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Measuring the Impacts of Off-Season Berry Imports

Carlos Arnade and Fred Kuchler

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Abstract

This report estimates the value to U.S. consumers from the increased availability of strawberries, blueberries, blackberries, and raspberries during winter months. Findings suggest that additional supplies of these fruits from domestic off-season and foreign producers are especially valuable to consumers because they occur in winter months, when domestic fruit production is relatively low, consumers' choices are fewer than during spring, and prices are high. Findings also suggest that consumers would benefit from further reductions in seasonal production cycles. However, consumers receive larger benefits from making off-season berries available (having some berries rather than none) than from increasing supplies to the extent that off-season prices fall to in-season levels.

Keywords

seasonal imports, berries, compensating variation, consumers' welfare, virtual prices

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Contents

USDA
United States Department of Agriculture

A report summary from the Economic Research Service

October 2015

Find the full report at *www.ers.usda.gov/publications/err-economic-research-report/err197*

Measuring the Impacts of Off-Season Berry Imports

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What Is the Issue?

In recent years, a wide variety of fresh produce has become available to U.S. consumers during the winter. Increased off-season production domestically and imports of fresh produce into the United States, especially from the Southern Hemisphere (where the production season is opposite to that of the United States), offer consumers increased availability, more varieties, and, possibly, lower prices. Consumer benefits from off-season produce availability could be large, but there is little empirical evidence of the dollar value of these benefits.

Focusing on fresh berries—strawberries, blueberries, blackberries, and raspberries, which together account for 16 percent of retail fresh fruit expenditures in 2015—this study asks two questions: What is the value to U.S. consumers of the recent increase in the availability of fresh berries in winter (i.e., the value of having some berries available in winter rather than having none)? Second, how large would the consumer benefits be if these berries were available at in-season (spring) prices during the off-season (winter) in the United States?

What Did the Study Find?

The largest benefits (measured as an increase in consumer well-being by identifying the dollar value consumers place on greater availability) were associated with increasing berry availability from zero to current levels; smaller benefits might accrue from lowering off-season prices to in-season levels. Among the four berries, benefits are largest for strawberries. Annual consumer benefits of increasing wintertime strawberry supply from zero to its current level are 89 percent of average annual expenditures on all berries. Looking forward, rather than taking a historical perspective, if consumers paid springtime produce prices in the winter for strawberries (i.e., if off-season availability were substantially increased from current conditions), that change would generate benefits of $520 million annually, or 19 percent of average annual expenditures on all berries.

Benefits of increasing the supply of blueberries from zero to its current level were estimated to be $377 million, or 14 percent of annual expenditures on all berries. If current off-season availability of blueberries were increased (reduced seasonality), consumers would receive a $451-million benefit. Benefits of the initial increase in the supply of raspberries were estimated to be $225 million, with an additional $232 million possible from further reductions in seasonality.

ERS is a primary source of economic research and analysis from the U.S. Department of Agriculture, providing timely information on economic and policy issues related to agriculture, food, the environment, and rural America.

Benefits of the initial increase in the supply of blackberries were estimated to be $76 million, with benefits of $23 million from further reductions in seasonality.

How Was the Study Conducted?

Until the early 2000s, strawberries were not widely available in U.S. grocery stores during the winter. More recently, other berries became available in winter. When there were no retail sales, there were no recorded wintertime retail prices. Thus, it is not immediately obvious what price change should be used to judge the value of the increase in availability. This study adapted methods used to estimate consumer benefits of new product introductions—methods that have been used to evaluate novel electronic products and new branded products where prices are always missing prior to products being marketed—in order to estimate the benefits of berries becoming available in the winter.

Benefits were calculated as a compensating variation: the amount of money you would have to take away from a consumer to leave him or her exactly as well-off as before the price reduction. The compensating variation amounts to a difference in expenditures at different sets of prices, holding consumer well-being constant. The expenditure function was calculated based on estimates of a system of demand equations for berries. Berry demand equations were estimated using retail scanner data from 2009 to 2012. Expenditure differences were simulated by incorporating changes in retail prices.

The analysis rests on three assumptions. First, the seasons in which domestic production and imports are available do not overlap: domestic and imported berries are not supplied at the same time, so there is no direct price competition. Second, for consumers, the difference between imports and domestic berries is that transportation costs are higher for imports, raising the retail price above that of in-season domestic berries. Third, estimation is manageable because estimated berry demand focuses on substitution among berries, implicitly assuming berries are a separable group of fruit products for which consumers first decide between purchasing a berry product or something else.

Measuring the Impacts of Off-Season Berry Imports

Introduction

The U.S. retail supply of fresh produce is unlike that of manufactured foods, which are available year-round with prices contained in a narrow band. For many produce items, the quantity available in winter is a small fraction of that available in the spring, and winter retail prices are much higher than spring prices. For example, retail strawberry prices in late December have been twice that of prices in May in recent years (fig. 1). The high prices of produce in winter have not gone unnoticed. For many years, the entire supply chain has treated seasonal production cycles (or seasonality), which limits the fresh fruit and vegetables that are available for consumers to purchase depending on the season, as a problem to be solved.

Suppliers have employed a variety of technologies to address seasonality. For example, advances in storage technology adopted in the 1960s made it possible to market apples year-round (Washington State Apple Commission, 2010). The ability of fruits to withstand cold has been a focus of researchers at the University of Minnesota since the inception of its breeding program in 1878 (University of Minnesota, Minnesota Landscape Arboretum, 2014). Its successes (e.g., Honeycrisp, Zestar!®, and SnowSweet™ apples; various stone fruits; and grape varieties) all come to market early and capitalize on early-season high prices. Canadians were the first North Americans to adopt greenhouse tomato production and now produce tomatoes in all but two winter months (Cook and Calvin, 2005). More recently, tomato greenhouses in Mexico and the Southwestern United States produce year-round and compete with field-grown tomatoes.

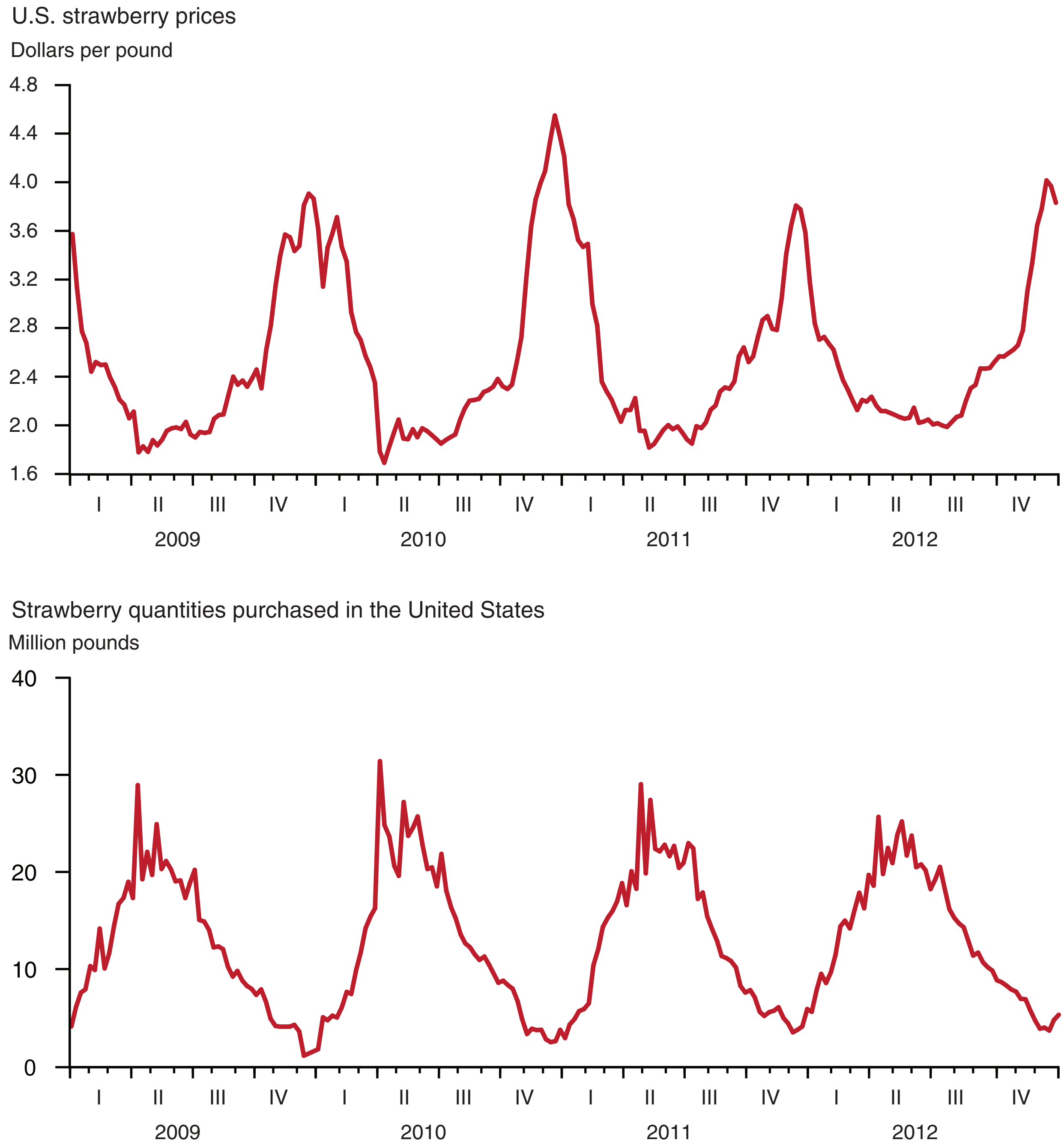
These developments have benefited U.S. consumers as the retail supply of fresh fruit and vegetables has expanded beyond their traditional seasons. In particular, two forces have reshaped produce availability throughout the year: initially, trade, and more recently, off-season increases in domestic production. First, moving produce from the Southern Hemisphere to the United States can also increase the winter supply of fruits and vegetables, as seasons in the Southern Hemisphere are opposite those in the United States. Although doing so incurs large transportation costs, this trade can alleviate the difficulty for U.S. suppliers of duplicating springtime conditions in the winter.

