The Welfare Impacts of New Demand-Enhancing Agricultural Products
The Case of Honeycrisp Apples[1]

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Background

- Apples are one of the most popular fruits worldwide and apple varieties have been improved by cultivation and selection.
- 7,500 over the world, 2,500 in the United States, and more than 100 sold in retail stores.
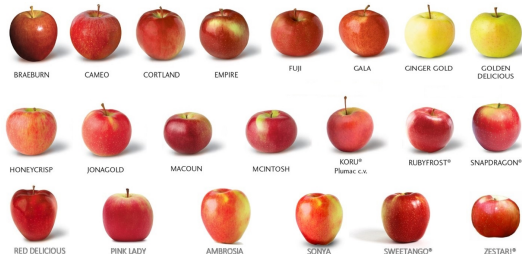
- Production
    - All continental states
    - Commercial productions in 32 states, led by WA, NY, MI, and PA.

Background

- Consumption
  - Second most consumed fruit (over $2 billion since 2007)
  - 70% of total production are sold in the market of fresh fruits
  - Average annual consumption per capita
    14.3 pounds in 2009, and 16.6 pounds in 2014

Table 1. Apple Market Shares by Variety (Percent of Total Volume)

Variety	2009-Fall	2010-Fall	2011-Fall	2012-Fall	2013-Fall	2014-Fall
Gala	27.58	30.50	32.89	30.58	30.30	31.46
Red Delicious	21.66	21.66	18.18	19.11	15.73	13.25
Fuji	9.57	8.02	8.82	9.98	10.26	11.51
Granny Smith	10.70	10.48	10.82	10.69	9.50	10.75
Honeycrisp	3.81	5.83	6.63	6.34	6.79	8.56
Golden Delicious	5.74	4.84	4.32	3.78	3.58	3.48
Mcintosh	6.03	5.52	5.25	4.38	4.81	4.82
Pink Lady/Cripps Pink	0.51	0.56	0.45	1.03	1.51	1.05
Braeburn	1.19	1.22	0.61	0.80	0.71	0.67
Jazz/Scifresh	0.35	0.61	0.36	0.88	0.98	1.10
Top 5	73.31	76.50	77.33	76.70	72.59	75.53
Top 10	87.14	89.24	88.31	87.58	84.17	86.65

Source: IRI Infoscan Data.

- New Variety
  - The price of a new variety with preferable attributes is higher than that of regular apples in both conventional and organic markets (Slattery et al. 2011).
  - Honeycrisp (Minnesota, 1991, 2006, 2008)

Table 2. Apple Market Prices by Variety (Dollars per Pound)

Variety	2009	2010	2011	2012	2013	2014
Gala	0.63	0.60	0.63	0.70	0.70	0.65
Red Delicious	0.50	0.52	0.56	0.58	0.61	0.64
Fuji	0.68	0.76	0.76	0.82	0.76	0.83
Granny Smith	0.77	0.80	0.80	0.89	0.89	0.85
Honeycrisp	2.11	1.85	1.97	2.30	2.24	2.07
Golden Delicious	0.89	0.91	0.98	1.06	1.00	0.90
Mcintosh	0.63	0.63	0.68	0.79	0.67	0.62
Pink Lady/Cripps Pink	1.26	1.28	1.20	1.25	1.18	1.17
Braeburn	1.16	1.23	1.29	1.46	1.51	1.55
Jazz/Scifresh	1.75	1.46	1.17	1.10	1.24	1.21

Source: IRI Infoscan Data.

1. New products in food and agricultural markets.
   - 3,500+ new varieties of fruit and vegetables (USDA 2017)

2. Investments in the agricultural research and development (R&D)
   - Public investments
   - Patent protection laws
   - Private investments (research programs with near term commercial consequences)

Research Objective

This paper is to evaluate the welfare changes in the U.S. apple market due to the introduction of Honeycrisp apples.

