\right]$. Using the definition $Z = -\frac{P_1 - P_0}{P_0}$ in (3), implies that $\frac{Q_1 - Q_0}{Q_0} = Z\varepsilon$. Hence, the change in producer surplus can then be written down as follows:

$$\Delta PS = P_0 Q_0 Z \left[1 + 0.5 Z\varepsilon\right]. \tag{4}$$

As discussed in the previous section, the change in consumer surplus in Figure 1 is $\Delta PS = P_1 bcd =$ the rectangle $P_1 bfd +$ the triangle $bcf =$ the rectangle $P_1 gcd$ - the triangle bgc. This suggests that the change in consumer surplus can be calculated as: $\Delta CS = (P_1 - d) Q_0 - 0.5 (Q_0 - Q_1)(P_1 - d)$. Re-arranging terms, $\Delta CS = (P_1 - d) Q_0 \left[1 + 0.5 \left(\frac{Q_1 - Q_0}{Q_0}\right)\right]$. We can define $P_1 - d = (P_0 - d) - (P_0 - P_1) = KP_0 - ZP_0$ and $\frac{Q_1 - Q_0}{Q_0} = Z\varepsilon$, such that:

$$\Delta CS = P_0 Q_0 (K - Z) \left[1 + 0.5 Z\varepsilon\right]. \tag{5}$$

The change in total surplus can then be defined as the sum of the change in producer and consumer surplus $\Delta TS = \Delta PS + \Delta CS$ and from (4) and (5) can be re-written as:

$$\Delta TS = P_0 Q_0 K \left[1 + 0.5 Z\varepsilon\right]. \tag{6}$$

Equations (4), (5), and (6) are then the fundamental welfare measures one can use to ex ante assess the potential economic impact of a food safety event in the blackberry industry. However, these equations represent static "snapshots" of the welfare effects at a particular time period t (i.e., t can be weeks, months, or years). From the spinach outbreak experience, it seems that a reasonable time period for analysis of an outbreak may be monthly. This suggests that a subscript t can be attached to the demand shift parameter – K_t (i.e.,such that the magnitude of the downward shift in demand is becoming smaller over time). Welfare calculations can be computed for each month t and the discounted sum of these monthly changes in surplus measures (say, over 24 months) can represent the total welfare effect of the food safety event.

3.2 Empirical Implementation Issues: Assumptions, Parameters, and Data

From equations (4), (5), and (6), there are several parameters and values that need to be defined to empirically calculate the changes in economic surplus due to a food safety event. But before we define the different parameters we use in our surplus model, it is important to point out again that the blackberry industry has two distinct markets – fresh and processed. Hence, we need to assess the impact of a food safety event for these two different markets and the parameters for analyzing these markets may be different. However, due to data limitations, we may need to utilize the same parameter(s) for both markets in some cases.Our calculations are also based on grower price for fresh and processed fruit. Our model therefore does not include any associated costs with packaging, cold storage, and shipping of fresh fruit, or processing and cold (freezer) storage costs; the added cost of cold storage would be impacted by the time of the year a food safety event occurred. For example, if a food safety event were to occur in the middle of winter, cold stored, frozen blackberry fruit might not be saleable or would need to be stored longer (at added cost) until the food safety scare passed.

First, we need estimates of the demand and supply elasticities – η and ε, respectively. Ideally, we would want separate sets of demand and supply elasticities for the fresh and processed blackberry markets. However, we did not find any demand elasticity estimate for processed blackberries. Sobekova (2012) is the only study we found that estimated demand elasticities for US blackberries, but only for the fresh market. Sobekova (2012) estimated a demand elasticity of -1.88 for US fresh blackberries, based on weekly supermarket data from 52 cities. This suggests that consumers of fresh blackberries tend to be sensitive to price changes (i.e., elastic). We use this estimate as our demand elasticity for our fresh blackberry surplus model (Table 2).

For the processed blackberry market, we utilize existing studies that estimated fresh and processed fruit demand elasticities in general(see, for example, Jiang and Marsh (2012); Mekonnen, Huang, and Fonsah (2012); You, Epperson, and Huang (1998)). In general, these studies suggest that fresh fruit demand elasticities tend to be lower in absolute value than processed fruit demand elasticities, ranging from 7% to 58% lower (i.e., with a median around 25%). From this insight, we assume that the demand elasticity for processed blackberries is 25% higher (in absolute value) than the fresh blackberry demand elasticity (i.e., -2.35) (Table 2).