Trade has augmented the produce supply in the off-season (when domestically supplied produce is sparse to strict) with a wide and increasing range of foods. Exports of grapes, stone fruits, and avocados from Chile (Cook, 2001) or asparagus and processed artichokes from Peru (Ferrier and Zhen, 2014; Meade et al., 2010) to the United States have helped address some of the Northern Hemisphere's winter demand.

Second, developments in storage technology and plant breeding have also substantially reduced the seasonally imposed limits on the supply of produce (Arnade et al., 2005). The retail supply of fresh fruit and vegetables has started to look more like the supply of manufactured foods, where availability is year-round and retail prices do not vary with seasons. Consumers benefit from such changes by having more months each year to purchase a wide array of fresh fruit and vegetables.

Figure 1

Weekly U.S. retail strawberry prices and quanities purchased



Note: Both prices and quanities are weekly and for retail markets. Roman numerals refer to yearly quarters.
Source: USDA, Economic Research Service calculations using IRI InfoScan data.

Impacts of trade and technology are especially prominent in the retail market for fresh berries (here defined as strawberries, blueberries, raspberries, and blackberries). Until the early 2000s, berries were unavailable to most U.S. consumers outside of their short domestic production seasons. For example, in 1980, the U.S. Bureau of Labor Statistics (BLS) reported monthly strawberry prices for April, May, and June. In all other months, strawberries were available in grocery stores so infrequently that monthly prices could not be constructed.[1] This situation began to change in following years with prices reported in March and July. Twenty-four years later and onward, BLS reports prices every month, suggesting there is now year-round availability (Kuchler and Stewart, 2008). Off-season availability of berries may represent a significant welfare gain for U.S. consumers.[2]

More recent events suggest the berry market is changing again, with the off-season supply rising toward the in-season supply. In the period 2005-08, annual imports of strawberries averaged 142 million pounds. In 2013, strawberry imports more than doubled to 330 million pounds (12 percent of annual utilization). Raspberry imports averaged 21 million pounds from 2004 to 2008 but more than tripled to 73 million pounds in 2013 (65 percent of annual utilization). Blueberries averaged 81 million pounds from 2005 to 2008 and more than tripled by 2013 to 228 million pounds (53 percent of annual utilization) (USDA, Economic Research Service, 2014a). Note that most imports occur in the fall and winter months when domestically supplied berries are at their lowest. The retail blueberry market depends entirely on imports November-February (USDA, Agricultural Marketing Service, 2014).

Long-term trends in U.S. per capita availability of fresh fruits are increasing (USDA, Economic Research Service, 2014b), with per capita availability (fresh weight equivalent) of 106.50 pounds in 1980 and 131.04 pounds in 2012 (the most recent data). Availability increased 29.9 percent, and the average annual growth rate over the period was 0.6 percent. The berry share of 1980 fresh fruit availability was 2.0 percent (2.15 pounds), but it grew to 7.5 percent (9.50 pounds) by 2012. That is, the berry share of fresh fruit availability increased 3.75 times. In 2012, berries were 16.0 percent of retail expenditures on fresh fruit (see Data section below).

[1]U.S. city average monthly strawberry prices are maintained under the title “CPI—Average Price Data.” See http://www.bls.gov/data.

[2]In some details, the off-season strawberry supply differs from that of other berries. The domestic strawberry season now extends through a large portion of each year. Moving from a springtime supply to a year-round retail supply began with development of new strawberry varieties with greater resistance to cold and disease, along with varieties that bore fruit in the summer. However, in general, all berry crops evolved similarly—technological changes occurred and berries began to be shipped from new locations and in nontraditional seasons.

Methodology

This study aims to measure the benefits to consumers of increasing the off-season availability of berries. A close examination of reductions in retail prices and increases in purchases can reveal much about the benefits consumers receive from increased availability. But what if initially there is nothing being sold—nothing is available in the off-season? Without a reported price for off-season berries, it is not immediately obvious how to evaluate the benefits of berries becoming available, albeit in limited quantities, during winter. The absence of a reported retail price could mean the product was unavailable at any price—an infinite price—or it could mean that the price was finite but still too high for many consumers' budgets. That is, a first look at the problem does not offer a price change to examine; the answer is initially indeterminate.

To measure the benefits of increasing availability of off-season berries, we adapt methods for estimating benefits of new-product introductions. These methods were intended for evaluating benefits of wholly new goods, like cell phones in the 1990s (Hausman, 1999) or new varieties of familiar products (Hausman, 1997; Hausman and Leonard, 2002). Berries are familiar foods, unlike cell phones; at their introduction, cell phones were a product consumers had never seen before. And berries are not like a new variety of breakfast cereal, also initially unfamiliar to consumers. But strawberries in winter were a novelty to consumers until the early 2000s, and other berries took longer to become available in winter. Only a few years ago, off-season berries were new to consumers.

Hausman's method for valuing new product introductions finds an exact measure of the monetary value consumers assign to the change. Unlike consumers' surplus that is subject to changes in the marginal utility of money, compensating variation (here denoted *CV*) is the amount of money you would have to take away from a consumer to leave the consumer exactly as well off as before a price decline. It is the change in income that just compensates the consumer for the price change. Hausman showed that the *CV* is estimable. However, the calculations depend on finding the lowest price that would assure that nothing would be purchased.

Hausman's insight was that parameters from a system of demand equations could be used to construct the consumers' expenditure function, the minimum expenditure given a utility level. The expenditure function shifts with different prices, and when consumer well-being is held constant the shift is equivalent to the *CV*. We use estimated parameters from a system of berry-demand functions to specify a consumer expenditure function. Comparing expenditure function estimates at different sets of prices enables us to calculate the *CV* associated with increasing the levels of interhemispheric exchanges—namely, we estimate the benefits to consumers of retail berry prices falling. To evaluate the current gains from off-season availability of berries, we simulate the expenditure function when prices are so high that no one would purchase berries, and again using recent grocery store prices realized from wintertime purchases. The difference in expenditures is the value consumers attach to having off-season berries. Looking to the future, we also consider the benefits of moving from the current situation (in which berries are available year-round but at prices that swing widely across seasons) to a much larger level of imports that would allow springtime prices to prevail in the winter.

After 1973, Chile began exporting apples and grapes to the United States; over the 1980s and 1990s, Chile expanded this trade to include stone fruit products (Arnade and Sparks, 1993). More recently, Chile has exported strawberries, raspberries, blackberries, and blueberries (Chilean Fresh Fruit Association, 2014) during fall and winter. Although Mexico has become a major supplier of several berry crops to the United States during the winter, this study uses Chile's export season[3] as a benchmark period for measuring the consumer benefits arising from the initiation of off-season imports. A few years ago, domestic supplies were not large enough to show up at all in market statistics during this part of the year. We estimate the benefits derived from making some berries available in U.S. retail markets during these months. Our prospective case is more speculative—during the same window of time, we ask what it would be worth to consumers to have the current wintertime berry supply expand to the size of the springtime supply, driving wintertime prices to the lower springtime levels.

We focus on berries because the introduction of berry exports from Chile[4] is an example of a clearly specified, albeit small, change in the seasonal supply of fruit. That feature makes it possible to gauge the value of benefits consumers receive by having some berries available during winter, as opposed to having none. We can also simulate the benefits that might accrue from having wintertime berry prices fall to springtime prices. While berries make up a small component of produce supplied to U.S. consumers, the history of berry supply is one of absence during the winter (until recently). Thus, expansion of that supply into the winter months unambiguously yields benefits for consumers. The magnitude of these benefits, however, has not yet been tallied.

The introduction of a new product might offer large efficiency gains, supporting new industries and providing benefits to consumers (Romer, 1994). Many studies have estimated the consumer welfare benefits arising from new product introductions (Bonfrer and Chintagunta, 2004; Pofahl and Richards, 2009). From a consumer-welfare perspective, new products generate both a price effect and a variety effect. The price effect is what a typical trade model would capture—imported goods compete with domestic goods and cause prices to fall, conferring a price benefit to consumers. However, new product introductions also satisfy consumers' desires for variety—a little of each good is preferred to a large quantity of a single good—and such introductions widen the consumption set (a variety effect) (Hausman and Leonard, 2002).[5]

Our focus is entirely on the variety-effect component of consumers' benefits from berry imports. The variety effect is likely to be the larger component of the addition to consumers' surplus as long as consumers actually prefer more seasonal variety in their consumption habits.[6] Broda and Weinstein (2006) also recognized that opening a market to international trade can have effects similar to the introduction of new products and that Hausman and Leonard's approach can guide empirical estimation of welfare effects. Our study applies Hausman and Leonard's method to measuring consumer benefits from seasonal trade.

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[3]The Chilean Fresh Fruit Association (2014) advertises that blueberries are available for export mid-October through the end of April, strawberries are available from late October through the end of March, raspberries are available from late October through the end of May, and blackberries are available from mid-November through mid-March.

[4]Whether berries were imported from Chile or another country matters to importers but not to consumers, so long as consumers view berries as a commodity. The benefits to consumers of increased availability and lower prices would be the same in either case.