- Why do I choose the U.S. apple market?
  - The second most valuable fruit in the United States (USDA 2016)
  - The success of the breeding programs at the land grant universities
  - The development of newly patented varieties (Rickard et al. 2013)
- How does a new apple variety affect the market?
  - Consumers (preferences for diversity and benefits from price competition)
  - Producers (demand increase)

- Returns to agricultural R&D

- Economic impacts from the introduction of a new product

- Consumer valuation of different apple varieties

Analytical Framework: Consumer Utility

- Indirect utility of a consumer i from purchasing product j at t

$$u_{ijt} = \delta_{jt} + \mu_{ijt} + \epsilon_{ijt}$$

where ϵ_{ijt} represents consumer's preferences for diversity, δ_{jt} is the mean utility s.t. $\delta_{jt} = -\alpha p_{jt} + \mathbf{x}_j' \beta + \xi_{jt} + \boldsymbol{d}_t$, and μ_{ijt} is the consumer heterogeneous taste.

$$
\begin{aligned}
\mu_{ijt} &= \begin{bmatrix} -p_{jt} & \mathbf{x}_j \end{bmatrix} (\Pi \mathbf{D}_{it} + \Sigma \mathbf{v}_{it}) \\
&= -p_{jt} \left(\pi_{p1} D_{i1t} + \cdots + \pi_{pL} D_{iLt} + \sigma_p v_{ipt} \right) \\
&\quad + \sum_k x_{jt}^k \left(\pi_k D_{i1t} + \cdots + \pi_{kL} D_{iLt} + \sigma_k v_{ipt} \right).
\end{aligned}
$$

where $\Sigma = diag\left(\sigma_p, \sigma_1, \ldots, \sigma_K\right)$ and $\mathbf{v}_{it}$ is the unobs. tastes.

- Normalized outside option $\mu_{i0t} = \delta_{0t} + \mu_{i0t} + \epsilon_{ijt}$ where δ_{0t} and μ_{i0t} are normalized to be zero.

Analytical Framework: Market Demand

Market demand is characterized by a system of share equations.

- Consumer maximization problem and consumer set for product j

$$C_{jt} \equiv \left\{ (D_{it}, v_{it}, \epsilon_{i\cdot t}) \mid u_{ijt} \geqslant u_{ilt}, \ \forall l = 0, \ldots, J \right\}.$$

- Market share for product j at t is

$$s_{jt} = \int_{C_{jt}} dP(D, v, \epsilon).$$

In practice, the simulated market share is used;

$$s_{jt} = \sum_i s_{ijt} \times w_i = \sum_i \frac{\exp\left(\delta_{jt} + \mu_{ijt}\right)}{1 + \sum_{m=1}^{J} \exp\left(\delta_{mt} + \mu_{imt}\right)} \times w_i,$$

where w_i is the constant weight for consumer i.

Oligopoly Competition on the Supply Side

- Firm maximization problem and F.O.C.

$$\max_{\mathbf{p}_r} M \times \sum_{j \in J_r} \left(p_j - mc_j\right) s_j\left(\mathbf{p}_r, \mathbf{p}_{-r}\right)$$

F.O.C.: $s_j\left(\mathbf{p}_r\right) + \sum_{j \in J_r} \left(p_j - mc_j\right) \dfrac{\partial s_j\left(\mathbf{p}_r\right)}{\partial p_j} = 0, \ \forall j = 1, \ldots, I.$

In vector notation, $\mathbf{s}\left(\mathbf{p}\right) + \triangle\left(\mathbf{p}\right)\left(\mathbf{p} - \boldsymbol{mc}\right) = 0$, where $\triangle\left(\mathbf{p}\right)$ is the substitution matrix such that

$$\triangle\left(\mathbf{p}\right)_{jk} = \begin{cases} \partial s_j\left(\mathbf{p}\right)/\partial p_k, & \text{if } j, k \in J_r \\ 0, & \text{otherwise} \end{cases}.$$

Analytical Framework: Supply and Pricing Rule

- Pricing rule

$$\mathbf{s}\left(\mathbf{p}^{\text{eqb}}\right) + \triangle\left(\mathbf{p}^{\text{eqb}}\right)\left(\mathbf{p}^{\text{eqb}} - \hat{\boldsymbol{mc}}\right) = 0$$

where $\hat{\boldsymbol{mc}} = \mathbf{p}^{\text{obs}} + \triangle\left(\mathbf{p}^{\text{obs}}\right)^{-1}\mathbf{s}\left(\mathbf{p}^{\text{obs}}\right)$.

