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Ex Ante Economic Evaluation of Technologies for Managing Postharvest Physiological Disorders

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Abstract: Recently there has been much progress in the development of technologies that use biomarkers to detect and manage postharvest physiological disorders for apples in long-term storage. Such technologies have the capacity to alleviate fruit loss by allowing storage operators to more effectively manage the disorder by adjusting stock distribution. The technology may also reduce costs for storage materials and associated management activities. However, as is common for many new technologies that have not yet been adopted commercially in agriculture, the net economic value of the technology is not well understood and is difficult to assess *ex ante*. In horticultural markets that include quality (and price) differentiated products, technologies that affect grading are expected to impact revenues in non-trivial ways. Here we develop a framework to assess the likely range of economic implications associated with the adoption of the biomarker technology that allows a greater share of fruit to be marketed in a higher grade and may influence the costs of storing fruit. Results indicate that modest improvements in the share of higher quality fruit lead to increased profits of between 0.99% and 3%. A more optimistic scenario that increases the share of fruit in higher grades and decreases material costs in storage would increase profits by approximately 4.4%. Our analysis and results are specific to the case of biomarker use to manage postharvest disorders for 'Empire' apples, yet the framework can be used with varietal-specific price and yield information to assess the *ex ante* economic implications of adopting the technology more generally.

Keywords: Apples, Biomarkers, Economics of innovation, Postharvest physiological disorders, Technological change.

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Introduction

An accurate *ex ante* evaluation of novel innovations is difficult when the benefits of the new technology to individual producers are not very well understood. This is further complicated in food and agricultural markets as new technologies are often controversial and the benefits are not shared equally to all constituents (including all products and all producers) in the supply chain. New technologies are typically described as either revenue-enhancing or cost-reducing. Revenue-enhancing technologies have the capacity to increase yields, increase quality, and influence prices if the final products are transformed or are able to enter new markets. Cost-reducing technologies often introduce innovations that reduce overall input use or allow producers to switch to less expensive inputs. In some cases we observe innovations that are both revenue-enhancing and cost-reducing.

The economic implications of new technologies that are considering commercialization are of paramount concern for industry stakeholders. Agricultural economists are keenly aware of these questions and offer a range of practices to measure the potential benefits and costs of new technologies, yet much of this work is tailored to a specific technology and a specific industry. For example, Lemieux and Wohlgenant (1989) and Lesser, Bernard, and Billah (1999) present frameworks to examine the *ex ante* economic impacts of specific biotechnologies in animal agriculture that had not yet been deregulated and commercialized. Much of this earlier work examined industries with relatively little product differentiation, and in the modeling effort the technology was assumed to affect all products in the same way. Horticultural crops, however, often are highly differentiated across varieties and even within varieties. For many fruit crops there are different grades, and then within each grade there are various size classifications. If new technologies introduced into horticultural markets affect products differentially, then the economic framework for evaluation needs to accommodate these idiosyncrasies.

Motivation

The empirical example that motivates our work is the use of biomarkers to manage postharvest physiological disorders in long-term controlled atmosphere apple storage. Such disorders are non-trivial for some of the major apple varieties produced in the United States, and they can lead to significant economic losses for apple producers (Rudell and Watkins, 2011). Some of the most critical physiological disorders that occur in apple storage include superficial scald for ‘Granny Smith’, soft scald for ‘Honeycrisp’, external CO_2 injury for ‘Empire’ and firm-flesh browning for ‘Empire’ (see illustrations in Appendix A). Biomarker technologies have the capacity to be a revenue-enhancing technology if they provides reliable information that would allow the storage operator to reduce the share of down-graded fruit and/or to market a greater share of the stored fruit in higher quality grades. The biomarker technology could also lead to reduced costs if fewer materials are needed in storage.

Here we focus specifically on firm flesh browning of ‘Empire’ apple [*Malus sylvestris* (L.) Mill var. *domestica* Borkh.] fruit which is a major cause of revenue loss for growers and storage operators in New York State. Symptoms typically become visible after several months in storage (in the May or June following harvest in the northern hemisphere), but can occur earlier in some years. Flesh browning is not externally visible and mostly starts at the stem end of the fruit in the shoulder region (Lee et al., 2012). ‘Empire’ apples are air stored to meet market demands until about December with fruit for marketing beyond this time usually being controlled atmosphere (CA) stored. Both air-stored and CA-stored fruit are often treated with the inhibitor of ethylene perception, 1-methylcycopropene (1-MCP) (Watkins, 2008). A storage period of at least 10 months is desired by the whole fruit and fresh cut industries, but the cultivar is susceptible to several physiological disorders that limits its storage potential (Watkins et al., 1997; Watkins and Liu, 2010). Flesh browning has been especially problematic for the fresh cut industry as only apples with no internal browning – even slight browning in the stem end region (shoulder) – are acceptable.

‘Empire’, a cross between ‘McIntosh’ and ‘Delicious’, was released in 1966 (Derkacz et al., 1993). It is a major cultivar in the Northeastern United States, particularly in New York State as well as in Canada. ‘Empire’, at almost 1,860 hectares, was the second most planted cultivar after ‘McIntosh’ in the northeast in 2006 (NASS, 2012), and is the fifth most important cultivar in the United States with a total production of 170,000 tons in 2011 (Lehnert, 2012). The popularity of the cultivar is due to its fresh eating qualities with an excellent sugar/acid balance and good texture. ‘Empire’ is also an ideal cultivar for the fresh cut slice industry (Kim et al., 1993) and increasing production has been diverted to meet this market segment.