We also did not find any empirical estimates of blackberry supply elasticities (for both fresh and processed markets). The only study we found that estimated demand elasticities for a berry fruit, specifically blueberries in British Columbia, Canada, is Yang (2008) who estimated a short-run supply elasticity of 0.22 using a supply response model, and signifying an inelastic supply in the short-run. Inelastic short run supply elasticities (below 1.0) are consistent with previous studies in perennial crops (Askari and Cummings , 1976), as well as California vegetables (Russo, Green, and Howitt, 2008). A short-run elasticity estimate is also appropriate for our study because of the short two-year (monthly) time frame of our model. Therefore, we use this 0.22 supply response elasticity for our economic surplus analysis (Table 2). Note that we use this single estimate for both fresh and processed blackberries since we believe producers of fresh and processed blackberries will typically respond to price changes the same way.

The second set of parameters we need to define are the initial price (P_0) and quantity (Q_0) of blackberries. In this analysis, we utilize the 2012 quantity and price data from the National Agricultural Statistics Service (NASS) for Oregon, as presented in Table 1. Even though these data only represent production and prices in Oregon, this state is the predominant source of cultivated blackberries in the US and these are the only price and quantity data for fresh and processed blackberries that are publicly available.[1] Hence, for fresh market blackberries we utilize the 2012 fresh market price of $2.11/lb and fresh market production quantity of 2.92 million lb (Table 2). For processed blackberries, we use the 2012 processed price of $0.76/lb and processed production quantity of 50.6 million lbs. (Table 2).

Because the economic surplus analysis is conducted on a monthly basis, we need to calculate a monthly estimate of production available in the market using the annual production totals listed above. For the fresh market, fresh blackberry from Oregon are only typically available in the June to mid-October window each year (i.e., the blackberry season) and can be stored for only two weeks. Hence, we assume that the 2.92 million lbs. of annual fresh blackberry production is available 5 months in a year and in these months the available fresh produce available in the market is 584,000 lb per month (2.92 million divided by 5). In our surplus analysis, we assume that the food safety event occurs right before this five month window, which implies that the fresh produce market was affected in the first five months of our 24 month window and the lingering effects of this scare was felt by the fresh blackberry in the following five month window the next year (i.e., months 14 to 17 in our analysis). For the processed market, we assume that the 50.6 million lb of processed production is available in the market throughout the year such that the monthly processed blackberry is 4.2 million lb per month (50.6 million divided by 12). This implies that throughout the 24 month analysis period the monthly processed blackberry available in the market is 4.2 million lb and packers do not withhold trying to sell processed blackberries in the presence of a food safety event. This means that our outbreak impact estimates are likely the upper bound of the effect. In the processed blackberry scenario, we still assume that the food safety event occurs immediately prior to the fruiting season.

Lastly, we need to define the proportionate demand shift for each period t (K_t) in order to empirically implement our economic surplus model in the previous section. This value can be derived by using the

[1] Note that the numerical approach developed in this study can still be utilized (likely with only slight modifications), even if new data are available that encompass a wider geographical range or for a different geographical region.

following equation:

$$K_t = \overline{K}_t p_t A_t, \quad (7)$$

where $\overline{K}_t$ is the estimate of the percentage demand shift for period t, p_t is an estimate of the probability that the $\overline{K}_t$ will actually occur in period t, and A_t can be interpreted as the proportion of blackberry consumers that reduced demand by $\overline{K}_t$. The value $\overline{K}_t$ is estimated using the percentage change in expenditures that Arnade, Calvin and Kuchler (2009) estimated for the spinach outbreak for each week after the outbreak (over the period of 68 weeks).[2] As mentioned above, there has been no widespread US blackberry food safety event where actual estimates of blackberry demand or expenditure reductions were documented over time. Hence, we use the only available data (as far as we know) that comprehensively studied outbreak-induced demand reductions (over time) for a particular produce commodity. The estimates of the percentage downward shift in demand for selected months after the outbreak are in Table 2.