[5]Many studies have measured diversity in consumers' purchase patterns, beginning with a study by Theil and Finke (1983). Jekanowski and Binkley (2000) did so for some major categories of food and for brands within categories. They showed that consumers prefer variety. However, their variety measures do not lend themselves to measuring the value of specific new products.

[6]Ruan et al. (2007) considered whether imported raspberries compromised farm-level demand for domestic raspberries. They found that fresh-market imports had no significant effect on U.S. fresh-market prices.

Our focus builds on previous research using trade models that measure the benefits accruing from trade on an annual basis. Examining benefits from changes in average annual prices may fail to capture the variety effect and thus may understate the gains from trade. This failure is especially problematic for measures of produce trade. Focusing on annual prices will mask the importance of off-season imports—most transactions occur when markets are supplied by domestic producers, at in-season low prices, so annual data will mirror in-season transactions. Thus, if the focus is on annual prices, the periods in which there is relatively little competing produce available to consumers will largely be ignored. In other words, initiating transactions in the winter months when the marginal utility of consumption is relatively high may cause wintertime prices to fall from very high levels, greatly improving consumer well-being. However, as the scale of such transactions is typically small compared to in-season transactions, the large benefits may be invisible when only annual data are considered.

Characterizing the Benefits of Increased Seasonal Variety

This study's compensating variation (*CV*) approach measures the welfare gains from trade and increased seasonal variety in consumers' diets. Hausman and Leonard (2002) specify compensating variation (*CV*) as

$$(1) \qquad CV = E\,(\boldsymbol{P}_1, P_n, \boldsymbol{r}, U_1) - E\,(\boldsymbol{P}_0, P_n^*(\boldsymbol{P}_0), \boldsymbol{r}, U_1)$$

where *CV* is the change in the consumers' expenditure function (*E*), and the difference is taken before and after the introduction of a new product. Utility is held at the post-introduction utility level U_1. Competing products are treated as being available before the new product was introduced at price (vector) $\boldsymbol{P}_0$ and at price (vector) $\boldsymbol{P}_1$ after the introduction. P_n is the price of the new product after its introduction and P_n^* is the inferred price of the new product prior to introduction. Hausman and Leonard call this the virtual price and define it as a price high enough to ensure zero demand for the products. In other words, the introduced product is treated as if it were available before it was introduced, but at a price so high that no one would purchase it. To emphasize the attributes of this price, we refer to it as the choke price. A vector of other product prices, $\boldsymbol{r}$, are included in equation 1. These goods are assumed separable and their prices unaffected by the introduction.

In adapting the Hausman and Leonard approach to the problem of estimating the benefits consumers receive from increased availability of off-season berries, we make two simplifying assumptions:

1. The seasons in which domestic production is available and the season in which imports are available do not overlap. With this assumption, domestic and imported berries are not supplied at the same time, so there is no direct price competition.[7]

2. Consumers do not discriminate between domestic berries and imported berries. Advances in storage and transportation technology allow importers to supply berries to the U.S. market that are largely equivalent to domestic berries (Coyle and Ballenger, 2000).[8] The main difference

[7]Over time, both the domestic supply season and the import season have lengthened. When domestic production and imports both add to availability, price falls further. Thus, our methods are likely underestimating benefits in following years.

[8]Compared to other fruit, berries have a relatively short shelf life. In the distant past, transportation across hemispheres might have taken a major share of shelf life, leaving imported berries at retail quicker to deteriorate than domestic berries. Advances in storage and transportation technology make it reasonable to assume that consumers think of imports and domestic berries as indistinguishable. If there were real differences in shelf life, grocers would be unlikely to carry imports, as in-store losses would be costly and they would risk routinely disappointing consumers. That imports are commonly stocked indicates these types of costs are negligible.

between imports and domestic berries is that transportation costs are higher for imports, raising the retail price above that of in-season domestic berries.

These two assumptions allow the dollar value of benefits consumers receive from the introduction of off-season berries to be calculated for the initiation of trade based on observed off-season prices and calculated choke prices. The benefits arising from further increasing the off-season availability of berries can be calculated based on observed off-season and in-season prices.

Consumer Benefits of Initiating Seasonal Trade

When describing the market impacts of interhemispheric imports of produce, it is natural to think of two seasons: the part of the year in which markets are supplied by domestic farmers (here denoted in-season production), and the part in which imports prevail (denoted as the off-season). Our first assumption comes from the observation that berries, whether imported or domestic, cannot be stored long as fresh fruit. Thus, there is little possibility that consumers substitute between off-season and in-season berries. It is therefore possible to write the annual expenditure function as the sum of two components—an expenditure function for the months in which importers supply the market (E_I) and an expenditure function for the months in which domestic farmers supply the market (E_D):

$$E = E_I\,(\boldsymbol{P_I^M}, \boldsymbol{P_I^D}, U_I) + E_D\,(\boldsymbol{P_D^M}, \boldsymbol{P_D^D}, U_D). \quad (2)$$

Expenditures during the off-season are a function of prices and well-being or utility, denoted U_I. The variable $\boldsymbol{P_I^M}$ is written with the subscript $\boldsymbol{I}$ to indicate the off-season period and with superscript M to indicate prices for imported goods. Prices for domestic products during the off-season are denoted by the vector $\boldsymbol{P_I^D}$. In-season prices are denoted using the same convention. Utility may differ between periods. Prices of other products, denoted $\boldsymbol{r}$ in (1), are dropped as their presence does not affect this study's analysis.

Treating the off-season and the in-season supplies as occurring in non-overlapping periods means that the measure of consumer benefits associated with the initiation of imports will only depend on prices and consumption during the months in which importers supply the market. This seasonal separation and the calculation of benefits are described in the appendix.

Our second assumption is that the only difference consumers recognize between in-season and off-season berries is price, and the price difference reflects the market reality that it costs more to bring berries into the U.S. supply chain from South America than from California. This differs from Hausman and Leonard (2002), who focused on branded products (goods that can be differentiated). Such goods have packaging that can be used to draw consumers' attention to unique product attributes. Advertising campaigns that raise consumers' awareness of product differences are common, but fruit is often sold as a commodity with relatively few identifying attributes.[9] Thus, we treat each berry crop as a commodity, undifferentiated by origin or other attributes that might follow origin.[10] From consumers' perspectives, therefore, imports are perfect substitutes for domestic berries. The implication of the second assumption is that there is one berry demand function for each berry crop

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[9]Since September 30, 2008, country-of-origin labels have been mandatory for fresh and frozen produce (http://www.ams.usda.gov/AMSv1.0/cool). Thus, consumers might be aware of origin when shopping. However, they would already be aware that fruit is imported as long as they are aware of the seasons.

[10]Retailers distinguish among varieties of many other fruits, such as apples, pears, and oranges. At retail, Red Delicious apples and Granny Smith apples are priced differently. IRI data also maintain those distinctions. However, IRI data contain no variety distinctions for berries; granularity of its data is no finer than, say, strawberries.

and demand is not differentiated by origin or season. In effect, one price will prevail for each berry crop at any time.

Consider first a situation (regime 1) in which there are no imports, so that domestic fruit is available only during part of the year (the climate makes it physically or financially impossible for domestic farmers to produce in the rest of the year). In regime 2, we allow imports during those months when domestic farmers cannot supply the fruit. In regime 2, imported fruits are available part of the year and domestic fruits are available during another part of the year.

As long as consumers treat domestic and imported berries as perfect substitutes, there will be only one market price. In the appendix, we show that, in this case, the dollar value of consumer benefits derived from increased off-season availability reduces to difference between the off-season expenditure functions, evaluated at a constant utility level:

(3) $$CV = E_I(\boldsymbol{P_I^M}, U_I) — E_I(\boldsymbol{P_I^M}(\boldsymbol{P_I^D}), U_I).$$

$\boldsymbol{P_I^M}$ is a vector of off-season berry prices and $\boldsymbol{P_I^M}(\boldsymbol{P_I^D})$ are choke prices of berry products, depending on prices for domestically-produced berries. The importance of equation 3 is that the first right-hand-side term represents actual expenditures over the period in which imported fruit prices were observed. The second term represents what expenditures would have been if the consumption of imported fruit were zero in the post-introduction period. Given the expenditure function and choke prices, along with the assumption that consumption is a good measure of well-being, the *CV* can be calculated.

Consumer Benefits of Increasing Seasonal Trade

Separating expenditures into in-season and off-season components can also be used to examine the value of new technologies, which could lead to a future in which the supply chain finds cost-effective ways to add to off-season supplies. Despite the climate-imposed limits on domestic production, imports enable U.S. consumers to purchase fresh berries throughout the year. However, as off-season purchases are small relative to in-season domestic production, the potential for off-season supply has only been partially tapped. Further advances in plant breeding or storage technology might make off-season supply quantitatively similar to in-season supply. Additionally, technological changes might reduce the cost of interhemispheric shipping, eliminating seasonality in the quantity of produce available. The *CV* could be expressed as the difference in consumer expenditures between a future in which the price for imported produce falls to the domestic in-season price and the current situation:

(4) $$CV = E_I(\boldsymbol{P_I^M}(\boldsymbol{P_D^D}), U_I) — E_I(\boldsymbol{P_I^M}, U_I).$$

This *CV* represents the value consumers receive from new technologies that reduce seasonality.[11]

[11]As *CV* is a difference, most theoretical discussions clearly define starting and ending points along with the sign of the difference. Otherwise, it would be difficult to systematically classify changes as beneficial or costly. Here, whenever berries become more readily available, expenditures fall, yielding unqualified benefits. For that reason, we ignore the sign of *CV* formulas. Similarly, calculated expenditure reductions in the Results section are all presented as positive numbers and are treated as measurements of benefits.

