An Ex-Ante Analysis of the Feasibility of Fortifying Processed Cheese with Omega-3 Fatty Acids

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Abstract

Studies have been conducted in the extant literature dealing with the fortification of reduced-fat cheddar cheese with n-3 fatty acids, processed cheese fortified with fish oil emulsion, selected cheeses fortified with vegetable and animal sources of omega-3 fatty acids and the fortification of processed cheese spread with omega-3 fatty acids. But no studies currently exist that deal with the economic feasibility of the fortification of processed cheese. This ex-ante analysis takes into account simulated market conditions, via demand and supply curves, and evaluates the percentage increase in the demand for processed cheese needed to offset the incremental costs of fortification in order to maintain producer profitability. The methodology involves the use of a partial equilibrium framework, often referred to as Equilibrium Displacement Modelling (EDM). To eliminate concerns about uncertainty of parameter values with the EDM approach, our work utilizes not only various values of own-price elasticities of demand and supply but also a range of the marginal costs associated with the fortification process. In this way we provide a check on the robustness of the empirical results. Bottom line, with only minimal shifts in the demand for processed cheese, we demonstrate that fortification with omega-3 fatty acids can occur without any loss in producer profits. This finding supports the contention that fortification of processed cheese indeed is economically feasible for manufacturers. The additional important by-products for manufacturers in doing so are the diversification of their product line and the provision of a healthier product to consumers. In addition, the potential increases in the demand for processed cheese due to the fortification with omega-3 fatty acids also is beneficial to dairy farmers, to retailers, and to consumers.

Key words: Fortification of cheese products, omega-3 fatty acids, equilibrium displacement model, economic feasibility

JEL classification: D10, D12

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Background

Consumers purchase fortified foods and beverages, including dairy-based beverages, cheese, yogurt, and ice cream, to prevent illness or to manage specific health concerns (Beery, October 25, 2018). Fortification started as a public health intervention about 100 years ago in the United States and proved to be an effective approach to eradicating nutrient-deficiency illnesses, such as goiter, addressed by the iodization of salt in 1924; rickets, addressed by the addition of vitamin D to milk in 1933; and neural tube birth defects, addressed by a mandate from the U.S. Food and Drug Administration to enrich cereal grains to be fortified with folic acid starting in 1998 (Institute of Medicine Committee on Use of Dietary Reference Intakes in Nutrition Labeling, 2003).

The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) define fortification as "the practice of deliberately increasing the content of an essential micronutrient in a food irrespective of whether the nutrients were originally in the food before processing or not, so as to improve the nutritional quality of the food supply and to provide a public health benefit with minimal risk to health" (Allen, de Benoist, Dary, and Hurell, 2006). Ingredients for example may be added as concentrated, purified compounds, such as fiber, minerals, omega-3 fatty acids, plant extracts, probiotics, proteins and vitamins.

Over the past two decades, there has been a surge in interest among public and health professionals of the health effects associated with omega-3 fatty acids, a group of polyunsaturated fatty acids which include α-linolenic acid as well as its long-chain metabolites eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Simopoulos, 2002). DHA and EPA are considered to have beneficial effects in the prevention and management of cardiovascular disease, hypertension, diabetes, arthritis, inflammatory diseases, cancers and autoimmune disorders (Kris-Etherton *et al.,* 2002; Calder, 2006; Gebauer *et al.*, 2006; MacLean *et al.,* 2006; Goldberg and Katz, 2007; Lombardi and Terranova, 2007; Yokoyama *et al.,* 2007; Gogus and Smith, 2010; and Renuka *et al*., 2016). Products rich in omega-3 fatty acids represent one of the fastest developing trends in the food industry (Ganesan *et al.*, 2014).

