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Consumers' welfare and off-season produce imports

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Abstract

In recent years, produce imports to the United States from the southern hemisphere made wintertime consumption common. Focusing on imports of fresh berries – strawberries, blueberries, blackberries and raspberries – this study asks what is the value to consumers of increasing the availability of berries in winter? The study adapts Hausman's new product introduction methods. The largest benefits were associated with initiating trade. Further increases suggest smaller benefits. Among the four berries, consumer benefits of initiating trade are largest for strawberries at $2.5 billion, over twice current expenditures. Further price reductions might generate further benefits of $520 million annually.

Keywords: seasonal imports, compensating variation, virtual prices

JEL classification: D120, F61

1. Introduction

The US retail supply of fresh produce displays strong seasonality – systematic and predictable variations in price and quantity throughout the calendar year. For many fruits, annual production cycles persist; the quantity available in winter is a small fraction of what is available in the summer and winter farm prices are multiples of summer prices (Plattner, Perez and Thornsbury, 2014). Perishability varies among fruits and annual farm price patterns are especially strong for fruits that have relatively short shelf lives. The seasonal pattern of farm prices is mirrored in retail prices, but for some fruits, seasonality has diminished. That is, the amplitude of annual price and quantity cycles has diminished and there are fewer months in which fruits are not generally available at retail (Arnade and Pick, 1998). The off-season high prices have created incentives for the entire supply chain to add to off-season supply.

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Suppliers have employed a variety of technologies to increase the availability of produce throughout the year. For example, advances in storage technology that were adopted in the 1960s made it possible to market apples year round (Washington State Apple Commission, 2010). Cold hardiness has been a focus of the University of Minnesota since the inception of its breeding programme in 1878 (University of Minnesota, Minnesota Landscape Arboretum, 2014). Its successes (e.g. Honeycrisp, Zestar!® and SnowSweet™ apples, and various stone fruit and grape varieties) all come to market early and take advantage of early-season high prices. Canadians were the first North American adopters of greenhouse tomato production, producing in all but two winter months (Cook and Calvin, 2005). More recently, tomato greenhouses in Mexico and the Southwest United States allowed year-round production and competition with field-grown tomatoes.

These successes have benefitted consumers as the retail supply of fresh fruit and vegetables has expanded beyond traditional seasonal bounds. However, the fastest way to augment the off-season produce supply is to import during the off-season. Moving produce from the southern hemisphere to the United States offers the greatest potential for realising the benefits derived from seasonal differences as seasons are opposite to the United States. In the fall and winter, domestic producers have to struggle with the problem of duplicating springtime or summertime conditions. Southern hemisphere producers have no such problem at that time. In effect, comparative advantage is not fixed, but varies seasonally among trading partners.

Trade has augmented the off-season produce supply and has done so for a wide and increasing range of foods. Shipping southern hemisphere grapes, stone fruits and avocados from Chile (Cook, 2001) or asparagus and processed artichokes from Peru (Meade, Baldwin and Calvin, 2010; Ferrier and Zhen, 2014) to the United States has proved itself a physically and financially viable means of meeting some of the winter demand. Arnade, Pick and Gehlar (2005) showed that seasonally imposed limits on the supply of fruit have decreased.

The working hypothesis in this paper is that suppliers' long-term response to high off-season prices is best understood by knowing how much off-season trade is worth to consumers. As an example, we examine the off-season demand for berries. Berries are familiar foods, but initiating trade makes berries supplied in fall and in winter much like a new product introduction. Looking back a few years, berries were unavailable to most consumers outside of their short domestic production seasons. For example, in 1980, the Bureau of Labor Statistics found strawberries in grocery stores frequently enough to report prices only April through June.[1] Twenty-four years later and onward, the Bureau of Labor Statistics reports prices every month, suggesting that there is now year-round availability (Kuchler and Stewart, 2008). That is, in 1980, it would have been very unlikely that a shopper would encounter strawberries in grocery stores in December. The strawberry is not a new or novel

1 The US city average monthly strawberry prices are maintained under the title 'CPI—Average Price Data'. See http://www.bls.gov/data.

product, but the strawberry in winter is a recent product introduction. Like any new product introduction, there is potential for large efficiency gains, supporting new industries and providing benefits to consumers (Romer, 1994). This recent addition to the retail food supply, off-season availability of berries, may represent a significant welfare gain for US consumers. And berries are a small part of off-season trade.

We focus on berries because the initiation of berry exports from Chile is an example of a clearly specified, albeit small, change in the seasonal supply of fruit. Those features make it possible to gauge the value of benefits consumers received by having some berries available during fall and winter, as opposed to having none. And with the same method we can simulate further increases in availability: the benefits that might accrue to having fall and wintertime berry prices fall to springtime prices. While berries make up a small component of produce supplied to US consumers, the history of berry supply is one of the absences during the fall and winter until recently. Thus, expansion of that supply into non-traditional parts of the year unambiguously yields benefits for consumers. The magnitude of those benefits, however, has not yet been estimated.