International Trade and the External Political Environment

The United States and the European Union (EU) have embarked on ambitious negotiations to create a comprehensive free trade agreement known as the Transatlantic Trade and Investment Partnership (TTIP). The agreement aims to promote trade between the two regions through three mechanisms: i) increasing market access, ii) enhancing regulatory coherence and cooperation, and iii) developing and updating trade rules. Many expect that the TTIP negotiations concerning market access and trade rules will progress without significant debate (Akhtar and Jones, 2013), while the discussions concerning differences in domestic regulations will continue to be highly contested (Fontagné, Gourdon, and Jean, 2013).

Agricultural markets receive relatively high levels of support and protection in both regions, and therefore are sensitive to the discussions surrounding the TTIP. It is widely expected that the liberalization of U.S. and EU tariffs will affect agricultural markets in both regions, and understanding the economic effects of such changes is relatively straightforward. However, there also exist a number of non-tariff barriers that impact U.S.-EU trade in food and agricultural markets—many that are driven by regulatory differences between the regions—and quantifying the effects these policies is much less straightforward.

In apple markets, one of the key regulatory differences between the EU and the United States relates to the use of materials to manage pests and other issues in the orchard and in storage. The United States and the EU have regulations that govern the amount of material that can be found on domestically-produced and imported food products known as maximum residue levels (MRLs), and there exist many examples where there are non-trivial differences in MRLs between EU member states and the United States. These differences are often considered to be non-tariff barriers which reduce trade and can complicate trade negotiations such as those concerning the TTIP. In particular, the EU has recently banned the use of diphenylamine (DPA) as a material in apple storage, and this is a product that has been widely used by storage operators in the United States to control postharvest physiological disorders for selected apple varieties. Therefore, if the biomarker technology could be effectively used to replace the need for DPA (or other storage materials), it may be able to help secure export markets that have banned DPA and may also reduce the net costs of storage. Conversely, a ban on DPA in the absence of other solutions to manage postharvest physiological disorders could have large negative implications for apple producers and storage operators. It is critically important to consider how this ban on the use of DPA will affect U.S.-EU trade in apples, and how it will impact profitability of producing and storing apples for EU export markets. Furthermore, the framework developed here will give us a better understanding for how the adoption of biomarker technologies could mitigate the economic consequences of this ban on DPA to U.S. apple producers and storage operators.

A Description of the Evaluation Framework

The objective of this research is to quantify the potential economic benefits of adopting biomarkers that would help to manage a specific postharvest physiological disorder for the 'Empire' variety, namely flesh browning. Here we outline a framework that uses information on prices and yields for specific grades and sizes of fruit, as well as data on the costs of production and storage. Essentially, we develop a tool to help the industry better understand the potential benefits of the biomarker technology and to assess a range of potential willingness to pay (WTP) measures that describe the value of the new technology. We present results across a range of market simulations to provide a wider spectrum of the potential benefits of the biomarker technology.

Our analysis is done in three stages. In the first stage we outline the annual costs of orchard production and the costs of storing 'Empire' fruit in a controlled atmosphere room. In the second stage we employ a range of prices and yields to calculate revenues across the various grades and sizes of 'Empire' fruit. A range of net profits to the producer/storage operator can be evaluated using the information outlined in stages 1 and 2. In the third stage we simulate how the adoption of biomarkers might affect the shares of fruit marketed in the various grades, and ultimately how that would affect net profits. The unit of observation for this exercise is approximately 2000 bins that each contain 840 pounds of fruit, or approximately 42,100 18.1 kg boxes of fruit; this is the amount of fruit that is used to fill a typical storage room with 'Empire' fruit in New York State.

Data

The data used in our analysis were calculated based on per acre data available in DeMarree (2010), Gallardo (2012), and Doerflinger et al. (2015), and then adjusted to reflect the market for 'Empire' fruit produced in New York State. The unit of observation in our analysis is one storage room which we assume contains approximately 2000 bins (840 lbs per bin) of fruit. If we assume that a high density orchard produces 1400 18.1 kg boxes per acre, then approximately 42000 boxes of fruit from 30 acres is required to fill one storage room. Therefore, the costs and revenues discussed below are specific to 30 acres of fruit production and to one storage room of fruit. The values described below and used in our analysis are meant to be generally representative and to serve as references points, however, the framework is designed to easily accommodate other values that may more accurately reflect market conditions for a specific firm or for a different variety.

In Table 1 we outline the categories of costs involved in the production and storage of 42,000 boxes of fruit. Here our objective is to characterize all of the costs involved in producing and storing the fruit; in some regions the fruit production and storage may be vertically integrated and controlled by a single firm, whereas in other regions these two activities may be operated by separate firms. Variable costs include labor requirements for harvesting and other orchard activities, interest on capital, and the materials applied to the orchard throughout the growing season. Fixed costs include expenses related to overhead, machinery and equipment, and operator salary. The storage costs reflect the costs for managing the fruit in long-term storage including sorting, packaging, and monitoring, and the materials used in storage. The storage costs do not include the fees collected by fruit marketing agency; these fees are deducted from the per box prices used to calculate revenue flows. Overall, variable costs represent approximately 63% of total costs, fixed costs represent approximately 22% of total costs, and storage costs represent approximately 15% of the total costs.