According to the Report of the Joint WHO / FAO Expert Consultation on the Risks and Benefits of Fish Consumption (2010), the daily recommended intake of omega-3 fatty acids should be at least 250mg/day for healthy life. But, the intake level of omega-3 fatty acids typically is far below the recommended level (Kolanowski, 2005). Typically, consumers do not get enough intake of omega-3 fatty acids through their diet alone since the most widely available source is cold water oily fish such as salmon which are not always consumed on a regular basis. Fortification of commonly consumed food products with omega-3 fatty acids is considered as a viable way of providing the health benefits to people without major alteration in their dietary habits (Garg *et al.*, 2006). The increased recognition of the importance of omega-3 fatty acids in the diet, coupled with its limited availability in natural food sources, makes fortification a noteworthy solution in closing the nutrition gap for better health and disease prevention/management.

Most dairy products provide the minimal fat basis needed to more easily incorporate omega-3 oils (Bouhlal, 2012). Additionally, dairy products share the image of "being good-for-you" given that they deliver essential nutrients to consumers. Interventions in the dairy industry include yogurt carrying added health benefits in the way of probiotics. This exposure is very important when looking for new opportunities to proliferate healthy functional food ingredients such as omega-3 fatty acids. Dairy products, particularly cheese and butter, have been shown to possess good delivery systems for elevated levels of omega-3 fatty acids. (Kolanowski and Weißbrodt, 2007). As such, dairy products represent potential for the use of fortification with omega-3 fatty acids. Overall, omega-3 fatty acids can be easily added to cheese with only minor changes (Bouckley, 2017).

Objective

Studies have been conducted in the extant literature dealing with the fortification of reduced-fat cheddar cheese with n-3 fatty acids (Martini *et al.*, 2009), processed cheese fortified with fish oil emulsion (Ye *et al.*, 2009), selected cheeses fortified with vegetable and animal sources of omega-3 fatty acids (Bermudez-Aguirre and Barbosa-Canovas, 2011), and the fortification of processed cheese spread with omega-3 fatty acids (Renuka *et al.*, 2016). But no studies currently exist that deal with the economic feasibility of fortification of processed cheese. In this light, the objective is to determine the effects of fortifying processed cheese with omega-3 fatty acids on the profits of manufacturers. Fortification implies additional costs of production for cheese processors. This ex-ante analysis takes into account simulated market conditions, via demand and supply curves, and evaluates the percentage increase in the demand for processed cheese needed to offset the incremental costs of fortification in order to maintain producer profitability. This work then makes a contribution to the extant literature in regard to the feasibility of fortifying processed cheese with omega-3 fatty acids. Without question, this analysis provides valuable information to all stakeholders in the dairy industry, including dairy farmers, manufacturers, retailers, and consumers.

Methodology

The methodology involves the use of a partial equilibrium framework, often referred to as Equilibrium Displacement Modelling (EDM) (Davis and Espinoza, 1998). With this approach, the industry is represented by demand and supply relationships for processed cheese. The impact of the fortification of processed cheese with omega-3 fatty acids is modelled as shifts in demand and supply from an initial equilibrium. Changes in prices and quantities that arise when the system equilibrium is displaced are estimated, as are the consequent changes in producer surplus reflecting welfare changes to manufacturers of processed cheese.

To invoke this methodology, we initially obtain estimates of the own-price elasticity of demand for processed cheese products from the economic literature. Subsequently, we determine producer surplus (synonymous with profit) considering the case of linear demand and supply functions. Finally, we establish by how much the demand for the new product (fortified processed cheese) would have to shift to the right so that producer surplus remains the same after the fortification. That is, we determine the minimum demand increase on a percentage basis required so that manufacturers would at least cover the marginal costs in producing processed cheese fortified with omega-3 fatty acids.

Estimates of the Own-Price Elasticity of Demand for Processed Cheese

From the extant economic literature, the own-price elasticities for processed cheese (as a category) have been estimated to be -0.36 (Schmit *et al.,* 2003); -0.68 (Bouhlal, 2012); -0.70 (Gould and Lin, 1994); and -0.99 (Davis *et al.,* 2010). This review of previous work related to the demand for processed cheese demonstrates that there is no unique value for the own-price elasticity of demand. Based on past work, the own-price elasticity for processed cheese has ranged from -0.36 to -0.99. The variation in these own-price elasticities is attributed to the difference in the nature of data used, the time period considered, and in the type of economic model estimated.