The point of estimating these benefits is broader than the berry market. Trade economists have often been called upon to provide estimates of benefits and costs of proposed changes in trade policy, especially reductions in tariffs and trade barriers. The 2004 agreement between Chile and the United States that lowered tariffs most during the US winter is credited with doubling the value of Chile's fruit exports (OECD, 2013). Similarly, analysis of the North American Free Trade agreement – launched on 1 January 1994 and fully implemented 1 January 2008 – between the United States, Mexico and Canada, pointed to 'expansion in all facets of fruit and vegetable exports . . .' (Stout *et al.*, 2004: 39). Clearly, trade analysts have been aware that seasonal trade could be valuable to consumers. But there was no method for quantifying the benefits to consumers of greater availability of fruit during a season when availability was otherwise especially low.

1.1 The twin benefits of reduced seasonality

Measuring the benefits that accrue to consumers from changes in relative prices of imported and exported goods has long been the goal of trade studies (Huber, 1971; Baldwin and Murray, 1977; Robinson and Thierfelder, 2002; Bernhofen and Brown, 2005). Economic theory emphasises that after trade is initiated consumers benefit because imported goods are less expensive than equivalent domestically produced goods. And the price of domestically produced goods has to fall to compete with imports. Theory and empirical studies both focus attention on the benefits consumer receive from lower prices, the price effect.

Yet trade also increases the variety of goods that are available to consumers. In the context of new product introductions Hausman and Leonard (2002) showed consumer benefits can be decomposed into a price effect and a variety effect. The latter comes from widening the consumption set. Unlike the price effect, the variety effect often goes unmeasured despite being a direct benefit of trade. Here, we measure the variety effect in one market: the value to consumers of off-season imports of berries.

For this task, we adapt Hausman and Leonard's (2002) method for evaluating the welfare gains arising from the introduction of new products. Many studies, using similar methods, have estimated the consumer welfare benefits – price effects and variety effects – arising from new product introductions (Hausman, 1997; Bonfrer and Chintagunta, 2004; Pofahl and Richards, 2009). Bernhofen and Brown (2005) developed a (non-seasonal) trade model using similar methods. But the benefits from initiating produce trade across hemispheres can be best described as a variety effect. As southern hemisphere seasons are exactly opposite those in North America, the season in which domestic production is available often does not overlap with the import season. Thus, berry imports might not directly compete with domestic production and imports might not influence prices paid for domestic produce. In this case, consumer benefits arise only from goods that are newly available in fall and winter. The price effect could be relatively small or even zero.[2] 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.

Our focus deviates from previous trade research because trade models tend to measure the benefits that accrue on an annual basis. Examining, say, benefits from changes in average annual prices may fail to capture the variety effect and thus may be understating the gains from trade. This failure is especially problematic for produce. Focusing on annual prices will mask the importance of off-season imports: most transactions occur at in-season low prices, so annual data will mirror in-season transactions. As such, the periods in which there is relatively little competing produce available to consumers will be largely ignored. That is, initiating transactions in the fall and winter months when the marginal utility of consumption is relatively high may cause fall and wintertime prices to fall from very high levels, greatly improving consumer well-being. But as the scale of such transactions is typically small compared with in-season transactions, the large benefits may be invisible when only annual data are considered.

To carry out this analysis we estimate a system of demand functions for berries and use the estimated parameters to specify a consumer expenditure function. Comparing expenditure function estimates at different sets of prices allows us to calculate the compensating variation (CV) associated with increasing the levels of interhemispheric exchanges. CV is the change in income necessary to restore the consumer to his original utility level after a price change. It measures how far apart two indifference curves are by measuring the distance between tangent lines. In this case, it is the monetary value of increased availability and lower prices for berries. CV is more exact than consumers' surplus unless demand is insensitive to income.

2 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 US fresh-market prices.

Retrospectively, we simulate the expenditure function when prices are so high that no one would purchase berries and again using recent grocery store prices realised from wintertime purchases. The difference in expenditures is the value consumers attach to initiating off-season imports. Prospectively, we also consider the benefits of moving from the current situation in which seasonal price variations have been partially reduced by the current, relatively small, level of imports to one in which springtime prices prevail in the winter.

As our analysis calculates the benefits of first initiating trade during seasons in which there was no domestic production, the baseline is a period of no trade and no recorded prices. Our analysis is based on imputed changes in the price of four varieties of berries during a short import season.