Revenue is derived from prices and yields earned across the various sizes in the different grades of fruit. Four general quality grades are used in the United States: “U.S. Extra Fancy” (ExFy), “U.S. Fancy” (Fy), “U.S. no. 1” (#1), and “Commercial” (C) by §51.300 and §51.301 of the U.S. standards for grading of apples (USDA, 2002). In our analysis, we focus on the ExFy, Fy, and C grades given the very small share of ‘Empire’ fruit that is marketed in the #1 grade. “U.S. Extra Fancy” is the highest grade and, therefore, brings the highest price; standards for fruit size and red coverage for this grade are high, and in some years can be difficult to achieve for the bicolored cultivars. Whole fruit prices are determined by grade as well as size, which ranges between 72 and 163 fruit per box. This refers to an average fruit weight of approximately 265 to 116 g. Fresh cut requires from 100 to 115 count boxes with individual fruit weight between 190 to 170 g.

In Table 2 we show the 10 year average prices and yields by grade and then by size within each grade. The average prices are calculated using data between 2002 and 2011, and this is a period that included a relatively wide range of prices for apples. The prices are highest for the largest fruit in the ExFy grade, and lowest for the fruit in the C grade. The net price represents the price the storage operator (or the grower/storage operator if the fruit production and storage activities are vertically integrated) receives after deducting the appropriate marketing fees and commissions. The yield shares show the approximate percent of the total crop that falls into each grade/size category, and these shares are used to calculate the quantity of fruit marketed under the different grade/size categories.

Simulations and Results

We simulate four scenarios that may unfold as a result of the adoption of the biomarker technology to manage physiological disorders in stored 'Empire' apples. The simulation work examines the economic effects of a biomarker technology that affects i) revenue through changes in the share of fruit that is marketed in the higher valued grades/sizes, ii) the cost of storing the fruit, and ii) some combination of changes in revenues and changes in costs. For each scenario, we manipulate the baseline cost and revenue data detailed in Tables 1 and 2 to assess the economic implications of a given change in the share of fruit marketed as higher quality or in the cost of storing the fruit. The changes that we consider are relatively modest, however, the framework is in place to model larger changes. Results from each scenario are then compared to the baseline case to understand how the conditions in each scenario change net profits for the 30 acre/2000 bin unit of production.

The analysis was conducted with the @Risk simulation program that uses an iterative process to generate multiple probabilistic outcomes. We use the information about the range of prices over the 10-year period to calculate an empirical distribution of prices for each grade/size category. The empirical distribution for prices is combined with the yields for each grade/size category to create an empirical distribution of total revenues for the 30 acre/2000 bin operation. This simulation exercise was done as a way of conducting a systematic sensitivity analysis that considers a wide set of possible revenue (and profit) outcomes. This allows us to report statistical properties of the empirical distribution of potential net profits rather than simply report mean values.

In the first two scenarios we consider the effects of the biomarker technology assuming it is able to detect disorders earlier and allow storage operators to market fruit sooner in better quality grades. In the first scenario, we examine the case where the bio-market technology allows 10% of some sizes of fruit to be marketed as Extra Fancy when it was otherwise marketed as Fancy. We decrease Fancy grade fruit in the 100, 113, 125, and 138 sizes by 10% and shift that to the corresponding sizes in the Extra Fancy grade. The full distribution of profits is shown in Figure 1 and is summarized in Table 3. In this scenario, the mean profits increase by approximately $1700 or by 0.99%. In the second scenario, we shift 10% of fruit in the Commercial grade to the same four sizes of fruit in the Extra Fancy grade (in equal quantities). Figure 2 illustrates the distributional impacts on net profits for scenario 2, and Table 3 shows that the mean profits increase by approximately $5200 or 3% compared to the baseline case.

In the third and fourth scenarios, we consider the outcome if the biomarker technology has the capacity to reduce storage costs via less use of DPA or less management of other resources used to store apples. In scenario three we model the effects of 10% lower storage costs, and in the fourth scenario we couple the lower storage costs with a reallocation of 10% of the Commercial grade fruit to the Extra Fancy grade. Figure 3 shows the distributional effects of a 10% reduction in storage costs, and Figure 4 shows the distributional effects of the reduction in storage costs coupled with the shift in fruit marketed in the higher quality grade. As shown in Table 3, the reduction in costs alone does not have a significant effect of mean net profits (an increase of 1.4%), but the effects are more significant when coupled with 10% of the fruit shifting from the Commercial grade to the Extra Fancy grade. In scenario 4, the mean net profits increase by approximately $8000 compared to the baseline case, or by 4.4%.

We also use our framework in four additional scenarios that examine the economic implications of a ban on DPA in the absence of an effective replacement technology (such as biomarkers). Here we consider the effects if 10% of the Fancy or Extra Fancy fruit is diverted to Commercial grade, and also consider scenarios with a 10% shift in fruit from Extra Fancy to Commercial grade plus changes in the net costs of storage. The results for these scenarios are shown in Table 4, and each scenario is compared to the baseline case. We find that shifting fruit from the Fancy grade to the Commercial grade does not have a significant economic impact (net profits to the growers and storage operators fall by 1.3%), however, if the ban on DPA results in a shift of 10% of Extra Fancy fruit to Commercial grade fruit, the economic effects are much larger (a decrease in net profits of 13.8%). The final two scenarios show the economic implications for a shift in the share of fruit marketed as Commercial grade coupled with changes in storage costs. We consider both a net decrease in storage costs (if the reduction in costs for DPA are not outweighed by other additional storage costs) and a net increase in storage costs (if the reduction in costs for DPA is outweighed by other additional storage costs for materials and management labor). The final row shows that a shift of 10% in fruit from the Extra Fancy grade to the Commercial grade plus a net increase in storage costs would reduce net profits by 15.2%. These results suggest that the ban on DPA could be significant, and crucially important for producers and storage operators following guidelines to export fruit to European markets.