Profitability of Fortification with Omega-3s

Upon taking into account the own-price elasticities of demand for the category processed cheese, we subsequently calculate the producer surplus for the industry and determine by how much the demand would have to increase on a percentage basis so that manufacturers would at least cover their marginal costs in producing processed cheese fortified with omega-3 fatty acids.

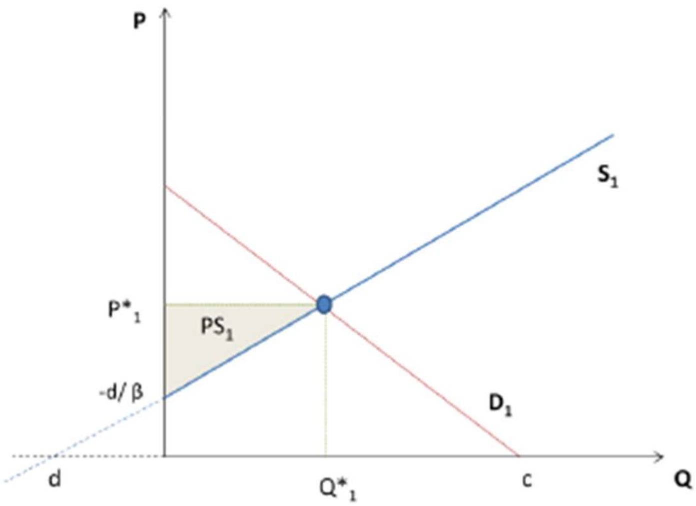
In the calculations, we assume both the demand and the supply functions are linear and that the shift in supply due to the change in marginal costs is a parallel shift. We also assume that the shift in demand is not only parallel but also to the right due the health benefits associated with omega-3 fatty acids. Further, we assume that the elasticity of demand is the same for processed cheese with and without fortification.

$Q_d = -\alpha P + c$: Demand

$Q_s = \beta P + d$: Supply

$Q_d = Q_s$: Equilibrium condition

Figure 1. Demand and Supply Relationship before Fortification



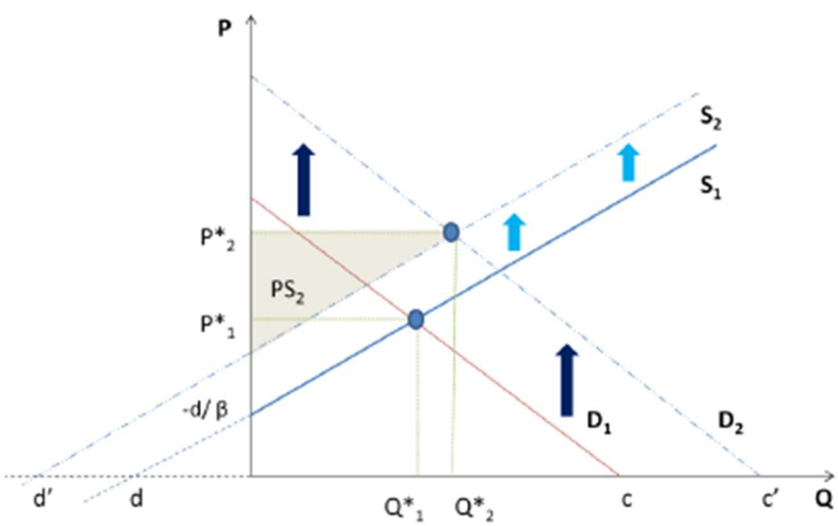
In Figure 1, we graphically portray the demand and supply of processed cheese before fortification. The demand curve reflects the inelastic nature of the demand for processed cheese.

After fortification, as illustrated in Figure 2, we have

$Q_d{}' = -\alpha P + c'$: Demand

$Q_s{}' = \beta P + d'$: Supply

Figure 2. Demand and Supply Relationship after Fortification



Subsequently, we determine the producer surplus before and after the fortification, labeled respectively as PS_1 and PS_2.