After 1973, Chile began exporting apples and grapes to the United States. Over the 1980s and 1990s Chile expanded into stone fruit products (Arnade and Sparks, 1993). More recently Chile has exported berries: strawberries, raspberries, blackberries and blueberries (Chilean Fresh Fruit Association, 2014). This paper uses Chile's export season[3] as a benchmark period for measuring the consumer benefits arising from the initiation of off-season imports. The retrospective case we examine estimates the benefits derived from a discrete event: Chile's addition to the US fall and winter supply of fresh fruit. Our prospective case is more speculative. Looking at the same window of time during which Chile typically exports, we ask what it would be worth to consumers to have the current fall and wintertime berry supply expand to be as large as the springtime supply, driving fall and wintertime prices to springtime levels.[4]

The next section presents our CV approach to measuring the welfare gains from trade and increased seasonal variety in consumers' diets. We specify expenditure functions such that when domestic and imported produce are available at distinct, non-overlapping seasons, the CV depends only on off-season expenditures. The expenditures that make up the CV are functions of observed prices and prices that can be inferred. Then we present the methods used to estimate the CV: (i) estimation of a demand system that yields the parameters needed to specify expenditure functions, namely parameters that relate prices to expenditures and (ii) the method for imputing prices for periods in which there were no berries available. The following data section describes the IRI (formerly Information Resources, Inc.) data that we used to estimate retail demand for blackberries, blueberries, raspberries and strawberries. We use the data to illustrate the variation in purchases across seasons. In Section 5, we first present a linear approximate almost ideal demand system (AIDS;

3 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 to the end of March, raspberries are available from late October to the end of May, and blackberries are available from mid-November to mid-March.

4 Our analysis treats the inception of trade as if it were the only event occurring in berry markets. Of course, markets are not static and availability continues to increase. Blueberry imports from Chile, for example, were 21 million pounds in 2005 and 134 million pounds in 2013. Changes in production and transportation technology continue to add to the sources of off-season supply: more than 99 percent of strawberry imports and more than 95 percent of raspberry imports came from Mexico in 2013 (USDA, Economic Research Service, 2014b).

Deaton and Muellbauer, 1980) and imputed fall and wintertime prices prior to imports. Changes in expenditure functions are simulated and benefits are calculated. After the discussion of results, we provide conclusions.

2. Characterising the benefits of increased seasonal variety

Hausman and Leonard (2002) write compensating variation, CV, as

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

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) $\mathbf{P}_0$ and at price (vector) $\mathbf{P}_1$ after the introduction. P_n is the price of the new product after its introduction and P_n^* is the imputed 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. That is, 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 emphasise the attributes of this price we refer to it as the choke price. A vector of other product prices, $\mathbf{r}$, 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 CV associated with increased berry imports, we make two simplifying assumptions. Our first assumption is that the seasons in which domestic production is available and the season in which imports are available do not overlap. The second is that consumers do not discriminate between domestically produced berries and imported berries. The assumptions lead to the ability to calculate CV for the initiation of trade based on observed off-season prices and choke prices that can be calculated. The CV for expansion of trade can be calculated based on observed off-season and in-season prices.

2.1 Consumer benefits of initiating seasonal trade: seasonality is reduced

When describing market impacts of interhemispheric imports of produce, it is natural to think of two seasons: the part of the year in which markets are dominated by domestic, or in-season, production and the part in which imports prevail. Berries cannot be stored long as fresh fruit so it is possible to write the annual expenditure function as the sum of two separable components: an expenditure function for the months in which imports dominate the market (E_{I}) and an expenditure function for the months in which domestic supply is largely produced domestically (E_{D}):

$$E = E_I(\mathbf{P}_I^M, \mathbf{P}_I^D, U_I) + E_{\mathrm{D}}(\mathbf{P}_D^M, \mathbf{P}_D^D, U_D). \tag{2}$$

Expenditures during the portion of each year when imports dominate are a function of prices and well-being or utility, denoted U_I. The variable $\mathbf{P}_I^M$ is written with the subscript I to indicate the off-season or import period and with superscript M to indicate prices for imported goods. Prices for domestically produced products in the period in which imports dominate are denoted by the vector $\mathbf{P}_I^D$. In-season prices are denoted using the same convention. Utility may differ between periods. Prices of other products, denoted by $\boldsymbol{r}$ in equation (1) are dropped as their presence does not affect the following analysis.