Conclusion and Industry Implications

The apple market includes a wide range of quality differentiated products (across varieties, grades, and sizes). The introduction of new technologies in this market can significantly influence how the product is categorized. Therefore, new technologies introduced into markets with highly differentiated products need to be examined carefully. In addition, when prices across the differentiated products vary, and when technologies allow for improvements in quality, the economic effects could be substantial. We study the effects of introducing biomarker technologies that manage postharvest physiological disorders for the ‘Empire’ apple variety. However, our framework is more generalizable and could be used to examine similar issues for other apple varieties, other crops, and other technologies.

Our results show that even small changes in the share of fruit that can be marketed in higher grades has the capacity to significantly impact the net profits to the producer and storage operator. For a 30 acre/2000 bin storage unit, a 10% increase in the share of Commercial grade fruit marketed as Extra Fancy fruit would increase the net profits by approximately 3%. Increasing this share of fruit plus a decrease in storage-related costs by 10% would increase net profits by 4.4%.

Here we employ a novel method to understand the benefits of the technology. We used detailed cost, price, and yield data for ‘Empire’ apples to assess the net benefits to apple producers and storage operators per 2000 bin room (or equivalently to 30 acres of orchard). The net benefits that we calculate provide a starting point for assessing the value of the technology to potential adopters. In some ways, this exercise provides us with a framework for evaluating a technology *ex ante*, or before the technology is fully commercialized and adopted. Effectively, the results from the scenarios allow stakeholders to better understand the industry’s maximum willingness to pay for a new technology in cases where the cost and the price of the technology are not well documented, and the technology is not yet widely available.

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Table 1. Estimated costs for production, harvest, storage, and marketing for 30 acres of 'Empire'

Name	**Costs per unit ($)**	**Units per 2000 bins or 30 acres**	**Costs per 2000 bins or 30 acres ($)**
Variable orchard costs			
Harvest labor (ton)	32.58	840	27370.50
Seasonal quality control (h)	11.47	146	1670.95
FT* truck/tractor driver (h)	17.54	146	2555.22
FT tractor driver (h)	14.37	146	2093.42
PT** truck/tractor Driver (h)	12.71	146	1851.59
Interest on operating capital (ha)	1,790	12.14	21730.60
Disease control (Fungi, Insect/mite, Herbicides) (ha)	1,329	12.14	16134.06
Chemical thinners (ha)	279	12.14	3387.06
Fruit thinning/return bloom (ha)	1,483	12.14	18003.62
Fertilizer (ha)	543	12.14	6592.02
Fixed costs			
Total overhead expense (ha)	919	12.14	11156.66
Average equipment investment replacement year (ha)	692	12.14	8400.88
Operators' management only (ha)	704	12.14	8546.56
Annual equipment expense (ha)	514	12.14	6239.96
Storage costs			
Marketing, & packaging (ton)	24.76	340	8422.12
Sorting & Storing Bins (ton)	13.18	340	4484.76
1-MCP (SmartFresh) (1.4 m^3)			7150.46
Diphenylamine (DPA) and application	4000	1	4000.00
Total Costs for stored fruit			159,790.50

[*Full time (FT); **Part time (PT)]

Table 2. Unit prices per box (18.1 kg), yields, and revenue for 30 acres of 'Empire'.

Grade/size	Average fruit weight (g)	Price per box (10 year average)	Net price per box (less fees[a])	Yield (shares)	Yield (boxes per 30A)	Revenue ($ per 30 A)
Extra Fancy (ExFy)						
163	116	13.02	8.38	6.01%	2,561	21,470
150	128	9.15	5.90	9.12%	3,888	22,924
138	136	12.00	7.73	11.18%	4,764	36,803
125	153	12.72	8.19	13.34%	5,687	46,573
113	167	19.56	12.60	12.47%	5,316	66,971
100	190	18.53	11.93	8.18%	3,485	41,586
88	215	18.82	12.12	3.30%	1,407	17,052
80	238	19.57	12.61	1.05%	446	5,625
72	264	19.55	12.59	0.26%	112	1,409
64	298	18.17	11.70	0.05%	21	249
1.1 kg bags	126	14.12	9.09	2.96%	1,261	11,467
1.25 kg bags	114	12.48	8.04	2.99%	1,275	10,245
Fancy (Fy)						
138	136	8.55	5.51	2.38%	1,016	5,593
125	153	8.30	5.35	2.74%	1,166	6,235
113	167	6.43	4.14	2.14%	913	3,778
100	190	8.00	5.15	1.32%	564	2,904
88	215	6.57	4.23	0.45%	192	811
80	238	7.09	4.57	0.12%	49	224
1.1 kg bags	126	10.60	6.83	3.52%	1,502	10,255
Commercial/Juice (C)						
1000		4.00	2.58	16.43%	7,003	18,039
Total				100%	42,627	330,213

[a] Fees include a packing charge of 30% and a commission expense of 8%. Costs for storage charges and materials used in storage are considered expenses and included in the costs shown in Table 1.

Table 3. Summary of the Financial Results for Selected Scenarios with the use of Biomarkers

Scenario	Description	Mean	Minimum	Maximum	Standard deviation	Median	Frequency of profits between \$165k and \$198k[a]	% change in mean profits compared to baseline
		dollars					*percent*	
0	Baseline	174315	121778	232065	16003	174106	63.78	n/a
1	Shift 10% fruit from Fy to ExFy grade	176037	127073	234357	16335	175720	65.00	0.987
2	Shift 10% fruit from C to ExFy grade	179555	129814	233830	16278	179006	66.40	3.006
3	Reduce storage costs by 10%	176815	131038	232371	16025	176472	65.80	1.434
4	Shift 10% fruit from C to ExFy grade and Reduce storage costs by 10%	182054	134496	236945	16755	181649	66.90	4.440

[a] This range reflects the mean profits in scenario 4 plus and minus one standard deviation.