In this case, we assume that blackberry consumers will react to an outbreak similarly to consumers of spinach. Admittedly, the demand reduction for spinach may not be the same as for blackberries, which is why the parameter p_t is included in equation (7) and we can make different assumptions on p_t to conduct sensitivity analysis for different magnitudes of demand reductions (i.e., we can set p_t lower than one if we think the demand reductions for blackberry will be lower than what was observed for spinach). A_t may be thought of as a value that controls the magnitude of the negative publicity about the outbreak and, consequently, how widespread the blackberry demand reduction is. It could be that the food safety event and news reports about the event are very localized such that only 20% of the consumers heard about the event and reduced demand by $\overline{K}_t$ ($A_t = 0.2$). In contrast, if there were widespread publicity about the outbreak (like the spinach event), such that 100% of blackberry consumers reduced demand by $\overline{K}_t$ then $A_t = 1$. Initially, we will assume that $p_t = A_t = 1$, which means that we assume that the estimated $\overline{K}_t$ is fairly accurate for blackberries and coverage of an outbreak in the blackberry industry is assumed to be widespread. But we also run the model for different values of p_t and A_t to determine how sensitive our results are to assumptions about these values.

A summary of all initial parameters and assumptions used in the economic surplus model for an outbreak induced demand shift for US blackberry markets is presented in Table 2.

4 Results and Discussion

The results of the ex ante numerical models to calculate the potential welfare effects of a food safety event in the fresh and processed blackberry markets are presented in Table 3.[3] The total welfare loss from a food

[2] The demand shift estimate for each month in the model is derived by averaging the weekly shifts from Arnade, Calvin and Kuchler (2009). The authors would like to thank Carlos Arnade (ERS) for providing their estimates.

[3] The spreadsheets that show the full numerical welfare calculations for the fresh and processed markets are available from the authors upon request.

safety event in both the fresh and processed markets is estimated to be around $16 million two years after the event.

4.1 Fresh and Processed Market Results

Based on our numerical model, the total loss in economic surplus due to an outbreak-induced reduction in fresh market blackberry demand is around $3 million (Table 3). This suggests that a food safety event in the fresh blackberry market would likely result in a $3 million loss to the industry. The losses are largest during the first two months after the outbreak occurs (~$700,000 in monthly losses). The losses from the outbreak slowly decreases as time goes by – decreasing to below $300,000 per month in the fourth to fifth months after the event and decreasing even further to below $200,000 per month, a year to two years after the event. This reduction in losses over time is a result of the demand curve moving back towards its pre-outbreak levels (which is consistent with behavior observed in previous outbreaks for other produce commodities).

For the processed blackberry market, the estimated total economic surplus loss from a food safety event is close to $13 million. As in the fresh blackberry market, losses in the processed blackberry market are highest two months after the event occurs. About $2 million per month in economic losses are expected to occur in the first two months. The losses range from about $540,000 to $1.1 million per month in the third to sixth months after the event. After one year, and up until two years after the event, the monthly economic losses due to the outbreak-induced demand shift will fall to less than $500,000 monthly.

When looking at the separate producer and consumer surplus results, it is clear that the bulk of economic losses due to a food safety event are shouldered more by the producers in both the fresh and processed blackberry markets than the consumers (see Table 3). Estimated producer surplus loss in the fresh blackberry market over the two-year period analyzed is about $2.8 million, while the consumer surplus loss is only about $324,000. In the processed blackberry market, the estimated producer surplus loss over the two-year period after an outbreak is about $12 million, while the consumer surplus loss is estimated to only be around $1 million. These results suggest that about 90% of the total losses from an outbreak are from losses in producer surplus. Hence, we can conclude that blackberry producers more strongly feel the adverse demand effects of a food safety event. In addition, the strong producer surplus effects estimated in our model reflects that other actors in the blackberry supply chain (i.e., like processed blackberry packers and processors) may also be more adversely affected. Note, however, that the health costs to consumers directly affected by the food safety event (i.e., medical and health expenses, or loss of life) are not included in the consumer surplus losses here. Inclusion of these types of losses would naturally increase the consumer welfare loss from the food safety event.

4.2 Sensitivity Analysis

The estimated welfare results in Table 3 crucially depend on the model assumptions made and the parameter values used (see Table 2). Hence, it is important to validate the sensitivity of the welfare impacts when key parameter values are changed. In this study, we examine how the welfare estimates change if we change the following: the demand elasticity, the supply elasticity, and the parameters p_t and A_t. Results of the sensitivity analysis are presented in Table 4.