Treating imports and domestic supply as occurring in non-overlapping periods means that the CV associated with the initiation of imports will only depend on prices and consumption during the months in which imports dominate. Consider first a situation (regime 1) in which there are no imports. During part of the year domestically produced fruit is available and for the remainder of the year climate makes it physically or financially impossible for domestic farmers to offer a positive supply. Then, allow imports during those months where climate prevents domestic farmers from supplying any product. In this second situation (regime 2), imported fruits are available part of the year and domestic fruits are available during another part of the year. Using the expenditure function in equation (2) the CV between regime 1 (there are no imports) and regime 2 (imports occur seasonally) can be written as:

$$\begin{aligned} \mathrm{CV} = {} & E_I(\mathbf{P}_I^M, \mathbf{P}_I^D(\mathbf{P}_I^M), U_I) + E_D(\mathbf{P}_D^M(\mathbf{P}_D^D), \mathbf{P}_D^D, U_D) \\ & - \{E_I(\mathbf{P}_I^M(\mathbf{P}_I^D), \mathbf{P}_I^D(\mathbf{P}_I^M), U_I) + E_D(\mathbf{P}_D^M(\mathbf{P}_D^D), \mathbf{P}_D^D, U_D)\}. \end{aligned} \tag{3}$$

The left side of the upper component of equation (3) represents regime 2, where off-season expenditures are a function of imported prices $\boldsymbol{P}_I^M$ and the choke price of domestic fruit – a choke price 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 (3) 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 imported berry choke prices, defined by in-season prices. Note that the expenditure functions during the domestic season are identical in the two regimes. Collecting terms, equation (3) can be rewritten as:

$$\mathrm{CV} = E_I(\mathbf{P}_I^M, \mathbf{P}_I^D(\mathbf{P}_I^M), U_I) - E_I(\mathbf{P}_I^M(\mathbf{P}_I^D), \mathbf{P}_I^D(\mathbf{P}_I^M), U_I). \quad (4)$$

Our second assumption is that consumers treat imported berries as perfect substitutes for domestically produced berries. This is also a break from the methods that Hausman and Leonard (2002) developed. Their focus was 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. Fruit is different. It is often sold as a commodity with relatively few identifying attributes.[5] Thus, we treat each berry variety as a commodity, undifferentiated by origin or other attributes that might follow origin. As such, from consumers' perspectives, imports are perfect substitutes for domestic fruit, and consumers do not discriminate between imported and domestically produced berries. The implication of the second assumption is that there is one berry demand function for each variety and demand is not differentiated by origin or season. In effect, at any time one price will prevail for each berry variety.

As long as consumers treat domestic and imported berries as perfect substitutes, the CV measure is reduced to

$$\mathrm{CV} = E_I(\mathbf{P}_I^M, U_I) - E_I(\mathbf{P}_I^M(\mathbf{P}_I^D), U_I). \quad (5)$$

The importance of equation (5) 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, CV can be calculated.

2.2 Consumer benefits of increasing seasonal trade: some seasonality is eliminated

The idea that expenditures can be separated into two seasonal components also lends itself to examining the value of new technologies: a future in which the supply chain finds cost-effective ways to add to off-season supplies. Despite the limits climate places on domestic production, purchases of berries now occur throughout the year. That is, imports have allowed some of the limits of climate to be overcome. The feasibility of interhemispheric imports has been attributed to advances in storage and transportation technology (Coyle and Ballenger, 2000). But, as off-season purchases are small relative to in-season domestic production, the constraints climate imposes on off-season supply have only partially been overcome despite the incentive of high off-season prices.

5 Since 30 September 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 made aware of origin when shopping. But, they would already be aware that fruit is imported as long as they are aware of seasons.

There remains an off-season during which supply is smaller and prices higher than in-season. Further advances in plant breeding or storage technology might make off-season supply quantitatively similar to in-season supply. Or, technological change might reduce the cost of interhemispheric shipping, eliminating seasonality in the quantity of produce available. The CV could be expressed as the difference in expenditures between a future in which the price for imported produce falls to the domestic in-season price and the current situation

$$\mathrm{CV} = E_I(\mathbf{P}_I^M(\mathbf{P}_D^D), U_I) - E_I(\mathbf{P}_I^M, U_I). \tag{6}$$

This CV represents the value consumers receive from new technologies that reduce seasonality.

3. Measuring the benefits of increased seasonal variety

3.1 Expenditure functions and demand systems

To measure the CV – either assessing the value that can be attributed to the off-season imports realised over preceding years or looking forward to new technologies that would further reduce seasonality – we estimate changes in expenditures when different prices are allowed. Carrying out this exercise requires the 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,

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

All but two of the parameters of the expenditure function can be recovered from the AIDS, as the AIDS was derived from the expenditure function. 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[6] is modelled using weekly retail point-of-sale store scanner data, which are described in greater detail in the next section. The typical share equation of the AIDS model is

6 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.