Measuring the Benefits of Increased Seasonal Variety

Expenditure Functions and Demand Systems

To measure the *CV*—either assessing the value that can be attributed to the off-season imports realized over preceding years or looking forward to new technologies that would further reduce seasonality—we estimate changes in expenditures when different prices are allowed. This exercise requires use of an estimated or simulated expenditure function. Therefore, the first step is to estimate the parameters of the expenditure function. The specific functional form adopted by Deaton and Muellbauer (1980) was, after a log transformation,

$$(5) \quad ln\, E(u,p) = \alpha_0 + \sum_k \alpha_k \ln(p_k) + \frac{1}{2}\sum_k \sum_j \gamma_{ij}^{*} \ln(p_k)\ln(p_j) + u\beta_0 \prod_k p_k^{\beta_k}$$

All but two of the parameters of the expenditure function can be recovered from the Almost Ideal Demand System (AIDS), as the AIDS was derived from the expenditure function. (See appendix for the mechanics of recovering the parameters that are not estimated in the AIDS model.) AIDS models specify budget shares of various goods in a household's total expenditure as functions of prices and actual expenditures. Demand for four types of berries is modeled using weekly retail point-of-sale store scanner data.[12] The typical share equation of the AIDS model is:

$$(6) \quad S_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} ln(P_j) + \beta_i ln\left(\frac{x}{PI}\right) + \varepsilon_i ,$$

where S_i represents the expenditure share of the i^{th} berry variety, P_j the price of the j^{th} berry variety, and γ_{ij} is the corresponding coefficient representing the influence of the j^{th} berry price on the purchase of the i^{th} berry variety. The term *ln x* represents the log of actual expenditures on berries.[13] The linear approximate AIDS (LA/AIDS) model we estimate deflates expenditures by the Stone Price Index, *PI*, the log of which is the sum of share-weighted log prices (Asche and Wessels, 1997).[14] Symmetry requires $\gamma_{ij} = \gamma_{ji}$ and homogeneity requires $\sum_j \gamma_{ij} = 0$, respectively. Adding-up requires $\sum_i \gamma_{ij} = 0$, $\sum_i \alpha_i = 1$ *and* $\sum_i \beta_i = 0$. For estimation, one share equation is dropped from the system to avoid singularity, but the dropped equation's parameters are recovered using the symmetry, homogeneity, and adding-up conditions. Uncompensated own-price elasticities (η_{ii}) and cross-price elasticities (η_{ij}), as well as conditional expenditure elasticities (η_i), can be calculated as

$$\eta_{ii} = -1 + \frac{\gamma_{ii}}{S_i} - \beta_i, \eta_{ij} = \frac{\gamma_{ij}}{S_i} - \beta_i \frac{S_j}{S_i}, \ \eta_i = 1 + \frac{\beta_i}{S_i}$$

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[12]Berries are assumed separable from other household purchase decisions. The reason for this assumption is that berries are soft fruit that can deteriorate quickly and they cannot be stored as long as most other fruit unless frozen. Hence, purchase decisions involving fresh berries would often be out of phase with decisions involving other fruit. In particular, blackberry purchases are often referred to as "impulse purchases" (Sobekova et al., 2013, p. 13). Storing (freezing) berries also differs from storing other fruits. Apples taken from controlled atmosphere storage are similar in appearance and sensory characteristics to more recently harvested apples, but frozen berries are physically different from fresh berries; frozen and fresh berries would not always be substitutable in use.

[13]Following Deaton and Muellbauer (1980), we distinguish between actual expenditures (x) and the expenditure function $E(u,p)$, though the two are equal for utility-maximizing consumers.

[14]Despite the popularity of the Almost Ideal Demand System (AIDS) functional form, it has some shortcomings. For example, Moschini (1995) shows that the Stone's Index is not invariant to units of measurement. However, in our case, the data closely fit the AIDS model.

Implicit in this procedure is the assumption that berries form a separable group of fruit products. In effect, consumers first decide between purchasing a berry product or something else. Then, having chosen to purchase berries, they choose which berry product to buy. When consumers substitute between a specific berry product and some other fruit product, there are two components to that decision.

Choke Prices

Once the expenditure function is estimated, the key step in valuing product introductions is deriving a virtual or choke price. Hausman and Leonard (2002) estimated demand equations and solved for prices. Setting quantities equal to zero then revealed choke prices (i.e., the demand system represented in equation 9 was used to calculate the price that would drive the new brand demand to zero, holding the prices of existing goods at their observed levels). In their study of potato chip introductions, Arnade et al. (2011) found that solving share equations for prices generated choke-price estimates with large variance; some estimated choke prices were unrealistically high and some were unrealistically low. As an alternative, they developed a technique using elasticities to generate choke prices, a method also used by Muhammad (2013). We follow this approach to derive choke prices for our models. We calculate choke prices using the definition of a price elasticity, $\eta = dln\, q / dln\, p$, and a base price, $\bar{p}$. From the definition of the elasticity,

$$\frac{q' - \bar{q}}{\bar{q}} = \eta \frac{p' - \bar{p}}{\bar{p}}.$$

at the choke price, $q' = 0$. Thus, the choke price p' can be calculated as

$$p' = \left(\frac{\eta - 1}{\eta} \right) \bar{p} \ .$$

Data

To estimate the retail demand for berries, we used proprietary data on food purchases from IRI (formerly Information Resources, Inc.) called InfoScan. A selection of retail establishments across the United States and Puerto Rico provide IRI each week with a record of all transactions (expenditures on each item purchased and quantity purchased), and there is a separate line for each item that crossed a store's scanner. The stores reporting include grocery stores, supermarkets, supercenters, convenience stores, drug stores, and liquor stores. Some retailers provide data at the store level (i.e., sales data for a particular brick-and-mortar location), while others provide data for stores within a market area and keep the store location of each transaction undisclosed. Each retailer defines geographic areas as it chooses. Over the period 2009-12, the data were derived from scanner records of 43,554 (2009) to 46,021 (2012) individual stores and 130 (2009) to 131 (2012) market areas. We used the revenue to reflect consumer expenditures. Then we summed the quantities from the individual store and market area data, identifying the total as U.S. weekly quantity purchased, and summed the expenditures from each source to calculate U.S. weekly expenditures. Weekly prices were then constructed as unit values.

Random weight products in InfoScan have information on variety (e.g., Red Delicious apple), cut (e.g., bone-in chicken), and descriptors for deli-prepared foods (e.g., cheese pizza). We excluded all products indicating any preparation beyond being bagged or placed in a container since our study focuses on berries. We also excluded several berry varieties that make up a relatively small part of the berry data (i.e., items identified as mixed berries, gooseberries, cranberries, and other). To maintain a consistent sample of stores across time, data from 2008 were excluded. Walmart was included in the sample at the beginning of 2009, greatly increasing average expenditures and quantities purchased and reducing average prices from that point onward.

Table 1 shows descriptive statistics (means and standard deviations) calculated from variables that were used to model demand for berries: total expenditures on berries by week, total quantity purchased by week, weekly price, and weekly budget share. The top portion of the table shows unconditional statistics, calculated without regard to seasons. The data show that strawberries are the largest share of the berry market whether measured in expenditures, pounds, or budget share. On a budget-share basis, blackberries, blueberries, and raspberries take on greater significance to the berry market than they do when considering product weight.

The lower part of table 1 shows the importance of seasons. Statistics were calculated for the portion of each year when Chile typically exports and for the remaining weeks of the year. That distinction reveals that average weekly expenditures and quantity purchased are lower during Chile's export season than they are at other times for all four berry crops. Except for blackberries, average weekly prices are higher during Chile's export season. In-season blackberry prices are higher than prices during the Chilean export season because prices typically rise in the short period before imports reach the U.S. market.