Table 4. Summary of the Financial Results for Selected Scenarios in the Absence of DPA and Biomarkers

Scenario	**Description**	**Mean**	**Minimum**	**Maximum**	**Standard deviation**	**Median**	**Frequency of profits between $158k and $190k[a]**	**% change in mean profits compared to baseline**
		dollars					*percent*	
0	Baseline	174315	121778	232065	16003	174106	73.0	n/a
5	Shift 10% fruit from Fy to Commercial grade	172099	117402	228131	16088	171844	89.5	-1.27
6	Shift 10% fruit from ExFy to Commercial grade	150355	107382	202614	14179	150242	29.5	-13.75
7	Shift 10% fruit from ExFy to Commercial grade and *reduce* storage costs by 10%	152855	110474	200336	14135	152574	35.7	-12.31
8	Shift 10% fruit from ExFy to Commercial grade and *increase* storage costs by 10%	147855	103823	195043	14347	147611	24.5	-15.18

[a] This range reflects the mean profits in scenario 0 plus and minus one standard deviation.

Figure 1. Scenario 1: Profit distribution for shift of 10% fruit from Fancy to Extra Fancy

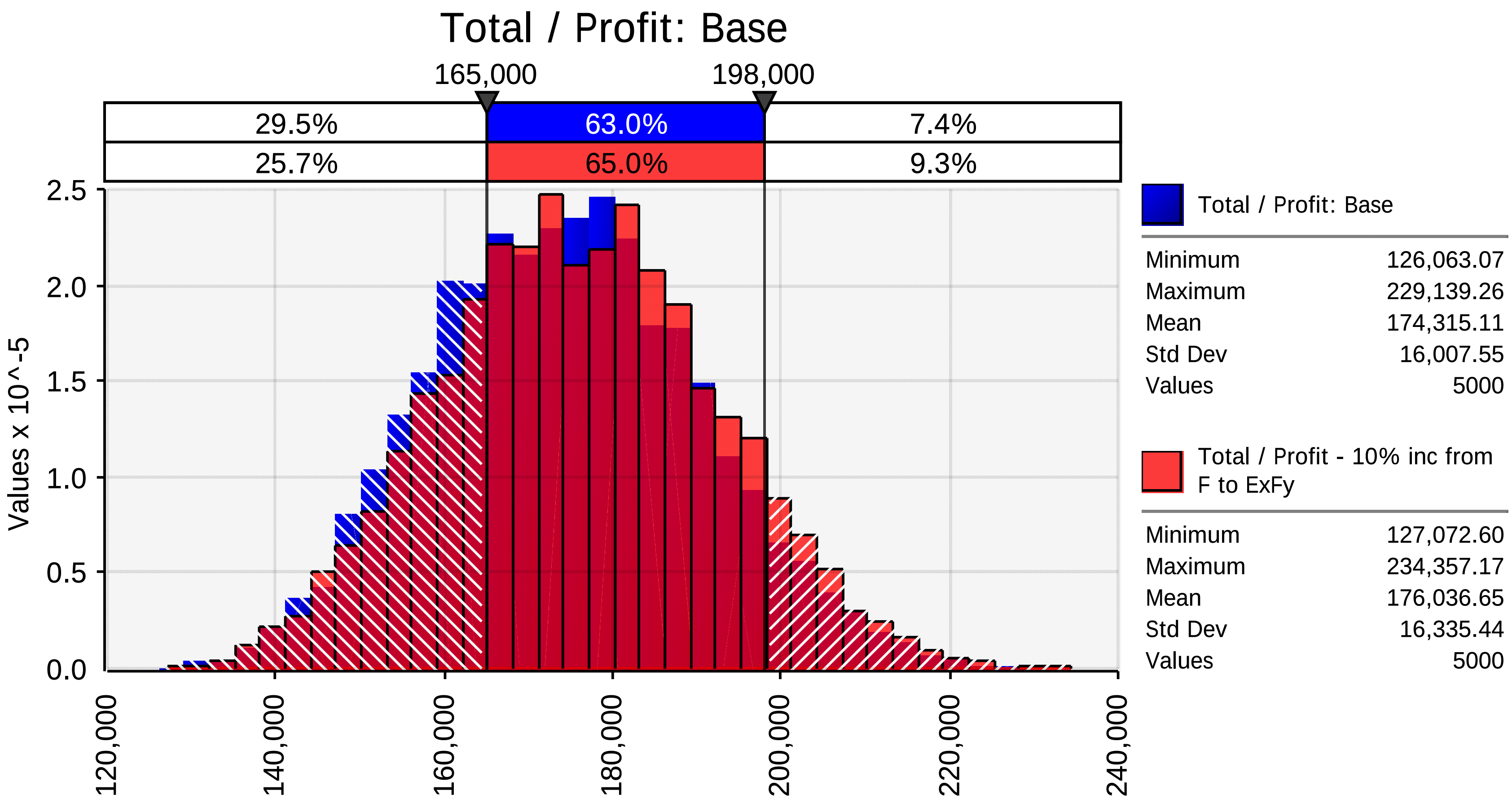


Figure 2. Scenario 2: Profit distribution for shift of 10% fruit from Commercial to Extra Fancy