- Compensating variation for consumer i is

$$
\mathrm{E}\left[CV_i\right] = \int \left[\overbrace{\frac{\ln\left(\sum_{j=0}^{J^{\text{with}}} \exp\left(u_{ij}\left(\mathbf{p}^{\text{with}}\right)\right)\right) - \ln\left(\sum_{j=0}^{J^{\text{without}}} \exp\left(u_{ij}\left(\mathbf{p}^{\text{with}}\right)\right)\right)}{-\alpha_i}}^{\text{welfare impact due to a new product (direct effect)}} + \right.
$$
$$
\left. \underbrace{\frac{\ln\left(\sum_{j=0}^{J^{\text{without}}} \exp\left(u_{ij}\left(\mathbf{p}^{\text{with}}\right)\right)\right) - \ln\left(\sum_{j=0}^{J^{\text{without}}} \exp\left(u_{ij}\left(\mathbf{p}^{\text{without}}\right)\right)\right)}{-\alpha_i}}_{\text{welfare impact due to price changes (indirect effect)}} \right] P\left(D\right)P\left(v\right).
$$

where $\mathbf{p}^{\text{with}}$ and $\mathbf{p}^{\text{without}}$ are the vectors of prices when Honeycrisp apples are available and not available in the market, respectively.

Data

1. IRI Store Scanner Data from Mar 2009 to Feb 2015
   - Sales quantities and prices (Store-UPC level)

2. American Community Survey
   - Consumer demographic variables (e.g., age and household income)

3. BLS Occupational Employment Statistics (OES) Survey
   - State level cost information (i.e., wage rates and ranges for cashiers, heavy truck drivers, light truck drivers, tractor operators, stock and material movers, and packagers)

4. USDA Agricultural Marketing Service
   - Terminal market prices in 15 markets by apple variety

Data Map
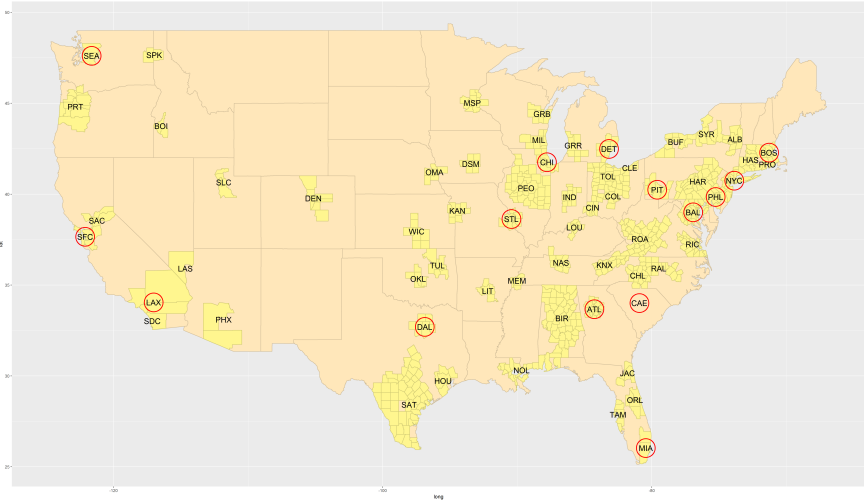
Table 6. Results from the Full Model