Table 1

Weekly berry purchases

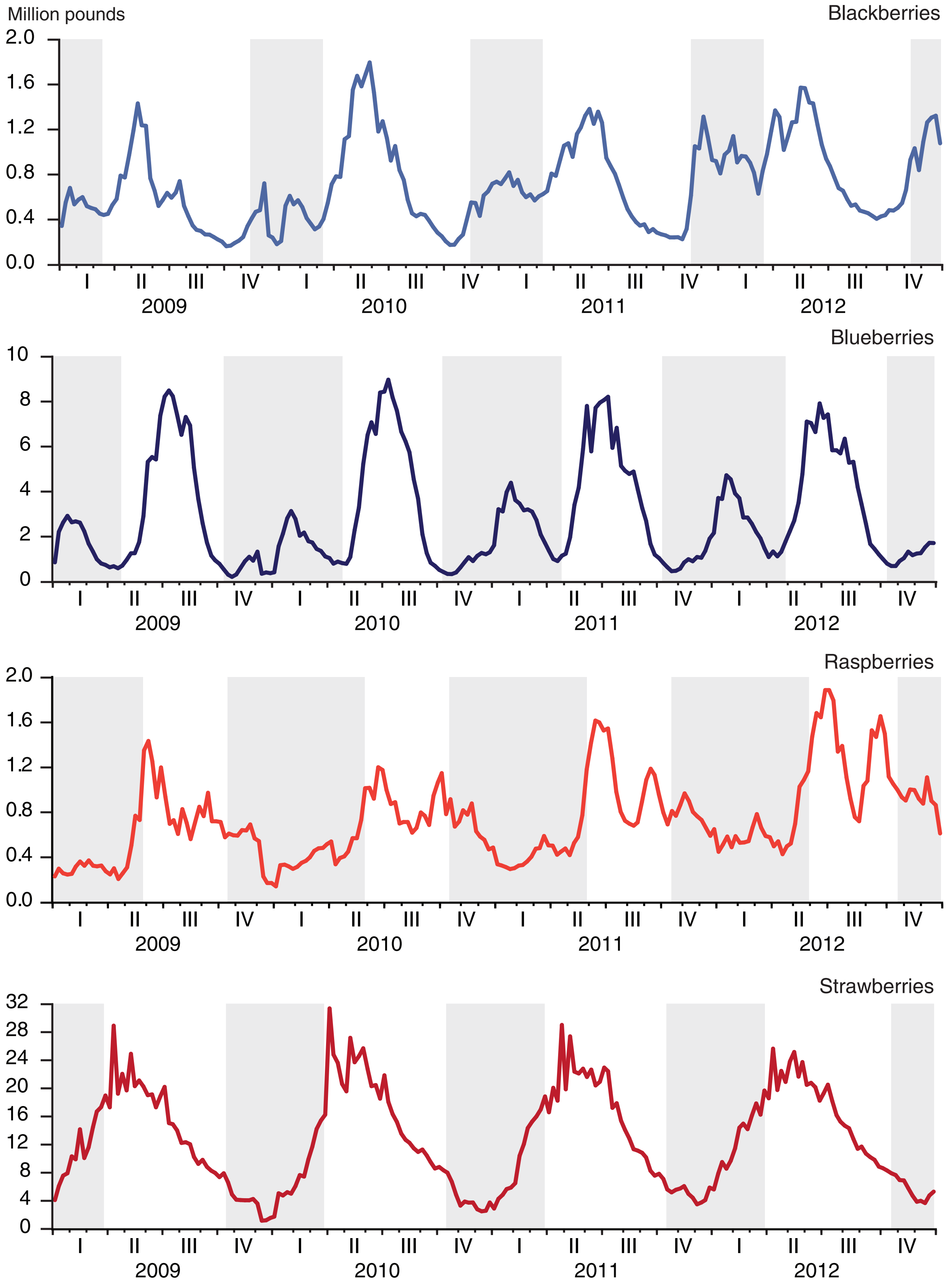
		Expenditures (million dollars)	Quantity (million pounds)	Price[2] (dollar per pound)	Budget share
Unconditional statistics (calculated without regard to seasons)					
Blackberries	Mean	3.8	0.7	5.76	0.08
	Std. dev.	1.5	0.4	1.07	0.03
Blueberries	Mean	13.0	2.9	6.26	0.26
	Std. dev.	5.8	2.4	2.60	0.07
Raspberries	Mean	5.2	0.7	7.70	0.11
	Std. dev.	1.7	0.4	1.68	0.04
Strawberries	Mean	28.5	12.8	2.54	0.56
	Std. dev.	11.5	7.1	0.66	0.08
Statistics by season[1]					
Blackberries during Chilean export season	Mean	3.6	0.7	5.44	0.09
	Std. dev.	1.0	0.3	0.78	0.03
Blackberries all other weeks	Mean	3.9	0.7	5.92	0.07
	Std. dev.	1.7	0.4	1.16	0.02
Blueberries during Chilean export season	Mean	10.0	1.6	7.41	0.24
	Std. dev.	3.6	1.1	2.30	0.07
Blueberries all other weeks	Mean	16.4	4.4	4.92	0.28
	Std. dev.	5.9	2.6	2.28	0.06
Raspberries during Chilean export season	Mean	4.5	0.6	8.64	0.11
	Std. dev.	1.3	0.2	1.43	0.04
Raspberries all other weeks	Mean	6.2	1.0	6.20	0.12
	Std. dev.	1.7	0.3	0.59	0.03
Strawberries during Chilean export season	Mean	21.9	8.0	3.08	0.53
	Std. dev.	9.5	5.0	0.64	0.09
Strawberries all other weeks	Mean	33.8	16.5	2.12	0.58
	Std. dev.	10.3	6.1	0.23	0.07

[1]The Chilean Fresh Fruit Association advertises that blueberries are available for export mid-October through the end of April, strawberries are available from late October through the end of March, raspberries are available from late October through the end of May, and blackberries are available from mid-November through mid-March.

[2]The price variable is a unit value, calculated as expenditures/quantity each week. These calculated prices were used to estimate the berry demand model, and the average of these weekly unit values is presented. Note that for each berry and both seasons, the mean of the weekly unit values is always higher than the mean of expenditures/mean of quantity because the mean of the weekly unit values is not weighted by quantity purchased.

Source: USDA, Economic Research Service calculations using IRI InfoScan data.

Figure 2
Quantities of berries purchased weekly in the United States, 2009-2012



Note: Gray areas indicate Chilean export seasons. Roman numerals refer to yearly quarters.
Source: USDA, Economic Research Service calculations using data from IR InfoScan and the Chilean Fresh Fruit Association.

Figure 2 shows time plots of weekly quantities of each of the four berries. Annual cycles are apparent in each, particularly for strawberries. For each berry, the peak to trough range is greater for expenditures than for quantities, so unit values (the calculated price) are also cyclical but with inverted peaks and troughs (i.e., when prices peak, quantities purchased and expenditures both take minimal values).

Gray areas in fig. 2 show the seasons in which Chile exports berries. Peak purchase levels occur each year outside the periods in which Chile exports (i.e., the peaks occur during periods in which supply is largely of domestic origin). Imports into the U.S. market appear to raise troughs in purchases. For blueberries, raspberries, and strawberries, the Chilean export seasons appear to cover the deepest troughs in purchases. The export season for blackberries is comparatively short, and these exports augment domestic supply for only part of the off-season. That is, part of the off-season displays quantities purchased at their lowest levels (fig. 2).

Results

Demand System Estimates and Choke Prices

Table 2 shows results of the LA/AIDS model estimated with berry data from IRI. A seemingly unrelated regression procedure was used to estimate the model (EViews 8), and share equations were estimated for blackberries, blueberries, and raspberries using 209 weekly observations. Coefficients and t-statistics for the strawberry equations were calculated using adding-up, symmetry, and homogeneity. Initial estimation showed evidence of first-order autocorrelation in residuals. We added a first-order autocorrelation term on the errors of each equation. For consistency with adding-up, we restricted these coefficients (Rho in table 2) to be the same across equations (Berndt and Savin, 1975).

All coefficient estimates are statistically significant at conventional significance levels. Results from share-based models are easiest to discuss in terms of price and expenditure elasticities. The own-price elasticities all indicated demands were price elastic, with estimates from -1.5 to -2.0. All the estimated cross-price elasticities are positive, indicating all berries substitute for each other to some extent. Andreyeva et al. (2010) reviewed studies on the price elasticity of demand for major food categories. Summarizing 20 studies of demand for the category "fruit," they reported that the mean elasticity was 0.70, with a 95-percent confidence interval that was wholly in the inelastic range. Our estimates should be larger as we are examining demand for individual fruits, where substitution possibilities are much larger than for entire categories. Sobekova et al. (2013) used weekly panel data from 52 U.S. cities to estimate price elasticities for the same four berry crops. Their own-price elasticity estimates ranged from -1.256 to -1.884, with rank order identical to ours, and their cross-price elasticities were also all positive.

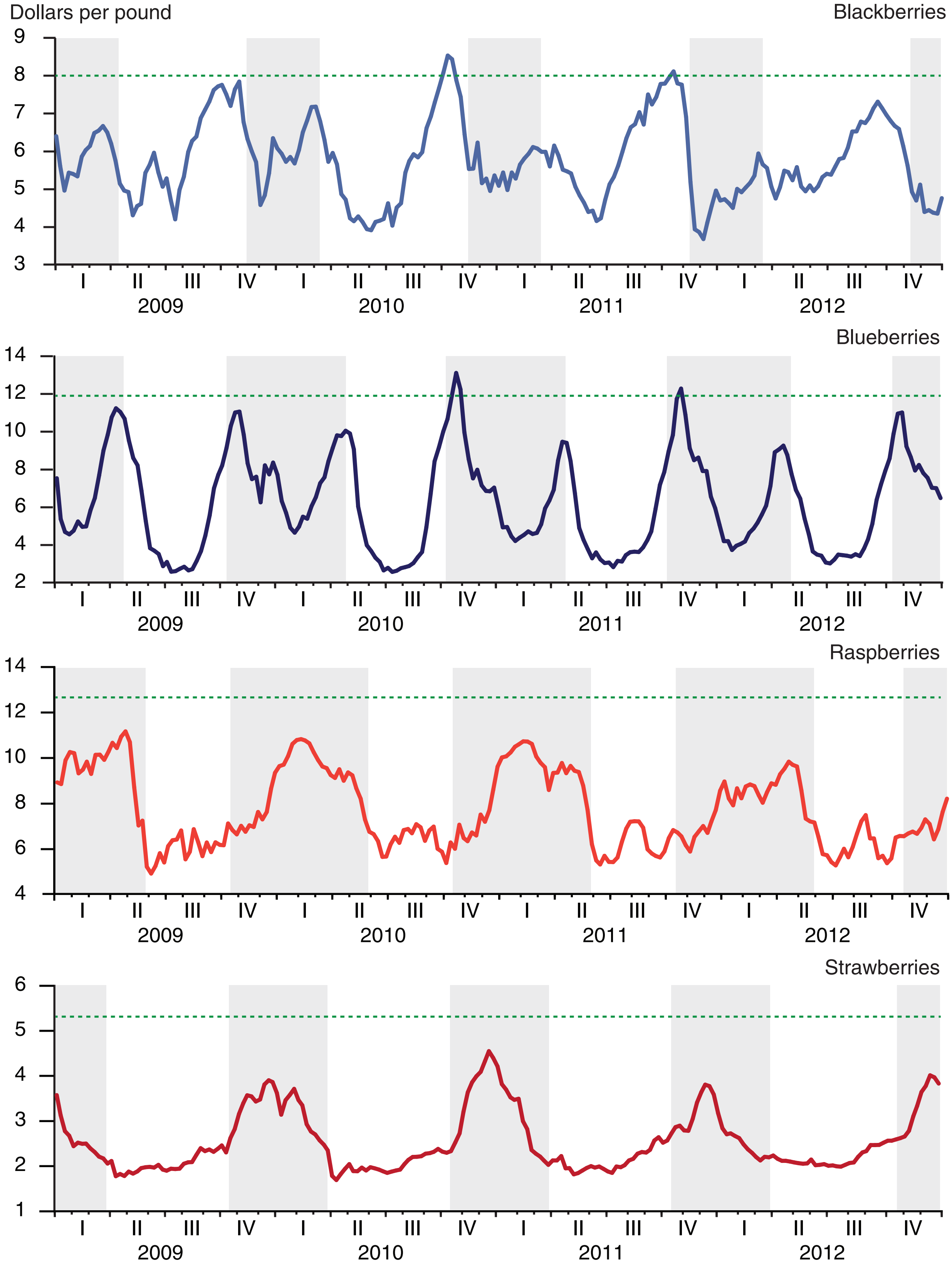
Choke prices were calculated from the estimated own-price elasticities. Figure 3 shows the relationship between weekly retail prices and the calculated choke prices. For each berry, the choke price was calculated as a deviation from a base price, where the base price was tallied as a 4-year average price over the weeks in which Chile typically exports each berry. The calculated choke prices are typically higher than average prices and only rarely exceeded by actual prices.