$$S_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln(P_j) + \beta_i \ln\left(\frac{x}{PI}\right) + \varepsilon_i \tag{8}$$

where S_i represent the expenditure share of the ith berry variety, P_j the price of the jth berry variety, γ_{ij} is the corresponding coefficient representing the influence of the jth berry price on the purchase of the ith berry variety. The term $\ln x$ represents the log of actual expenditures on berries.[7] The linear approximate AIDS model that we estimate deflates expenditures by the Stone price index, PI, the log of which is the sum of share-weighted log prices.[8]

Symmetry requires $\gamma_{ij} = \gamma_{ji}$ and homogeneity requires $\sum_j \gamma_{ij} = 0$, respectively. Adding up requires $\sum_i \gamma_{ij} = 0, \quad \sum_i \alpha_i = 0$ 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 $\eta_{ii} = -1 + (\gamma_{ii}/S_i) - \beta_i, \eta_{ij} = (\gamma_{ij}/S_i) - \beta_i(S_j/S_i)$, $\eta_i = 1 + (\beta_i/S_i)$. We use the estimated parameters from the demand system along with prices and expenditures on each berry to recover α_0 and β_0, the last two parameters of the expenditure function (7). Using the estimated parameters ($\hat{\alpha}_k$ and $\hat{\gamma}^*_{ij}$) and prices, part of the expenditure function can be subtracted from actual expenditures ($\ln x$) and moved to the left-hand side of the function (9)

$$\begin{aligned}\ln x - \sum_k \hat{\alpha}_k \ln(p_k) - \frac{1}{2}\sum_k \sum_j \hat{\gamma}^*_{ij} \ln(p_k)\ \ln(p_j) \\ = \alpha_0 + u\beta_0 \prod_k p_k^{\hat{\beta}_k} + v_i,\end{aligned} \tag{9}$$

where v_i is an error term. We assume that utility, u, is proportional to total quantity purchased, at least over the limited range examined here. Then, remaining terms α_0 and β_0 can be recovered as coefficients estimated in an OLS regression model.

7 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-maximising consumers.

8 The linear approximate AIDS model remains the standard procedure for studies of new product introductions (Hausman 1997; Hausman and Leonard 2002; Pofahl and Richards 2009; Arnade, Gopinath, and Pick 2011) despite Moschini's admonition that the Stone price index is not invariant with respect to changes in units of measurement. We estimated our model with the Stone index, but examined results using each of the three indices Moschini discussed as alternatives (with means as base period values): the Tornquist index (discrete approximation to the Divisia index), the log-linear analogue of the Paasche price index and the log-linear analogue of the Laspeyres price index. Own-price coefficients and elasticities using the Stone index are virtually identical to results from using the alternatives.

3.2 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, Gopinath and Pick (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, $\eta = d \ln q/d \ln p$, and a base price, $\bar{p}$. From the definition of the elasticity, $(q' - \bar{q}/\bar{q}) = \eta(p' - \bar{p}/\bar{p})$. At the choke price, $q' = 0$. Thus, the choke price, p', can be calculated as $p' = (\eta - 1/\eta)\bar{p}$.

4. Data description

To estimate the retail demand for berries, we used proprietary data on food purchases from IRI denoted InfoScan.[9] 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): a separate line for each item that crossed a store's scanner. The stores reported include grocery stores, supermarkets, supercentres, 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, keeping the store location of each transaction undisclosed. Each retailer defines geographic areas as they choose. Over the period 2009–2012 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. Here, it was straightforward to sum the quantities from the individual store and market area data, identifying the total as US weekly quantity purchased and sum the expenditures from each source to calculate US weekly expenditures. Then, following conventional use of scanner data (Capps and Love, 2002), weekly prices (unit values) were constructed as weekly expenditures divided by weekly quantity purchased.

Manufactured foods (fixed weight) carry the Universal Product Code (UPC) which conveys information about many product attributes. As such, stores accumulate detailed product records as items are scanned. Random weight products (produce that is hand-selected by consumers, deli items or meat that is

9 As the data are proprietary, source data are available from the authors for verification purposes only.

packaged and weighed in stores) do not carry UPC on labels, but InfoScan does include some product attribute information: variety (e.g. red delicious apple), cut (e.g. bone-in chicken) and descriptors for deli-prepared foods (e.g. cheese pizza). As our concern is with berries, we excluded all products indicating any preparation beyond being bagged or placed in a container. We excluded several varieties that make up a relatively small part of the berry data: 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. Clearly, 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.

But means and standard deviations are not enough to fully characterise the berry data. Figure 1 shows time plots of weekly quantities of each of four berries: blackberries, blueberries, raspberries and strawberries. Annual cycles are apparent in each. For each berry, the peak to trough range is greater for expenditures than for quantities, so unit values (here treated as prices) are also cyclical but with inverted peaks and troughs. Namely, when prices peak quantities purchased and expenditures both take minimal values.