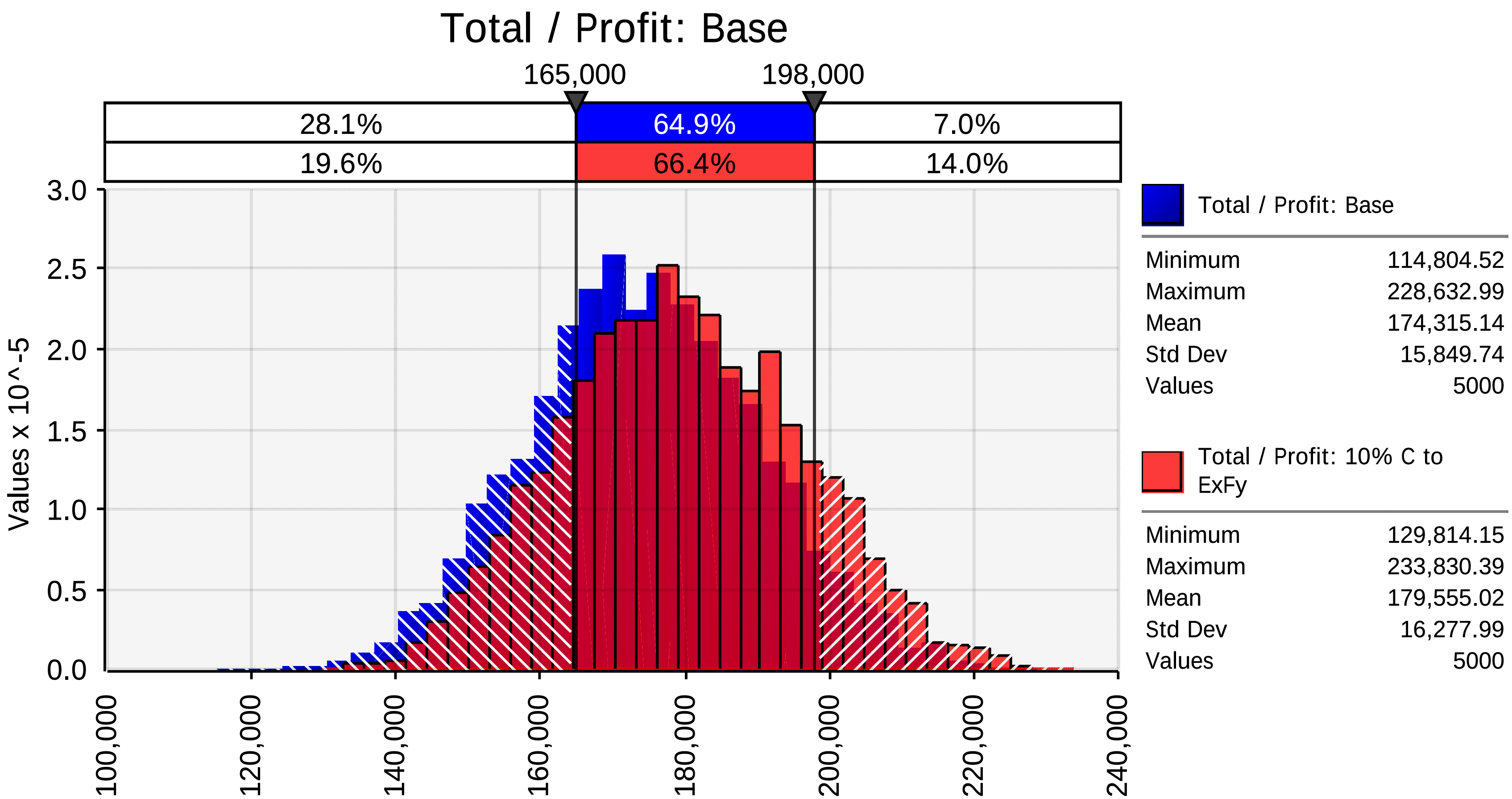


Figure 3. Scenario 3: Profit distribution for reduction in storage costs by 10%