Overall, the results of the sensitivity analysis suggest that the welfare estimates are more sensitive to the parameters p_t and A_t , as compared to the demand or supply elasticities. A 10% to 20% change in elasticities only alters our welfare estimates by less than 1%. In contrast, changes in p_t or A_t results in proportional changes in the welfare estimates that is almost the same as the percentage change in p_t or A_t. For example, when the negative publicity about an event is more localized such that $A_t = 0.2$ (i.e., a 0.8 reduction), the total discounted welfare loss from a food safety event is reduced by approximately 80% . This suggests that how widespread the outbreak (A_t) or how probable the food safety event is (p_t) largely determines the magnitude of welfare losses from a food safety event in the blackberry industry, should it occur. Changes in the demand and supply elasticity values do not have a substantial effect on the resulting welfare estimates. This suggests that even if these parameter values are not very accurate, our welfare results will not be totally unreasonable in terms of their magnitudes.

5 Conclusions and Implications

We analyze the potential market demand and economic welfare impact of a foodborne illness outbreak in the blackberry industry using an ex ante partial equilibrium demand-supply framework. Based on a numerical calculation approach derived from the aforementioned framework, we find that the total welfare loss from a food safety event in both the fresh and processed markets is estimated to be around $16 million (within two years after the outbreak). Approximately $3 million in economic losses would result from an outbreak-induced demand reduction in the fresh market blackberry industry, and about a $13 million in economic losses would be observed in the processed blackberry market. Our analysis further suggest that the negative effects of a food safety event in the blackberry industry would be more strongly felt by producers than consumers, since 90% the total welfare reduction is from decreases in producer surplus.

Results from this study have important implications to producers and stakeholders involved in the fresh and processed blackberry value chains. It is clear that a food contamination event linked to blackberries can result in devastating economic losses to the industry even just considering a short two-year window. In light of these potential short-run losses, producers should seriously consider the use of appropriate food safety practices (i.e., GAPs) in their operations to reduce the probability of a food safety event, and also think about whether the purchase of risk management tools (i.e., liability or recall insurance) is worth it in order to protect their businesses in the event of an outbreak. Given that reduction in the risk of a food contamination event is a "public" good that will benefit all blackberry producers, producer organizations and associations (i.e., the North American Raspberry and Blackberry Association (NARBA)) should consider increasing information dissemination efforts about proper food safety handling practices. Collective producer efforts to encourage safe handling practices would help in preventing (or at least reducing the probability of) an outbreak in the blackberry industry. Industry-mandated food safety testing, perhaps through a State Marketing Order (such as the one for California pistachios), could be a policy intervention that can be further studied to determine whether the potential benefits from the reduction in the probability of a blackberry outbreak (and the consequent economic losses avoided) would be enough to cover the cost of this type of regulation.

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Table 1. Acreage, yield, production, utilization, and grower price of blackberry grown in Oregon, 1980-2012.

Year	Acreage	Yield	Production	–Utilization ('000 lbs.)–		–Grower Price (US$/lb)–	
	(acres)	(lbs./acre)	('000 lbs.)	Fresh	Processed	Fresh	Processed
1980	3,400	8,470	28,800	400	28,400	0.41	0.20
1981	3,000	6,000	18,000	450	17,550	0.30	0.17
1982	3,000	6,830	18,600	900	17,700	0.44	0.23
1983	3,000	7,000	20,250	200	20,050	0.54	0.29
1984	3,100	6,190	19,200	400	18,800	0.50	0.50
1985	3,400	7,060	24,000	200	23,800	0.60	0.58
1986	3,600	6,390	23,000	200	22,800	0.67	0.61
1987	4,900	7,670	37,600	610	36,990	0.61	0.28
1988	4,400	7,720	33,950	1,100	32,850	0.58	0.30
1989	4,200	5,520	23,200	700	22,500	0.58	0.37
1990	4,150	7,730	32,100	900	31,200	0.93	0.37
1991	3,050	5,510	16,800	700	16,100	1.46	0.83
1992	4,700	9,110	42,800	1,100	41,700	0.89	0.44
1993	4,700	6,470	30,400	1,200	29,200	0.86	0.29
1994	5,040	7,480	37,700	1,200	36,500	0.95	0.36
1995	4,900	7,650	37,500	850	36,650	1.10	0.54
1996	5,030	5,710	28,700	750	27,950	1.29	0.87
1997	5,510	7,930	43,700	750	42,950	1.10	0.39
1998	5,600	6,730	37,700	500	37,200	1.21	0.44
1999	5,850	6,270	36,700	1,300	35,400	1.02	0.68
2000	6,110	7,00	42,800	800	42,000	1.12	0.47
2001	6,270	6,600	41,400	1,400	40,000	1.10	0.39
2002	6,500	7,200	46,800	1,400	45,400	1.12	0.42
2003	6,400	6,520	41,700	2,100	39,600	1.10	0.67
2004	6,300	7,600	47,900	1,600	46,300	1.11	0.70
2005	6,500	7,450	48,400	2,200	46,200	1.59	0.72
2006	6,900	6,140	42,400	2,700	39,700	1.49	0.81
2007	6,700	8,790	58,900	2,700	56,200	1.27	0.45
2008	6,700	6,730	45,100	3,200	41,900	1.61	0.54
2009	7,100	7,730	54,900	6,000	48,900	1.35	0.46
2010	7,500	5,820	43,660	4,160	39,500	1.67	0.67
2011	7,300	7,220	52,680	4,030	48,650	1.56	0.75
2012	6,800	7,870	53,520	2,920	50,600	2.11	0.76