At equilibrium, $PS_1 = \frac{1}{2}\left(P_1^* + {}^{d}/_{\beta}\right) * Q_1{}^*$ and $Q_d = Q_s$

Then $-\alpha P^* + c = \beta P^* + d$ and $P_1^* = \frac{c-d}{\alpha+\beta}$, $Q_1^* = -\alpha * \left(\frac{c-d}{\alpha+\beta}\right) + c$

Thus $PS_1 = \frac{1}{2}\left(\frac{c-d}{\alpha+\beta} + \frac{d}{\beta}\right) * \left(-\alpha * \left(\frac{c-d}{\alpha+\beta}\right) + c\right)$

(6) $$PS_1 = \frac{-\alpha}{2} * \left(\frac{c-d}{\alpha+\beta}\right)^2 + \frac{c(c-d)}{2(\alpha+\beta)} - \frac{d\alpha}{2\beta}\left(\frac{c-d}{\alpha+\beta}\right) + \frac{dc}{2\beta}$$

Similarly, we calculate PS_2 as

(7) $$PS_2 = \frac{-\alpha}{2} * \left(\frac{c\prime-d\prime}{\alpha+\beta}\right)^2 + \frac{c\prime(c\prime-d\prime)}{2(\alpha+\beta)} - \frac{d\prime\alpha}{2\beta}\left(\frac{c\prime-d\prime}{\alpha+\beta}\right) + \frac{d\prime c\prime}{2\beta}$$

To determine by how much the demand for processed cheese would have to increase so that the manufacturers would at least cover their marginal costs in producing omega-3 fortified cheese, we set the change in producer surplus, ΔPS, equal to 0 and we solve for c':

The change in producer surplus is given by

$$\Delta PS = \frac{\beta}{(\alpha+\beta)^2}c'^2 + \frac{\alpha d\prime}{(\alpha+\beta)^2}c' + \left[\frac{-\alpha(d'^2-(c-d)^2)}{2(\alpha+\beta)^2} - \frac{c(c-d)}{2(\alpha+\beta)} + \frac{\alpha(d'^2+d(c-d))}{2\beta(\alpha+\beta)} - \frac{dc}{2\beta}\right]$$

Solving for c' yields

(8) $$c' = \frac{\frac{-\alpha d\prime}{(\alpha+\beta)^2} \pm \left[\left(\frac{\alpha d\prime}{(\alpha+\beta)^2}\right)^2 - \frac{4\beta}{(\alpha+\beta)^2} * \left(\frac{-\alpha(d'^2-(c-d)^2)}{2(\alpha+\beta)^2} - \frac{c(c-d)}{2(\alpha+\beta)} + \frac{\alpha(d'^2+d(c-d))}{2\beta(\alpha+\beta)} - \frac{dc}{2\beta}\right)\right]^{\frac{1}{2}}}{\frac{2\beta}{(\alpha+\beta)^2}}$$

All parameters in equation (8) are known. α (the slope) and c (the intercept) are the demand equation parameters, β and d represent the slope and the intercept of the supply equation, and d' is related to the shift in the supply function due to the increase in the marginal cost.

From Figure 3, we determine d' as $d - d' = \frac{\Delta MC}{\sin \delta}$, where $\tan \delta = \beta$ and ΔMC is the change in the marginal cost of production due to the fortification.