Table 2
Results of berries' LA/AIDS model

	Coefficient	t-Statistic	Elasticities	t-Statistic
Blackberry share equation				
Constant	0.291	7.16		
Blackberry price	-0.078	-16.55	-2.039	-31.63
Blueberry price	0.014	4.25	0.193	4.33
Raspberry price	0.019	4.77	0.253	4.78
Strawberry price	0.045	8.48	0.615	8.64
Expenditure	-0.011	-4.28	0.851	24.33
Blueberry share equation				
Constant	0.614	6.10		
Blackberry price	0.014	4.25	0.056	4.32
Blueberry price	-0.166	-19.87	-1.631	-50.31
Raspberry price	0.026	6.32	0.104	6.38
Strawberry price	0.126	13.43	0.498	13.65
Expenditure	-0.016	-2.58	0.938	39.26
Raspberry share equation				
Constant	0.431	8.47		
Blackberry price	0.019	4.77	0.168	4.79
Blueberry price	0.026	6.32	0.240	6.47
Raspberry price	-0.107	-16.18	-1.946	-31.96
Strawberry price	0.062	9.02	0.565	9.26
Expenditure	-0.015	-4.46	0.869	29.68
Strawberry share equation				
Constant	-1.336	-10.87		
Blackberry price	0.045	8.48	0.078	8.06
Blueberry price	0.126	13.43	0.214	12.79
Raspberry price	0.062	9.02	0.106	8.50
Strawberry price	-0.233	-16.47	-1.458	-57.58
Expenditure	0.041	5.48	1.074	79.29
Rho	0.784	29.50		

Notes: LA/AIDS refers to the linear approximate Almost Ideal Demand System.
Source: USDA, Economic Research Service calculations using IRI InfoScan data.

Figure 3
Choke prices and weekly retail prices for berries



Notes: Choke prices are prices high enough to usually drive quantity demanded to zero. Horizontal dotted line indicates choke prices, and were calculated using the in-season average weekly price and the estimated price elasticity. Gray areas indicate periods in which Chile typically exports. Roman numerals refer to yearly quarters.
Source: USDA, Economic Research Service calculations using data from IRI InfoScan.

Dollar Benefits of Increased Seasonal Variety

Two cases are simulated and reported:

- Case 1 is the retrospective case, examining the consumer benefits of increased availability and having some berries available in the winter months. For each berry, the price is set equal to its choke price, and counterfactual expenditures are calculated and compared to expenditures based on recently observed prices.

- Case 2 is prospective, treating the current market conditions as a partial solution to the seasonality problem. There are wintertime berries being sold at prices some consumers accept, but prices are still far higher than in spring. This second case considers the consumer benefits of off-season berry prices falling from current levels to in-season levels. The case measures the benefits that would accrue to consumers if importers could bring berries to the United States in the winter at the same prices that domestic farmers do in the spring.

Figure 4 shows weekly expenditures on berries when one berry price is set at its choke price level and all others are at observed levels. The four sets of simulations were calculated for the particular season Chile exports each berry. In each case, simulated expenditures calculated with one price set at the choke price are higher than when all prices are at market levels. All four simulations show expenditures rising toward the onset of domestic production each year when prices are relatively high.

The top half of table 3 shows an annual summary of the four simulations shown in fig. 4. In case 1, on an annual basis, the strawberry compensating variation is far larger than the others, largely because the quantity of strawberries is so much larger and the price reduction is larger than that for other berries. In-season prices in case 2 were calculated as the average over the month with highest shipments (USDA, Agricultural Marketing Service, 2014). Highest monthly shipment numbers occur in June for blackberries, blueberries, and raspberries. Shipments of strawberries are highest in May each year. Figure 5 shows the off-season pattern of expenditures with market prices and with each berry price set at its in-season price. Annual summaries of the four simulations are in the bottom half of table 3.

Table 3
Results of compensating variation calculations

Berry type	Compensating variation (million dollars per year)	Compensating variation as a percent of average annual expenditures
Case 1: Choke prices decline to recently observed prices		
Blackberries	76.5	2.8
Blueberries	376.9	13.6
Raspberries	225.3	8.2
Strawberries	2459.7	89.0
Case 2: Off-season prices decline to in-season prices		
Blackberries	22.6	0.8
Blueberries	450.9	16.3
Raspberries	231.6	8.4
Strawberries	520.0	18.8

Source: USDA, Economic Research Service calculations using IRI InfoScan data.

The largest consumer benefits were associated with increasing berry imports from zero to their current levels (case 1); smaller benefits might accrue from lowering off-season prices further (case 2). Of course, this measure of consumer benefits does not take into account gains that could be attributed to increased competition. If competition from importers led U.S producers to lower the prices they charge in spring, the calculated benefits arising from berry imports would be higher.

The factor driving these consumer benefits is prices falling over the winter months—the difference between choke prices and market prices in the weeks in which Chile exports fruit. On average, these declines range from 49 percent (blackberries) to 69 percent (strawberries). Figures 1 and 2 highlight the situation over the months Chile exports berries. Compared to springtime, when domestic production is available, the quantity available in winter is relatively small and prices are relatively high. These facts raise the question behind case 2—suppose winter prices fell to spring prices, which might occur if other countries began supplying the U.S. market or if there are advances in technology (either through improvements in domestic storage or shipping). The average price decline would again be large, and the increase in quantity purchased would also be relatively large. Would consumers reap even larger welfare gains?

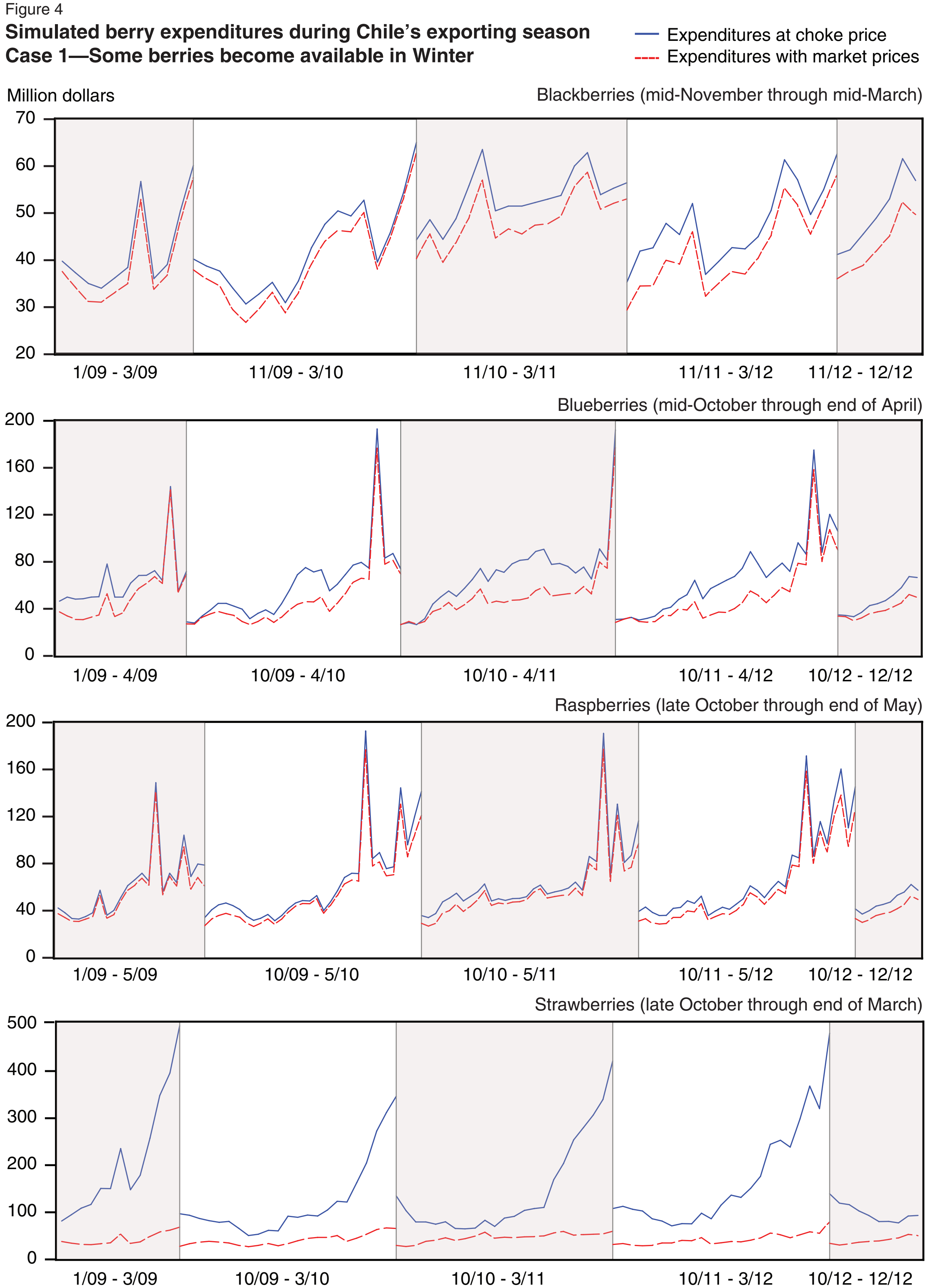
The annual tallies for case 2 reveal that the benefits of initiating trade do not scale-up. The difference between cases 1 and 2 is especially striking for strawberries. The consumer benefits of case 2 are a small fraction of those in case 1, and price changes alone are not enough to explain why. In case 1, strawberry prices fell on average 69 percent—dropping from the choke price to the prices in the winter. In case 2, prices fell 63 percent—dropping from the average winter price to average spring prices when domestic shipments peak. Yet, consumer benefits are much smaller in case 2 because the marginal utility of additional strawberries diminishes quickly. In effect, consumers are much better off having some small quantity of high-priced strawberries in the winter than not. They would be even better off (by $520.0 million annually, or 18.8 percent of average annual expenditures (simulated) on all berries) if they could purchase springtime quantities while facing springtime prices in winter, but this change adds much less to their well-being than does the former.