Table 1. Descriptive statistics for weekly berry purchases 2009–2012 – means and standard deviations

	Expenditures ($)	Quantity (pounds)	Unit values ($/pound)	Budget share
Blackberries				
Mean	3,785,179	715,922	5.76	0.077
SD	1,514,201	380,574	1.07	0.025
Blueberries				
Mean	12,967,516	2,924,595	6.26	0.256
SD	5,781,462	2,396,458	2.60	0.069
Raspberries				
Mean	5,170,937	738,762	7.70	0.111
SD	1,692,803	369,756	1.68	0.041
Strawberries				
Mean	28,549,841	12,760,594	2.54	0.556
SD	11,548,047	7,052,820	0.66	0.082

Note: 209 observations were used in calculations. Data are from IRI. SD, standard deviation.

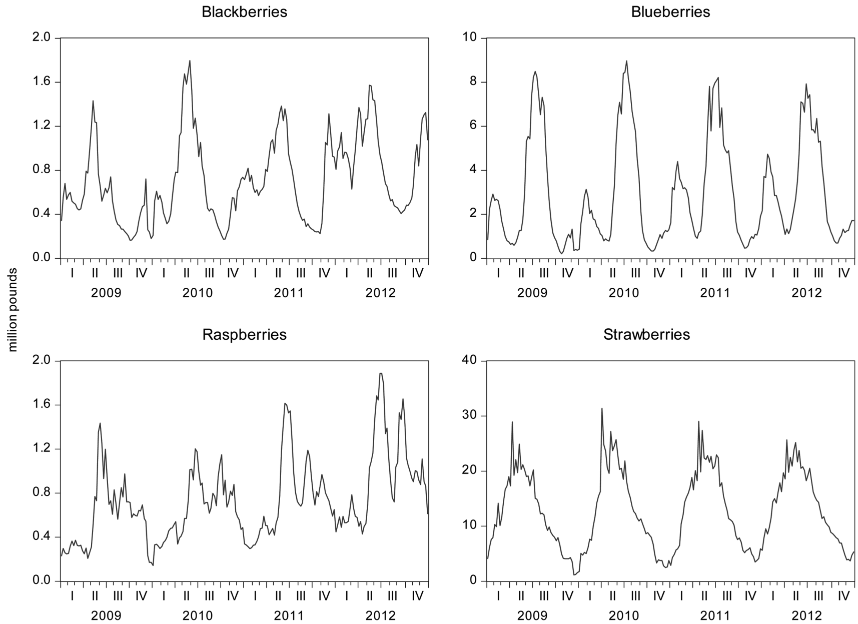

Fig. 1. Quantities of berries purchased weekly in the United States, 2009–2012.
Note: Data are from IRI.

5. Results

5.1 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). 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 that all berries substitute for each other to some extent.

A likelihood ratio test comparing the estimated model (unrestricted, denoted u) to a restricted model (denoted r) where all price and expenditure slopes are zero, indicates that the model fits the data very well. The LR statistic, λ, is the difference in log-likelihoods $\lambda = -2(\log L_r - \log L_u) = T(\log|\hat{W}_r| - \log|\hat{W}_u|)$. Here, $\log|\hat{W}|$ is the log-determinant of the residual sums of squares and cross-

Table 2. Results of berries LA/AIDS model: coefficient estimates and price and expenditure elasticities

	Coefficient (standard error)	Elasticities (standard error)
Blackberry share equation		
Constant	0.291 (0.041)	
Blackberry price	−0.078 (0.005)	−2.039 (0.064)
Blueberry price	0.014 (0.003)	0.193 (0.044)
Raspberry price	0.019 (0.004)	0.253 (0.053)
Strawberry price	0.045 (0.005)	0.615 (0.071)
Expenditure	−0.011 (0.003)	0.851 (0.035)
Blueberry share equation		
Constant	0.614 (0.100)	
Blackberry price	0.014 (0.003)	0.056 (0.013)
Blueberry price	−0.166 (0.008)	−1.631 (0.032)
Raspberry price	0.026 (0.004)	0.104 (0.016)
Strawberry price	0.126 (0.009)	0.498 (0.037)
Expenditure	−0.016 (0.006)	0.938 (0.024)
Raspberry share equation		
Constant	0.431 (0.051)	
Blackberry price	0.019 (0.004)	0.168 (0.035)
Blueberry price	0.026 (0.004)	0.240 (0.037)
Raspberry price	−0.107 (0.007)	−1.946 (0.061)
Strawberry price	0.062 (0.007)	0.565 (0.061)
Expenditure	−0.015 (0.003)	0.869 (0.029)
Strawberry share equation		
Constant	−1.336 (0.123)	
Blackberry price	0.045 (0.005)	0.078 (0.010)
Blueberry price	0.126 (0.009)	0.214 (0.017)
Raspberry price	0.062 (0.007)	0.106 (0.013)
Strawberry price	−0.233 (0.014)	−1.458 (0.025)
Expenditure	0.041 (0.008)	1.074 (0.014)
Model autocorrelation parameter		
Rho	0.784 (0.027)	