Then

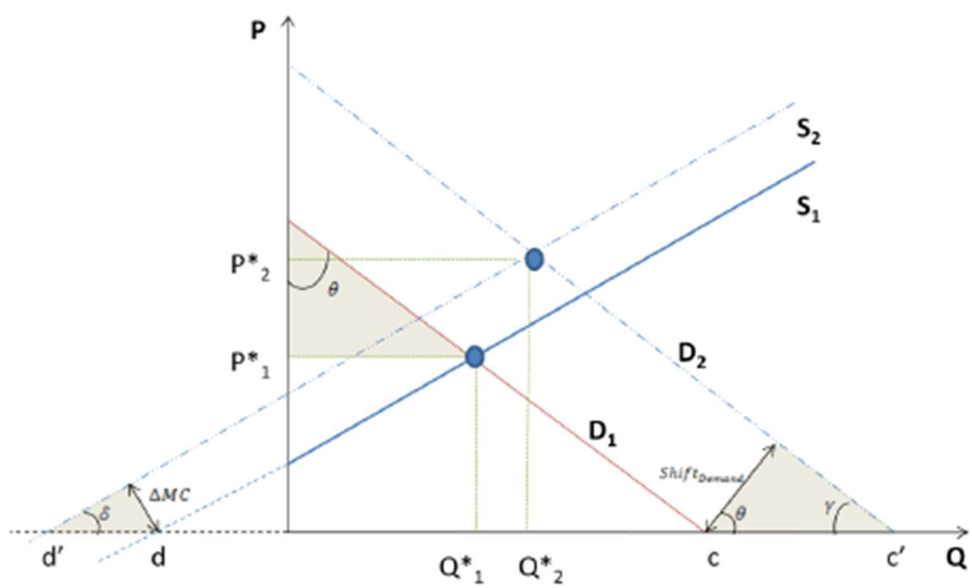
(9) $$d' = d - \frac{\Delta MC}{\sin(\operatorname{atan} \beta)}$$

Graphically we can see that the shift in demand is determined as

$Shift_{Demand} = (c' - c) * \sin \gamma$ where $\gamma = \frac{\pi}{2} - \theta$ and $\tan \theta = -\alpha$

Then $Shift_{Demand} = (c' - c) * \cos(\operatorname{atan}(-\alpha))$.

Figure 3. A Detailed Graphical Analysis of Demand and Supply Relationship after Fortification



Therefore, the percentage change in demand necessary to at least offset the marginal costs of producing processed cheese fortified with omega-3 fatty scids is given by

$$(10) \qquad \% \, Shift_{Demand} = \frac{(c' - c)\cos[\text{atan}(-\alpha)]}{c} \times 100$$

Demand Parameters

Initially, we adopt the estimated own-price elasticity of demand for processed cheese from the work of Bouhlal (2012). This estimated value of -0.68 is the most recent from the economic literature, and coincidentally is in the mid-range of published own-price elasticities of demand for processed cheese. From Bouhlal (2012), the parameters α and c are equal to -46.69 and 22.98 respectively. Hence $Q_d = -\alpha P + c$ the demand for processed cheese is expressed as $Q_d = -46.69P + 22.98$.

Supply Parameters

To the best of our knowledge, no information concerning the supply function of processed cheese products is available in the extant literature. Recall that the linear supply function is expressed as $Q_s = \beta P + d$. In this study we use different supply parameters β and d, relating to different values of the own-price elasticity of supply ϵ_s. The values chosen for ϵ_s range from 0.001 (extremely inelastic) to 10 (very elastic), accounting for the short-run and the long-run impacts of the change in marginal cost of production due to the fortification process.

The own-price elasticity of supply ϵ_s is equal to $\beta P / Q_s$. Hence, only the parameter β can be derived from ϵ_s and as such we need to impose values for the parameter d. To investigate the impact of different values of the intercept d, we perform a sensitivity test measuring the effects in the percentage change in demand needed at least to cover the marginal costs in producing processed cheese fortified with omega-3 fatty acids. If we keep the change in marginal cost (ΔMC) and the elasticity of supply ϵ_s constant, it turns out that imposing different values of the intercept d does not impact the empirical results (for details, see Bouhlal (2012)).