Source: USDA, National Agricultural Statistics Service (NASS)

Table 2. Initial parameters and assumptions utilized in the economic surplus model for analyzing the welfare effects of a food safety event in US blackberries.

Parameters/Assumptions of Interest	Fresh Market	Processed Market
Elasticities:		
Demand Elasticity (η)	-1.88	-2.35
Supply Elasticity (ε)	0.22	0.22
Blackberry Production and Price:		
Annual Production (Q_0) in lbs.	2,920,000	50,600,000
Price (P_0) in $US/lbs.	2.11	0.76
Proportionate shift in demand ($\overline{K}_t$) for:		
Month $t = 1$	0.60	0.60
Month $t = 2$	0.52	0.52
Month $t = 3$	0.33	0.33
Month $t = 4$	0.21	0.21
Month $t = 5$	0.18	0.18
Month $t = 6$	0.17	0.17
Month $t = 12$	0.14	0.14
Month $t = 18$	0.09	0.09
Month $t = 24$	0.03	0.03
Other parameters:		
p_t (proportion)	1.0	1.0
A_t (proportion)	1.0	1.0

Table 4. Ex ante economic welfare loss from a food safety event in the US fresh and processed blackberry industry (in US$ '000s).

Selected	Fresh Market			Processed Market		
months after outbreak	Loss in Producer Surplus	Loss in Consumer Surplus	Loss in Total Surplus	Loss in Producer Surplus	Loss in Consumer Surplus	Loss in Total Surplus
1	706	83	789	1,879	176	2,055
2	600	70	670	1,596	149	1,746
3	378	44	422	1,006	94	1,100
4	236	28	264	627	59	686
5	201	23	224	534	50	584
6	–	–	–	494	46	540
12	–	–	–	408	38	446
14	139	16	155	370	35	405
16	118	14	132	315	29	344
18	–	–	–	248	23	271
24	–	–	–	80	8	88
Totals:	2,769	324	3,093	11,678	1,093	12,771

Grand Total (Fresh+Processed)= 15,864

Notes: (1) All surplus values in this table are discounted presented values (in 2012 US$) discounted using a monthly rate of 0.4% (based on a 5% annual rate). (3) The blank (–) cells in the fresh market analysis indicates that these months coincide with the situation where fresh blackberries are not available in the market. (2) The "Totals" in the table are the sum of the discounted monthly total change in surplus for the full 24 months after the outbreak (not just the selected months presented in the main part of the table).

Table 4. Sensitivity analysis: Using alternative parameter values in the economic surplus model

Assumption/Parameter Change	—Fresh Market—		—Processed Market—	
	Change in discounted total surplus (in '000s US$)[a]	% Change	Change in discounted total surplus (in '000s US$)[a]	% Change
Demand elasticity (η):[b]				
± 10%	1.05	0.03	2.75	0.02
± 20%	1.95	0.05	5.08	0.04
Supply elasticity (ε):[b]				
± 10%	9.62	0.31	31.81	0.25
± 20%	19.04	0.62	63.09.65	0.49
p_t or A_t:[c]				
p_t or $A_t = 0.9$	319.03	10.32	1,308.70	10.25
p_t or $A_t = 0.9$	635.88	20.56	2,610.38	20.44
p_t or $A_t = 0.9$	1,573.43	50.88	6,473.32	50.69
p_t or $A_t = 0.9$	2,491.44	80.56	10,273.10	80.44

Notes: [a] In absolute value terms; [b] An increase (decrease) in demand or supply elasticity, increases (decreases) the discounted total surplus; [c] An increase (decrease) in p_t or A_t, increases (decreases) the discounted total surplus.