	Variable	(1)	(2)	(3)	(4)
Mean	Price	−11.048(1.800)***	−11.309(2.169)***	−11.052(2.782)***	−11.045(3.112)***
	Constant	−3.123(0.176)***	−2.480(0.275)***	−2.410(0.288)***	−2.011(0.281)***
	Sauce	0.525(0.065)***	0.228(0.041)***	0.477(0.105)***	0.432(0.107)***
	Baking	2.446(0.173)***	1.493(0.099)***	3.296(0.434)***	4.287(0.446)***
	Freezing	−5.982(0.704)***	−4.324(0.720)***	−6.070(1.047)***	−7.441(1.045)***
	Sweetness	−2.499(0.399)***	−2.393(0.366)***	−2.930(0.526)***	−4.642(0.525)***
	Local	3.204(0.099)***	3.102(0.121)***	3.011(0.164)***	3.177(0.165)***
	Small Regional	4.298(0.348)***	3.961(0.335)***	3.942(0.550)***	6.732(0.638)***
	Regional	2.319(0.095)***	0.781(0.848)	2.863(0.711)***	3.733(0.714)***
Interaction w. Shocks	Price		0.072(9.045)	0.076(11.534)	0.075(13.081)
	Constant		−0.086(6.940)	−0.091(5.962)	−0.091(6.232)
	Sauce			−0.032(6.183)	−0.031(7.205)
	Baking			−0.064(13.146)	−0.065(15.965)
	Freezing		−0.087(8.462)	−0.048(9.956)	−0.048(13.090)
	Sweetness		−0.067(12.414)	−0.041(7.732)	−0.042(9.291)
	Local		−0.020(20.600)	0.018(10.345)	0.019(12.567)
	Small Regional		−0.010(20.828)	0.041(41.967)	0.041(53.321)
	Regional		0.138(17.905)	0.118(13.765)	0.119(14.518)
Interaction w. Young Adult	Price	0.055(17.856)	0.071(23.635)	0.051(26.435)	−0.091(44.344)
	Constant				0.123(30.790)
Interaction w. Age	Price	0.001(15.654)	0.007(19.832)	−0.0004(26.361)	−0.209(54.739)
	Constant				0.178(35.595)
Interaction w. Income	Price	151.714(26.564)***	148.008(40.987)***	152.080(46.764)***	152.128(37.146)***
	Constant	4.067(5.478)	3.913(5.133)	4.071(8.582)	4.085(9.722)
	Sauce	1.287(4.534)		1.269(5.843)	1.263(6.314)
	Baking	4.729(4.636)		4.765(5.202)	4.783(5.930)
	Freezing	−20.761(7.100)***	−14.928(6.699)**	−20.843(10.353)**	−20.879(11.841)*
	Sweetness	−12.587(6.819)*	−9.316(7.001)	−12.616(10.178)	−12.658(11.037)
	Local	2.306(2.991)	0.836(3.031)	2.327(4.439)	2.336(4.929)
	Small Regional	10.929(3.801)***	10.258(4.593)**	10.985(5.210)**	10.994(5.399)**
	Regional	2.085(3.478)	1.994(5.596)	2.143(6.595)	2.161(6.914)
Inter. w. Inc^2	Price	−7.333(1.296)***	−7.139(2.004)***	−7.350(2.245)***	−7.352(1.797)***
GMM Objective		941.826	979.350	939.538	939.265
R^2 Min. Distance		0.898	0.821	0.806	0.818
Price Coef. > 0		0%	0%	0%	0%

Table 8. Equilibrium Prices (Cent per Pound) with and without Honeycrisp

	Price	C. Price	Price Change	Number of Markets where Price ≤ C. Price (Percent in Total)
Market Shares of the Honeycrisp ≥ 1 percent (481 Markets)				
Braeburn	67.86	67.98	0.12 (0.18%)	351 (73%)
Fuji	54.05	54.17	0.13 (0.22%)	389 (81%)
Gala	37.28	37.55	0.27 (0.72%)	473 (98%)
Golden Delicious	54.16	54.18	0.02 (0.04%)	291 (61%)
Granny Smith	41.90	41.96	0.06 (0.14%)	317 (66%)
Pink Lady/Cripps Pink	63.84	64.01	0.17 (0.27%)	370 (77%)
Red Delicious	34.58	34.79	0.21 (0.61%)	449 (93%)
Market Shares of the Honeycrisp ≥ 5 percent (96 Markets)				
Braeburn	67.08	67.48	0.39 (0.60%)	73 (76%)
Fuji	53.40	53.74	0.34 (0.64%)	81 (84%)
Gala	31.37	32.07	0.71 (2.23%)	95 (99%)
Golden Delicious	52.67	52.77	0.10 (0.19%)	70 (73%)
Granny Smith	41.92	42.15	0.24 (0.55%)	69 (72%)
Pink Lady/Cripps Pink	62.50	62.93	0.43 (0.69%)	74 (77%)
Red Delicious	33.44	34.00	0.56 (1.67%)	95 (99%)

Note: Price and C. Price represent the observed and the counterfactual price respectively. Both are averaged across retailer groups by sales quantity and deflated by regional price indices from the Bureau of Labor Statistics (BLS) with the base period at 1982-84. The price change is the difference between these two prices and the percentage change in prices is presented in the associated parenthesis.