Note: All p-values for model parameter estimates are less than 0.01 except for the expenditure term in the blueberry share equation. That p-value is 0.0101. All p-values for elasticity estimates are less than 0.01. Rho represents the same autocorrelation parameter in each share equation.

product matrices using the constrained and unconstrained estimators, respectively, and T is the number of observations. The LR statistic is distributed chi-square with degrees of freedom equal to the number of restrictions. We calculated $\lambda = 239.76$. At $p = 0.005$, chi-square is 23.59. The latter model included a correction for first-order autocorrelation to make the estimated model and restricted model differ only in the price and expenditure slopes.

Figure 2 shows the relation between weekly retail prices and the calculated choke prices. For each berry, the choke price was calculated as a deviation from a base price. Choke prices, p', were calculated as $p' = (\eta - 1/\eta)\bar{p}$, where $\bar{p}$ is the base off-season price (over the weeks Chile typically exports

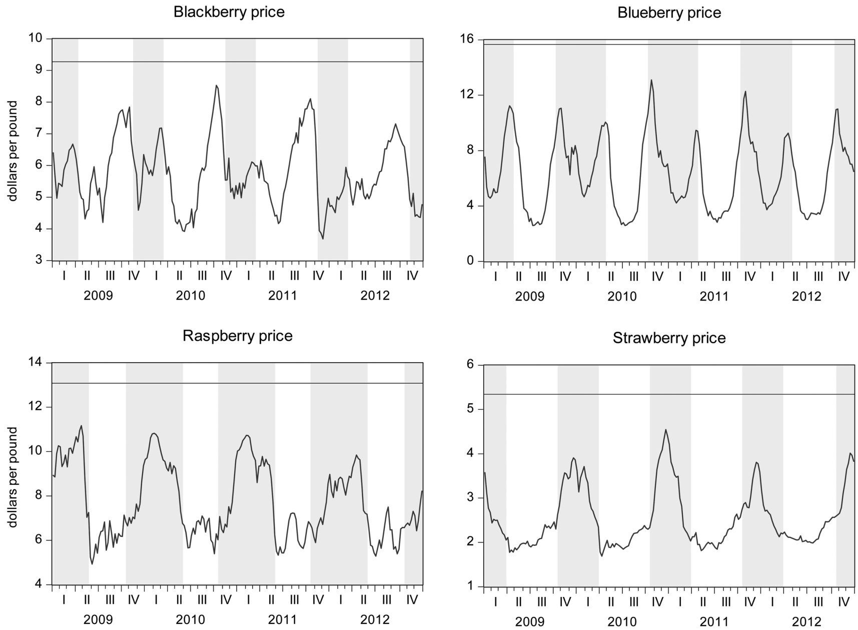

Fig. 2. Choke prices for berries and weekly retail prices. Horizontal lines indicate choke prices. Grey areas indicate periods in which Chile typically exports.
Note: Choke prices are prices that drive quantity demanded to zero. Data are from IRI.

each berry) and η is the own-price elasticity. For raspberries and strawberries, the average off-season price served as a base. Calculated choke prices were above the highest observed actual price. For blackberries, the Chilean export season is relatively short and there is a time each year when domestic supply and imports are both relatively small. Prices spike then and the average off-season price proved to be too low a base: highest actual prices observed in 2010 and 2011 exceeded the calculated choke price. Similarly, blueberry prices spike at the beginning of the Chilean import season and actual price peaks in 2010 and 2011 exceeded the calculated choke price. The problem is that prices are quite variable within the off-season period and within the in-season period. We revised our base for blackberries and blueberries to account for that variability. For these berries, the base was the average off-season price $+1$ standard deviation of the off-season prices. With that change in base prices, the calculated choke prices are, as Figure 2 shows, always higher than actual prices.

5.2 Dollar benefits of increased seasonal variety

Two cases are simulated and reported here:

- Case 1: prices fall from the choke price (where imports are zero) to the current level of off-season prices observed today, and

- Case 2: off-season prices fall from their current level to today's observed in-season prices (when shipments are largest).

Case 1 is the retrospective case, examining the consumer benefits of initiating trade and having some berries available in the fall and winter months. That is, for each berry, the price is set equal to its choke price and counter-factual expenditures are calculated and compared with 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 fall and 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. That second case measures the benefits that would accrue to consumers if importers from South America (or any source) could bring berries to the United States in the fall and winter at the same prices that domestic farmers do in the spring.