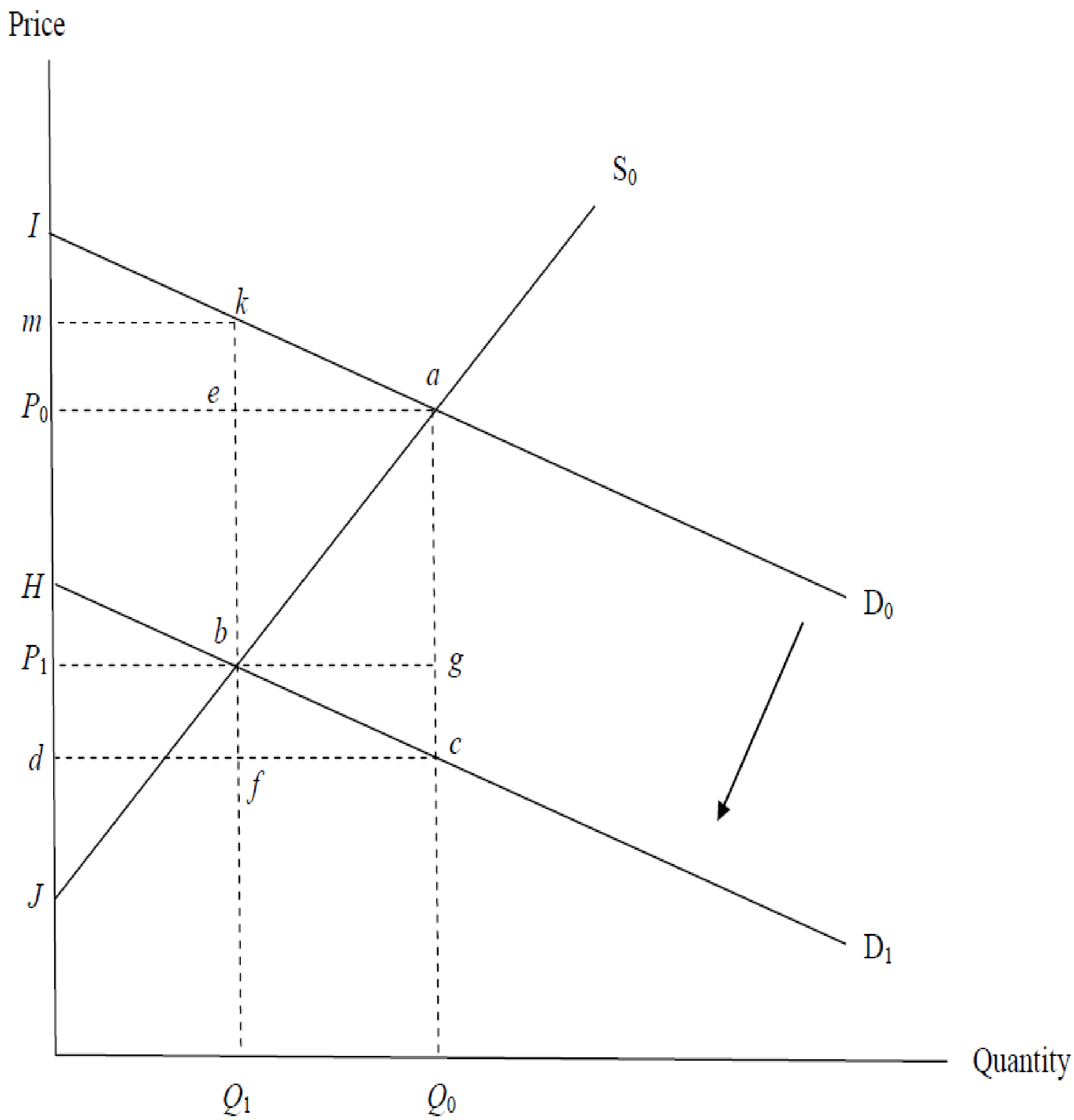

Figure 1. Conceptual Framework: Closed Economy Economic Surplus Model