For the other berries, benefits increase approximately in proportion to price declines. Benefits of the current supply of raspberries were estimated to be $225.3 million (case 1), with an additional $231.6 million possible from further reductions in seasonality (case 2). Case 1 simulates a 51-percent decrease in the price of raspberries, while case 2 simulates a 49-percent price decline. Benefits of the current supply of blueberries were estimated to be $376.9 million, or 13.6 percent of average annual expenditures on all berries. A further reduction in seasonality for blueberries creates an additional $450.9-million benefit (case 2). However, case 1 simulated blueberry prices falling 61 percent, while case 2 was based on average prices during the period in which Chile exports were 121 percent higher than the prices when shipments peak (i.e., case 2 simulates a much larger price reduction). Blackberries show case-1 benefits ($76.5 million) approximately four times larger than in case 2 ($22.6 million), but the price decline simulated in case 1 is also approximately four times larger than in case 2. The finding that strawberry consumption is subject to sharply diminishing marginal utility underscores how important it is to account for consumption across the calendar year when measuring the gains from trade. Notably, an annual model—relying on average annual data—would start with a base consumption level too high to reflect winter levels and too low to reflect spring levels. Thus the model would likely fail to capture the high values consumers place on newly available goods when those goods appear seasonally.

Of course market conditions do change. Over time, domestic suppliers have found ways to lengthen the time each year that domestic supplies are available. Imports have arrived from additional countries, often at lower prices. That is, new technologies that augment supply have replaced other technologies, and lower cost importers replaced the first off-season suppliers. The benefits calculated from the initial changes that made off-season consumption possible do not evaporate with adoption of a new technology or from import competition. Instead, the benefits of off-season availability increase as retail prices fall. But the source of these benefits changes. Benefits that were initially attributed to Chilean and Mexican production might in the nearby future be attributed to plant-breeding advances adopted by domestic farmers.

Figure 4

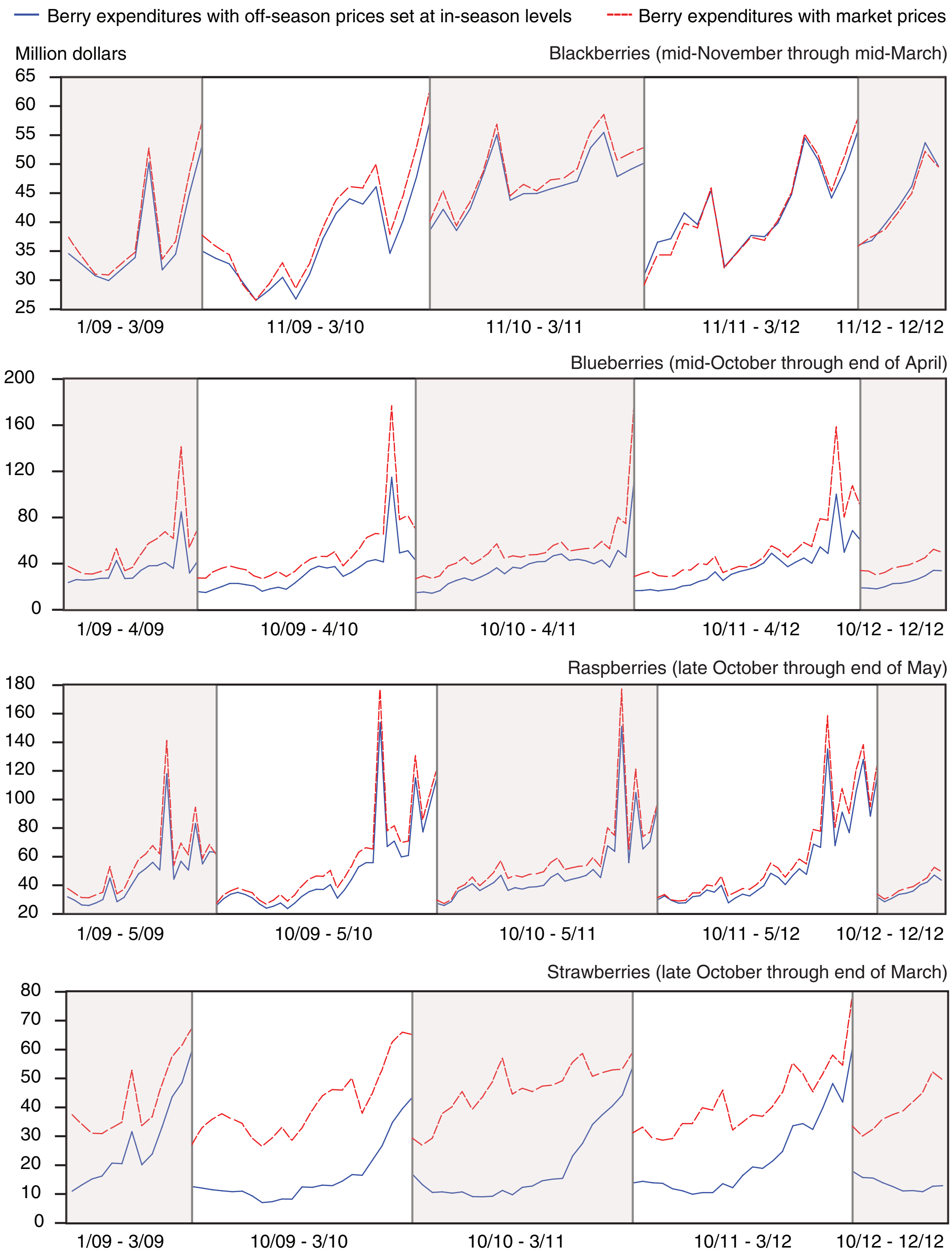
Simulated berry expenditures during Chile's exporting season
Case 1—Some berries become available in Winter



Notes: These graphs compare expenditures calculated with observed prices with expenditures in which one berry price is set at the choke price.
Source: USDA, Economic Research Service calculations using data from IRI InfoScan.

Figure 5

Simulated berry expenditures during Chile's exporting season
Case 2—Off season berry prices fall to in-season levels



Notes: These graphs compare expenditures calculated with observed prices with expenditures in which one berry price is set at in-season levels.
Source: USDA, Economic Research Service calculations using data from IRI InfoScan.

Conclusions

This study focused on the consumer benefits from increased availability of berries during winter months. It also examined additional benefits that might accrue to consumers if off-season prices matched those during domestic production seasons. The results show that making a product available, at a point in time when the initial level of consumption is zero or close to it, can generate large benefits for consumers.

The analysis rests on three assumptions. First, the seasons in which domestic production and imports are available do not overlap: domestic and imported berries are not supplied at the same time, so there is no direct price competition. Second, for consumers, the difference between imports and domestic berries is that transportation costs are higher for imports, raising the retail price above that of in-season domestic berries. Third, estimation is manageable because estimated berry demand focuses on substitution among berries, implicitly assuming berries are a separable group of fruit products for which consumers first decide between purchasing a berry product or something else.

The annual benefits derived from making berries available during the winter months range from $76 million for blackberries to $2.5 billion for strawberries. The range is wide partially because the market sizes are so different and diminishing marginal utility is apparent in the much larger strawberry market. The range is also wide because the season in which Chile—the country that defined our benchmark season—exports strawberries is centered on the annual price peaks and the season for blackberry exports is not. The results show that large benefits can come from small changes in seasonal access to fruit. Our results also point to the important role of trade in making a product seasonally available, a gain not typically measured in trade models.

The two scenarios simulated here—the initiation of trade and the further expansion of trade that drives off-season prices down to match in-season prices—show that consumers would benefit from both changes. Benefits from the former are larger, while benefits from the expansion of trade are speculative. However, the market reveals that it is financially feasible to grow and harvest produce in one hemisphere and market that same produce in another hemisphere. Speculating that the price might fall to a half or a third of current levels is reasonable, particularly given the possibility of further improvements in storage and transportation technology.