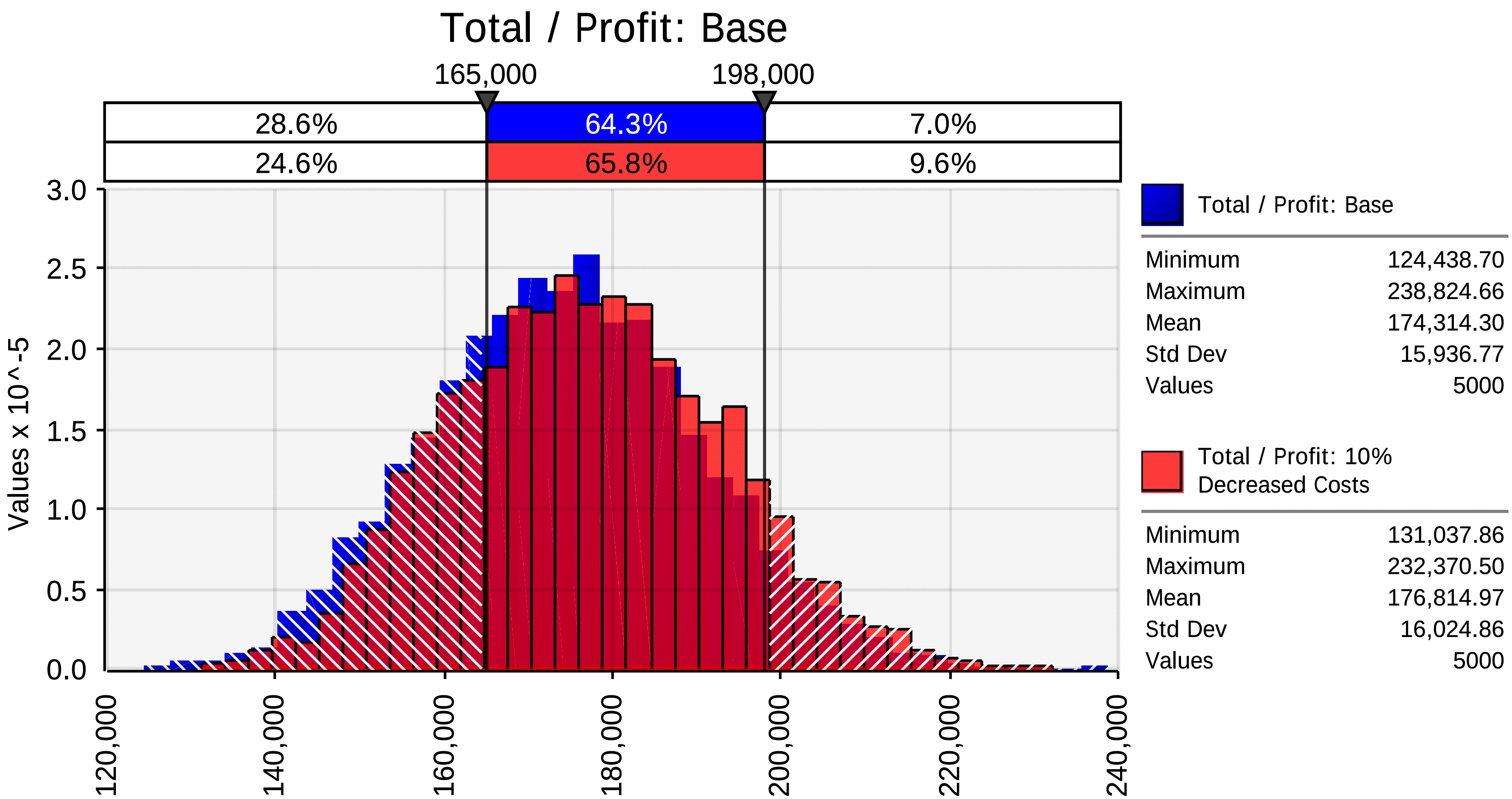
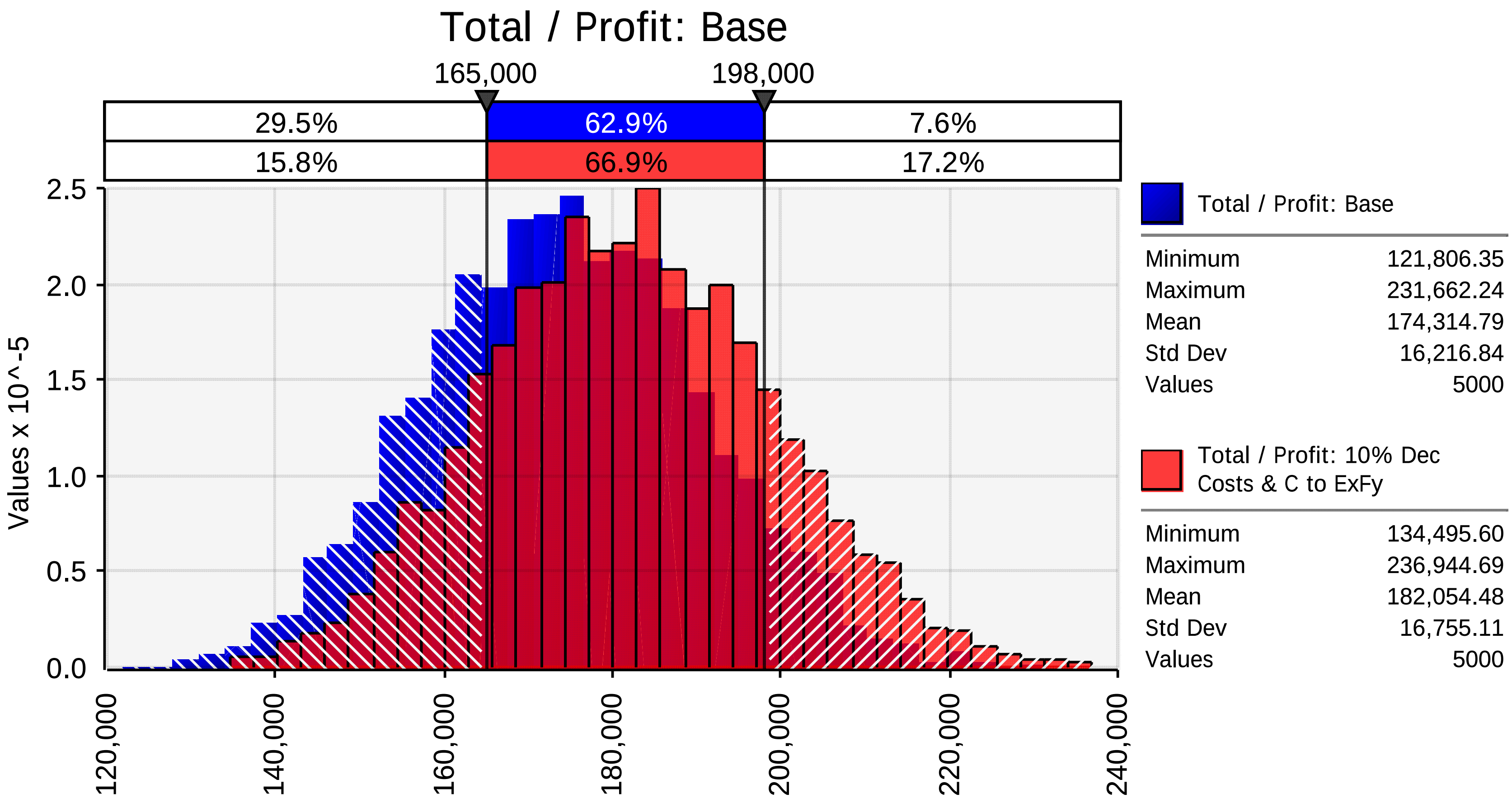
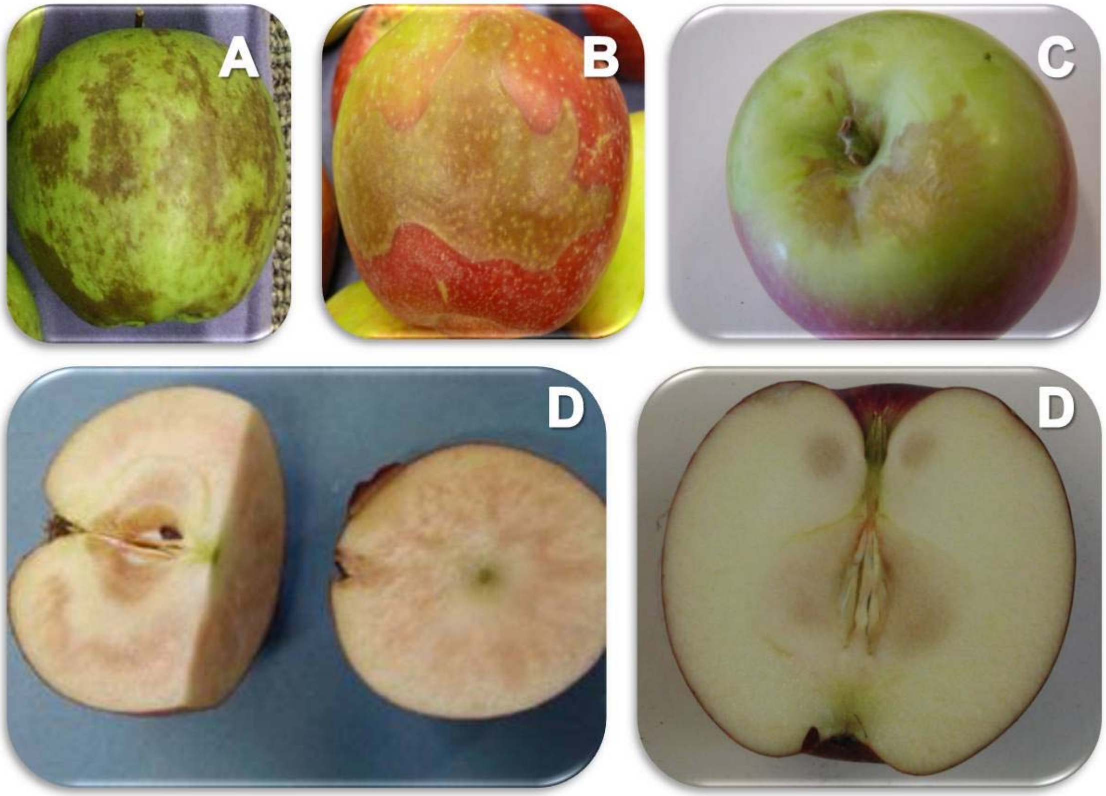