Change in Marginal Costs of Production with Fortification

Incremental or marginal costs of production with fortification include but are not necessarily limited to costs associated with retro-fitting of processing equipment, labor costs, and the ingredient costs for omega-3 fatty acids. The Global Organization for EPA and DHA Omega-3 (GOED), a trade association founded in 2006 which represents the worldwide EPA and DHA omega-3 industry (GOED, 2020), suggests that the marginal cost of production associated with fortification should not exceed 2 cents per serving (Bouhlal, 2012). As one example, a serving of a slice of American processed cheese roughly is equal to 1.5 ounces. Then according to the GOED, the change in marginal cost of production of processed cheese would be 3 cents per ounce. To check on the sensitivity of the change in marginal cost, we choose different values of ΔMC, ranging from \$0.01/ounce to \$0.20/ounce. Hence, we perform a sensitivity analysis in evaluating the impact of the various changes in marginal cost on the profitability of fortifying processed cheese with omega-3 fatty acids.

Changes in Demand Needed to Offset Incremental Fortification Costs

According to the results exhibited in Table 1, in most cases the percentage change in demand needed to offset the extra cost due to the fortification is negligible. Apart from cases of very inelastic supply or very high change in the marginal cost, the fortification of processed cheese with omega-3 fatty acids turns out to be economically feasible. For the situation where ΔMC= \$0.01/ounce, in the very short run, when the own-price elasticity of supply is very inelastic (0.001), the shift needed in demand is 9.37%. However, in moving toward larger values of the elasticity of supply, the shift in demand needed diminishes. To illustrate, when the own-price elasticity of supply is equal to 0.1, this percentage change in demand drops to 0.006%. When the own-price elasticity of supply is equal to 0.6, the shift in demand needed barely exceeds 0.001%. According to our findings, the more elastic the supply, the less the demand for processed cheese products needs to shift to the right in order to cancel out the incremental fortification costs. Fortification is not likely a viable option only in extreme cases when the supply is very inelastic.

Increasing the change in marginal cost due to fortification leads to increases in the percentage shift in demand needed to make the fortification strategy viable for producers so as to maintain profitability. We observe that when ΔMC= $0.03/ounce instead of the initial value of $0.01/ounce, all values associated with the percentage changes in demand corresponding to different own-price elasticities of supply rose considerably. Nevertheless, the demand shift values are still very small for ΔMC= $0.03/ounce, namely 0.34% when the own-price elasticity of supply is equal to 0.01, 0.005% when the own-price elasticity of supply is equal to 0.4, and 0.002% when the own-price elasticity of supply is equal to 1. Small own-price elasticities of supply are indicative of short-run effects, while larger own-price elasticities of supply are indicative of long-run effects. Hence, fortification is feasible for manufacturers not only in the short-run but also in the long-run. Importantly, the percentage change in demand needed to maintain producer profitability decreases with increases in the own-price elasticity of supply, making the fortification process more attractive in the long-run.

The same results are obtained even when choosing very high changes in marginal cost due to fortification. In the extreme case where ΔMC= $0.20/ounce, we still observe the same pattern, namely that the percentage change in demand needed to maintain producer profitability decreases with increases in the own-price elasticity of supply. In this case, the change is marginal cost incidentally is tantamount to the average price of a slice of processed cheese (Bouhlal, 2012). Under this assumption then, fortification induces a 100% increase or doubling in the price of processed cheese. Even with this considerably high incremental or marginal cost, we can still say that fortification is economically feasible to producers since at non-extreme values of the own-price elasticity of supply, the demand shift needed is still manageable.

Changes in the Own-Price Elasticity of Demand

The previously discussed simulation analysis hinges on the estimated own-price elasticity of demand to be -0.68 from Bouhlal (2012). To push our analysis further, we investigate the impact of fortification with omega-3 fatty acids on producer surplus or profitability for own-price elasticity of demand values other than -0.68. Recall that from the economic literature, the own-price elasticity for processed cheese has ranged from -0.36 to -0.99. Subsequently, we allow the own-price elasticity of demand for processed cheese to vary from -0.4 to -1.2, and we compute the percentage change in demand needed to maintain producer profitability not only for different values of the own-price elasticity of supply but also for different values of marginal costs. To conform to space limitations, as exhibited in Table 2, we consider the situation where ΔMC=\$0.03/ounce, and we allow the own-price elasticities of supply to vary from 0.005 to 1. Results for other levels of marginal costs from \$0.01/ounce to \$0.20/ounce with various assumptions about the own-price elasticities of supply are available upon request from the authors.