Table 9. Sales Quantity (Million Pounds) and Sales Revenue (Million Dollars)

Year	Num. of Markets	Num. of IRI Cities	Sales Quantity					Sales Revenue				
			Honeycrisp	Other Apples	Total	C. Total	Changes	Honeycrisp	Other Apples	Total	C. Total	Changes
2009	42	29	13.35	127.10	140.45	131.00	9.41	12.58	48.62	61.20	50.43	10.77
2010	61	38	21.06	194.80	215.86	201.20	14.63	17.77	78.09	95.86	81.03	14.84
2011	78	39	29.99	227.50	257.49	235.90	21.54	22.71	89.26	111.97	93.11	18.86
2012	82	38	29.67	267.10	296.77	277.10	19.73	28.17	112.19	140.36	117.53	22.83
2013	107	43	42.22	353.50	395.72	367.60	28.11	36.13	137.41	173.54	144.13	29.41
2014	111	43	47.66	347.50	395.16	362.10	33.06	42.46	128.37	170.83	135.42	35.41
	Total		183.95	1517.50	1701.45	1574.90	126.48	159.82	593.94	753.76	621.65	132.12

Note: These results are based on the 481 markets where the market share of the Honeycrisp is greater than or equal to 1 percent. Other apples include all competing apple varieties. C. Total in sales quantity and sales revenue respectively represent the counterfactual quantity and revenue when the Honeycrisp is removed from the markets. The values of sales revenue are deflated by regional price indices from the Bureau of Labor Statistics (BLS) with the base period at 1982-84.

Table 11. Total Changes in Consumer Welfare (Million Dollars)

Year	Num. of Markets	Num. of IRI Cities	Change due to Increased Varieties	Change due to Decline in Prices of Competing Apples	Total Change in Consumer Welfare
2009	42	29	2.76 (91.09%)	0.27 (8.91%)	3.03 (100%)
2010	61	38	4.42 (92.28%)	0.38 (7.72%)	4.79 (100%)
2011	78	39	6.73 (92.45%)	0.54 (7.55%)	7.28 (100%)
2012	82	38	7.05 (91.56%)	0.66 (8.44%)	7.70 (100%)
2013	107	43	10.04 (91.11%)	0.98 (8.89%)	11.02 (100%)
2014	111	43	13.91 (91.51%)	1.29 (8.49%)	15.20 (100%)
Total			44.91 (91.60%)	4.12 (8.40%)	49.03 (100%)

Note: These results are based on the 481 markets where the market share of the Honeycrisp is greater than or equal to 1 percent. The values of consumer welfare are deflated by regional price indices from the Bureau of Labor Statistics (BLS) with the base period at 1982-84. The component ratios are presented in parentheses.

Conclusions

1. The average increase of consumer welfare is 3.14 cents per pound, of which 2.98 cents is explained by the increasing number of apple varieties and 0.16 cents by the price competition.

   Suppose the estimated welfare change from our sample can be extrapolated to the entire U.S. apple market. In that case, a back-of-the-envelope analysis suggests the introduction of Honeycrisp has increased total consumer welfare in the United States by about 940 million dollars between 2009 and 2014.

2. The introduction of Honeycrisp drives downwards the prices of competing apple varieties and the extent of price decline is positively associated with the market share of Honeycrisp.

3. The gains from sales revenue due to the introduction of Honeycrisp outweighs the loss due to the price decline of existing apple varieties.

Relevant News

News articles in *New York Times* and on *National Public Radio* claim that many growers in Washington state have been looking to switch from Gala and Red Delicious to Cosmic Crisp, a new variety derived from Honeycrisp (Karp 2015; Charles 2017).

This is in line with our finding that Gala and Red Delicious are the two varieties that suffer the largest decreases in prices from the introduction of Honeycrisp. Nevertheless, the incentives might quickly vanish as the growth of the Honeycrisp production will eventually reduce its price premium.