Figure 4. Scenario 4: Profit distribution for shift of 10% fruit from Commercial to Extra Fancy plus a 10% reduction in storage costs





Appendix A. Illustrations of Disorders for Selected Cultivars

Note: (A) superficial scald/'Granny Smith', (B) soft scald (internal - soggy breakdown)/ 'Honeycrisp', (C) external CO_2 injury/'Empire', (D) firm-flesh browning/'Empire'.

OTHER A.E.M. EXTENSION BULLETINS

EB No	Title	Fee (if applicable)	Author(s)
2015-10	Produce Procurement Study		McLaughlin, E., Park, K. and G. Hawkes
2015-09	Dairy Farm Business Summary, New York Small Herd Farms, 140 Cows or Fewer, 2014	($20.00)	Knoblauch, W.A., Dymond, C., Karszes, J. and R. Kimmich
2015-08	Dairy Farm Business Summary, Northern New York Region, 2014	($16.00)	Knoblauch, W.A., Dymond, C., Karszes, J., Howland, E., Murray, P., Buxton, S. and R. Kimmich
2015-07	Dairy Farm Business Summary, Hudson and Central New York Region, 2014	($16.00)	Knoblauch, W.A., Dymond, C., Karszes, J., Howland, E., Buxton, S., Kiraly, M., Kimmich, R. and K. Shoen
2015-06	Dairy Farm Business Summary, Western New York Region, 2014	($16.00)	Knoblauch, W.A., Dymond, C., Karszes, J., Howland, B., Hanchar, J., Petzen, J., Stoll, K. and R. Kimmich
2015-05	Dairy Farm Business Summary, New York Large Herd Farms, 300 Cows or Larger, 2014	($20.00)	Karszes, J., Knoblauch, W.A. and C. Dymond
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2015-03	Census of Agriculture Highlights New York State, 2012		Bills, N. and B.F. Stanton
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