Although our estimated welfare benefits are high, there is reason to suspect that the reported benefits in table 3 represent a lower bound. Our measurements of benefits reflect the difference in market conditions between the time at which wintertime berries were introduced and the current market situation. In the intervening period, both the import season and the months in which domestic berries are available have expanded. Now that there is a period each year in which there is direct competition between imports and domestic berries, prices are likely to be lower than they were when the two seasons were entirely separate. This benefits consumers and is the price effect discussed in traditional trade models (but not included here). Second, as Ferrier and Zhen (2014) have shown, year-round availability allows consumers to form consumption habits and increases overall demand. Future studies that measure the price effect and the habit-formation effect may reveal that the gains from off-season imports are even larger than those reported in this study.

Additionally, this study relies on data from a sample of retail stores—the InfoScan data represent a very large sample of retail stores in the United States, but it is still a sample. If the analysis were repeated with data from a full complement of retail stores or with data weighted to represent the entire United States, calculated benefits would likely be larger.

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Appendix: Mechanics of Simulating the Welfare Benefits From Falling Prices

Benefits of Initiating Trade

The function describing annual expenditures on berries (equation 2 in text) was constructed as the sum of two separable components—an expenditure function for the months in which importers supply the market (E_I) and an expenditure function for the months in which domestic farmers supply the market (E_D):

(1a) $$E = E_I\,(\boldsymbol{P_I^M}, \boldsymbol{P_I^D}, U_I) + E_D\,(\boldsymbol{P_D^M}, \boldsymbol{P_D^D}, U_D)$$

Expenditures during the off-season are a function of prices and well-being or utility, denoted U_I. The variable $\boldsymbol{P_I^M}$ is written with the subscript $\boldsymbol{I}$ to indicate the off-season period and with superscript $\boldsymbol{M}$ to indicate prices for imported goods. Prices for domestic products during the off-season are denoted by the vector $\boldsymbol{P_I^D}$. In-season prices are denoted using the same convention. Utility may differ between periods. Prices of other products, denoted $\boldsymbol{r}$ in (1), are dropped as their presence does not affect this study's analysis.

The CV between regime 1 (there are no imports) and regime 2 (imports occur seasonally) can be written as the difference in expenditures:

(2a) $$CV = E_I\,(\boldsymbol{P_I^M}, \boldsymbol{P_I^D}\,(\boldsymbol{P_I^M})\; U_I) + E_D\,(\boldsymbol{P_D^M}\,(\boldsymbol{P_D^D}), \boldsymbol{P_D^D}, U_D).$$
$$—\{E_I\,(\boldsymbol{P_I^M}\,(\boldsymbol{P_I^D}), \boldsymbol{P_I^D}\,(\boldsymbol{P_I^M})\; U_I) + E_D\,(\boldsymbol{P_D^M}\,(\boldsymbol{P_D^D}), \boldsymbol{P_D^D}, U_D)\}.$$

The left side of the upper component of equation 2a represents regime 2, where off-season expenditures are a function of imported prices $\boldsymbol{P_I^M}$ and the choke price of domestic fruit. The choke price is the minimum price that is high enough to drive demand to zero. Following Hausman and Leonard (2002) , the choke price is defined by the existing imported-goods prices. These expenditures are evaluated at domestic choke prices because when imports are available, domestic goods are not. The right side of the upper component represents in-season expenditures, and the choke price for imports appears because there are no imports at that time. This choke price is defined by the price of available domestic goods.

The lower component of equation 2*a* represents regime 1, in which there are no imports at any time. Here, off-season expenditures are a function of choke prices for both imported and domestic fruits, as neither product is available. The right side of the lower component represents in-season expenditures, and expenditures are a function of domestic in-season prices and imported berry choke prices, defined by in-season prices. Equation 2*a* can be rewritten as:

(3a) $$CV = E_I\,(\boldsymbol{P_I^M}, \boldsymbol{P_I^D}\,(\boldsymbol{P_I^M}), U_I) — E_I\,(\boldsymbol{P_I^M}\,(\boldsymbol{P_I^D}), \boldsymbol{P_I^D}\,(\boldsymbol{P_I^M}), U_I).$$
$$+\{E_D\,(\boldsymbol{P_D^M}\,(\boldsymbol{P_D^D}), \boldsymbol{P_D^D}, U_D) — E_D\,(\boldsymbol{P_D^M}\,(\boldsymbol{P_D^D}), \boldsymbol{P_D^D}, U_D)\}.$$

which is equivalent to:

(4a) $$CV = E_I\,(\boldsymbol{P_I^M}, \boldsymbol{P_I^D}\,(\boldsymbol{P_I^M}), U_I) — E_I\,(\boldsymbol{P_I^M}\,(\boldsymbol{P_I^D}), \boldsymbol{P_I^D}\,(\boldsymbol{P_I^M}), U_I).$$

Since the in-season expenditures are equivalent in both regimes[15] the *CV* between regime 1 and 2 reduces to the two terms represented in equation 4a.

Our second assumption is that consumers treat off-season berries as perfect substitutes for domestic berries (i.e., the only difference consumers recognize between domestic and imported berries is price, and the price difference reflects the market reality that it costs more to bring berries into the U.S. supply chain from South America than from domestic sources). This differs from Hausman and Leonard (2002), who focused on branded products (goods that can be differentiated). The implication of the second assumption is that there is one berry demand function for each berry crop and demand is not differentiated by origin or season. In effect, one price will prevail for each berry crop at any time. Then, the *CV* measure is reduced to:

(5a) $$CV = E_1(\boldsymbol{P}_{\boldsymbol{I}}^{\boldsymbol{M}}, U_1) - E_1(\boldsymbol{P}_{\boldsymbol{I}}^{\boldsymbol{M}}(\boldsymbol{P}_{\boldsymbol{I}}^{\boldsymbol{D}}), U_1).$$

The importance of equation 5a is that the first right-hand-side term represents actual expenditures over the period in which imported fruit prices were observed. The second term represents what expenditures would have been if the consumption of imported fruit were zero in the post-introduction period. Given the expenditure function and choke prices, along with the assumption that consumption is a good measure of well-being, the *CV* can be calculated and used to represent the consumer benefits from having berry products available year round.

Consumer Benefits of Increasing Seasonal Trade

Separating expenditures into in-season and off-season components can also be used to examine the value of new technologies, which could lead to a future in which the supply chain finds further cost-effective ways to add to off-season supplies. Examples might include new shipping and storage technologies that reduce costs of importing or plant breeding that increases cold hardiness of berry plants, expanding the domestic supply season. With either type of advance, the *CV* could be expressed as the difference in consumer expenditures between a future in which the price for imported produce falls to the domestic in-season price and the current situation:

(6a) $$CV = E_1(\boldsymbol{P}_{\boldsymbol{I}}^{\boldsymbol{M}}(\boldsymbol{P}_{\boldsymbol{D}}^{\boldsymbol{D}}), U_1) - E_1(\boldsymbol{P}_{\boldsymbol{I}}^{\boldsymbol{M}}, U_1).$$

This *CV* represents the value consumers receive from new technologies that reduce seasonality.[16]

Expenditure Functions and Demand Systems

To estimate the expenditure function, this study uses the specific functional form adopted by Deaton and Muellbauer (1980). After a log transformation, the expenditure function is:

(7a) $$ln\,E(u,p) = \alpha_0 + \sum_k \alpha_k ln(p_k) + \frac{1}{2}\sum_k \sum_j \gamma_{ij}^{*} ln(p_k) ln(p_j) + u\beta_0 \prod_0 p_k^{\beta_k}.$$

[15]Price effects are, of course, possible even though we assume they are absent here. By excluding potential price effects, we are focusing on the variety effect, a benefit that is overlooked in previous trade analyses.

[16]As CV is a difference, most theoretical discussions clearly define starting and ending points along with the sign of the difference. Otherwise, it would be difficult to systematically classify changes as beneficial or costly. Here, whenever berries become more readily available, expenditures fall, yielding unqualified benefits. For that reason, we ignore the sign of CV formulas. Similarly, calculated expenditure reductions in the Results section are all presented as positive numbers and are treated as measurements of benefits.

The demand system estimates parameters $\hat{\alpha}_k$ and $\hat{\gamma}^*_{ij}$ (all the parameters in the expenditure function except α_0 and β_0). We use the estimated parameters from the demand system along with prices and expenditures on each berry to recover α_0 and β_0. Multiplying the estimated parameters by log prices yields part of the expenditure function. Substituting actual expenditures (*ln x*) for *ln E(u,p)* and subtracting the log price terms yields all but a constant and the last right-hand-side term of equation 7a. That is, the remainder of the expenditure function is a constant α_0 and β_0, multiplied by $u\prod_k p_k^{\hat{\beta}_k}$. The latter can be calculated under the assumption that utility u is proportional to total quantity purchased, at least over the limited range examined here.

(8a) $$ln\,x - \sum_k \hat{\alpha}_k \ln(p_k) - \frac{1}{2}\sum_k \sum_j \hat{\gamma}^*_{ij} \ln(p_k) \ln(p_j) = \alpha_0 + u\beta_0 \prod_k p_k^{\hat{\beta}_k} + v_i$$

We append an error term v_i. Then, remaining terms and can be recovered as coefficients estimated in an Ordinary Least Squares (OLS) model regressing the calculated left-hand side of equation 8a on a constant and the calculated variable $u\prod_k p_k^{\hat{\beta}_k}$. Utility is represented by the total quantity purchased of all berry products. Once all the parameters of the expenditure function are estimated, different price regimes (along with total quantity) can be substituted in the function, and differences in expenditures can be calculated, simulating changes in consumer welfare.