As exhibited in Table 2, increases in the value of the own-price elasticity of demand (in absolute value) produce decreases in the percentage change in demand needed to offset the change in marginal cost of production due to fortification. When the ΔMC= $0.03/ounce and coupled with the own-price elasticity of supply equal to 0.005 for example, the shift in demand needed is 1.82% when the own-price elasticity of demand is -0.4; however, the demand shift needed drops to 0.68% when the own-price elasticity of demand is -0.8 and drops further to 0.45% when the own-price elasticity of demand of is -1.2. For the range of own-price elasticities of demand investigated, the shift in demand needed to offset the incremental or marginal cost due to fortification never exceeded 2%. This finding supports the contention that fortification of processed cheese is economically feasible for manufacturers. In doing so, manufacturers may diversify their product line, maintain profitability, and provide a healthier product to consumers.

Conclusion

This study deals with the economic feasibility of fortifying processed cheese with omega-3 fatty acids. Heretofore, studies have been conducted in the extant literature dealing with the fortification of reduced-fat cheddar cheese with n-3 fatty acids, processed cheese fortified with fish oil emulsion, selected cheeses fortified with vegetable and animal sources of omega-3 fatty acids and the fortification of processed cheese spread with omega-3 fatty acids. But no studies currently exist that deal with the economic feasibility of the fortification of processed cheese.

This ex-ante analysis takes into account simulated market conditions, via demand and supply curves, and evaluates the percentage increase in the demand for processed cheese needed to offset the incremental costs of fortification in order to maintain producer profitability. The methodology involves the use of a partial equilibrium framework, often referred to as

Equilibrium Displacement Modelling (EDM). To eliminate concerns about uncertainty of parameter values with the EDM approach, our work utilizes not only various values of own-price elasticities of demand and supply but also a range of the marginal costs associated with the fortification process. In this way we provide a check on the robustness of the empirical results. Bottom line, with only minimal shifts in the demand for processed cheese, we demonstrate that fortification with omega-3 fatty acids can occur without any loss in producer profits. This finding supports the contention that fortification of processed cheese indeed is economically feasible for manufacturers. The additional important by-products for manufacturers in doing so are the diversification of their product line and the provision of a healthier product to consumers. In addition, the potential increases in the demand for processed cheese due to the fortification with omega-3 fatty acids also will be beneficial to dairy farmers, to retailers, and to consumers.

Next steps include extending the EDM analysis to consider multiple products, conventional processed cheese and processed cheese fortified with omega-3 fatty acids. As well, with the introduction of processed cheese fortified with omega-3 fatty acids, we are in position to track the demand for this new product using scanner data from vendors such as Nielsen or from Information Resources, Inc. (IRI). With this tracking, we can empirically discern market shares between conventional processed cheese and processed cheese fortified with omega-3 fatty acids as well as discern the own-price elasticity of demand for the respective products. In this way, we may statistically test whether or not the own-price elasticities for the multiple products are the same. As well, it would be advantageous to survey manufacturers of processed cheese in order to obtain industry estimates of the marginal costs associated with fortification rather than rely on a broad range of \$0.01/ounce to \$0.20/ounce. Finally, determining whether or not cannibalization effects are evident for firms that offer multiple products for processed cheese would be of interest. The identification and assessment of cannibalization are integral factors when making strategic decisions about new product introductions such as processed cheese fortified with omega-3 fatty acids.

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Table 1. Percentage Change in Demand Associated with Various Measures of Marginal Cost and Own-Price Elasticities of Supply

ΔMC	Es	%Change Demand
0.01	0.001	9.3762
	0.005	0.3953
	0.01	0.1132
	0.05	0.0133
	0.1	0.0064
	0.2	0.0032
	0.3	0.0021
	0.4	0.0016
	0.5	0.0013
	0.6	0.0011
	0.7	0.0009
	0.8	0.0008
	0.9	0.0007
	1	0.0006
	3	0.0002
	5	0.0001
	10	0.0001
0.03	0.001	28.1286
	0.005	1.1860
	0.01	0.3397
	0.05	0.0399
	0.1	0.0193
	0.2	0.0096
	0.3	0.0064
	0.4	0.0048
	0.5	0.0038
	0.6	0.0032
	0.7	0.0027
	0.8	0.0024
	0.9	0.0021
	1	0.0019
	3	0.0006
	5	0.0004
	10	0.0002
0.05	0.001	46.8810
	0.005	1.9767
	0.01	0.5661
	0.05	0.0665
	0.1	0.0322
	0.2	0.0160
	0.3	0.0106
	0.4	0.0080
	0.5	0.0064
	0.6	0.0053
	0.7	0.0046
	0.8	0.0040
	0.9	0.0035
	1	0.0032
	3	0.0011
	5	0.0006
	10	0.0003
0.07	0.001	65.6334
	0.005	2.7674
	0.01	0.7926
	0.05	0.0931
	0.1	0.0451
	0.2	0.0224
	0.3	0.0149
	0.4	0.0112
	0.5	0.0089
	0.6	0.0074
	0.7	0.0064
	0.8	0.0056
	0.9	0.0050
	1	0.0045
	3	0.0015
	5	0.0009
	10	0.0004
0.10	0.001	93.7621
	0.005	3.9534
	0.01	1.1323
	0.05	0.1330
	0.1	0.0645
	0.2	0.0320
	0.3	0.0213
	0.4	0.0160
	0.5	0.0128
	0.6	0.0106
	0.7	0.0091
	0.8	0.0080
	0.9	0.0071
	1	0.0064
	3	0.0021
	5	0.0013
	10	0.0006
0.15	0.001	140.6431
	0.005	5.9300
	0.01	1.6984
	0.05	0.1995
	0.1	0.0967
	0.2	0.0480
	0.3	0.0319
	0.4	0.0239
	0.5	0.0191
	0.6	0.0160
	0.7	0.0137
	0.8	0.0120
	0.9	0.0106
	1	0.0096
	3	0.0032
	5	0.0019
	10	0.0010
0.20	0.001	187.5241
	0.005	7.9067
	0.01	2.2646
	0.05	0.2659
	0.1	0.1290
	0.2	0.0640
	0.3	0.0426
	0.4	0.0319
	0.5	0.0255
	0.6	0.0213
	0.7	0.0182
	0.8	0.0160
	0.9	0.0142
	1	0.0128
	3	0.0043
	5	0.0026
	10	0.0013

Es represents the own-price elasticity of supply. Details of the calculations are available from Bouhlal (2012).
ΔMC represents the change in marginal costs due to fortification.
%Change Demand refers to the percentage change in demand necessary in order to maintain producer profitability.

Source: Calculation by the authors.

Table 2. Percentage Change in Demand Due to Various Own-Price Elasticities of Demand and Supply for the Case where ΔMC=$0.03/ounce

Es	Ed	%Change Demand
0.005	-0.4	1.8160
	-0.68	1.1860
	-0.8	0.6813
	-1.2	0.4543
0.1	-0.4	0.0296
	-0.68	0.0193
	-0.8	0.0111
	-1.2	0.0074
0.3	-0.4	0.0098
	-0.68	0.0064
	-0.8	0.0037
	-1.2	0.0024
0.6	-0.4	0.0049
	-0.68	0.0032
	-0.8	0.0018
	-1.2	0.0012
1	-0.4	0.0029
	-0.68	0.0019
	-0.8	0.0011
	-1.2	0.0007

Es and Ed refer to the own-price elasticity of supply and the own-price elasticity of demand for processed cheese, respectively.
%Change Demand refers to the percentage change in demand necessary in order to maintain producer profitability.

Source: Calculation by the authors.