One major difference between the cases is that they represent changes at different margins. Case 1 is a change from zero availability. While off-season availability has been a small share of total annual consumption in recent years, the change modelled in Case 2 is an increase from one positive amount to another positive amount. The benefits consumers receive in each case are the result of large and discrete price reductions. However, the change in Case 2 could cover a price range over which consumers' marginal utility is lower than in Case 1. The relative sizes of the price changes are an empirical matter and either could be larger. However, the price reductions turn out to be of similar magnitude between the two cases (Table 3). As long as marginal

Table 3. Results of compensating variation calculations

Berry	Compensating variation ($ Million/year)	Actual expenditures ($ Million/year)	Compensating variation as a percentage of actual expenditures	Average percentage price reductions
Case 1: choke prices decline to recently observed prices				
Blackberries	104.6	197.8	52.9	41.4
Blueberries	580.6	677.6	85.7	52.7
Raspberries	235.2	270.2	53.7	34.0
Strawberries	2459.7	1491.7	164.9	42.3
Case 2: off-season prices decline to in-season prices				
Blackberries	22.6	197.8	11.4	11.6
Blueberries	450.9	677.6	66.6	54.8
Raspberries	231.6	270.2	85.7	34.0
Strawberries	520.0	1491.7	34.9	36.9

Note: In Case 1, average percentage price reductions refer to price declining from the choke price to the 2009–2012 average off-season price paid. That is, the percentage change is calculated as (average off-season price paid − choke price)/choke price. In Case 2, the average percentage price reductions refer to price declining from the 2009–2012 average off-season price paid to the average (2009–2012) in-season price paid during the month of greatest shipments. Namely, the percentage change is (in-season price − off-season price)/off-season price.

utility diminishes with growing consumption, Case 1 ought to display larger welfare gains for consumers.

Figure 3 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 towards 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 Figure 3. Case 1 is the retrospective view. On an annual basis, the

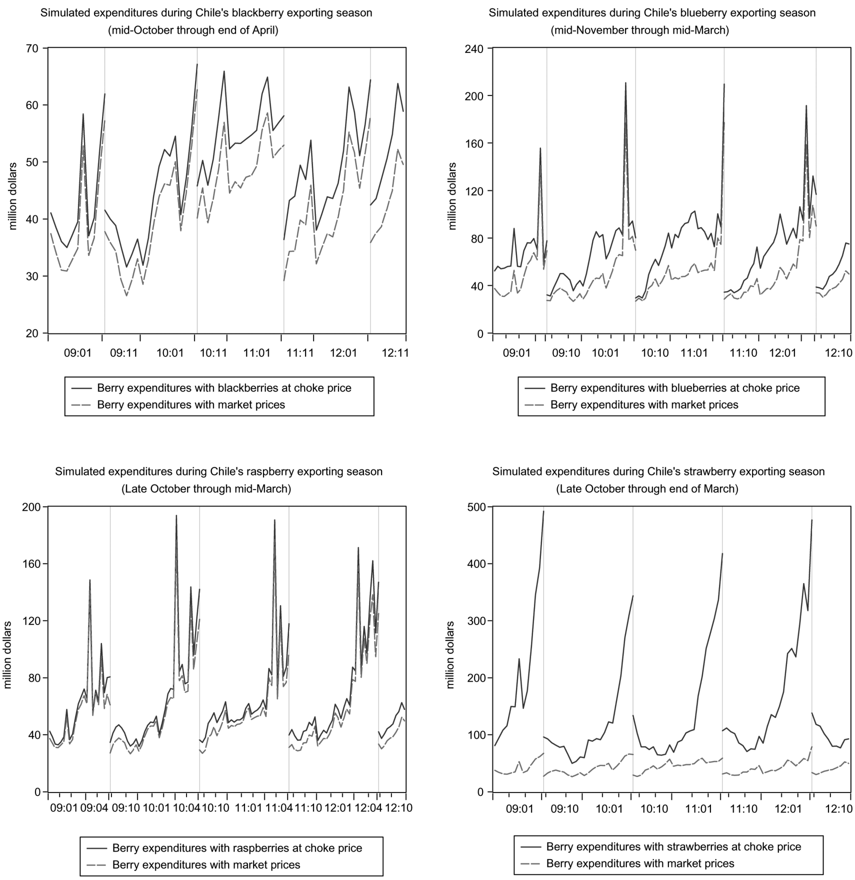

Fig. 3. Simulated weekly berry expenditures during Chile's exporting season. Case 1 – some berries become available in Winter.

Note: These graphs compare expenditures calculated with observed prices with expenditures in which one berry price is set at the choke price. Internal vertical lines denote the end of one Chilean export season and the beginning of another. Periods between export seasons are not shown.

Source: Authors' calculations using IRI InfoScan data.

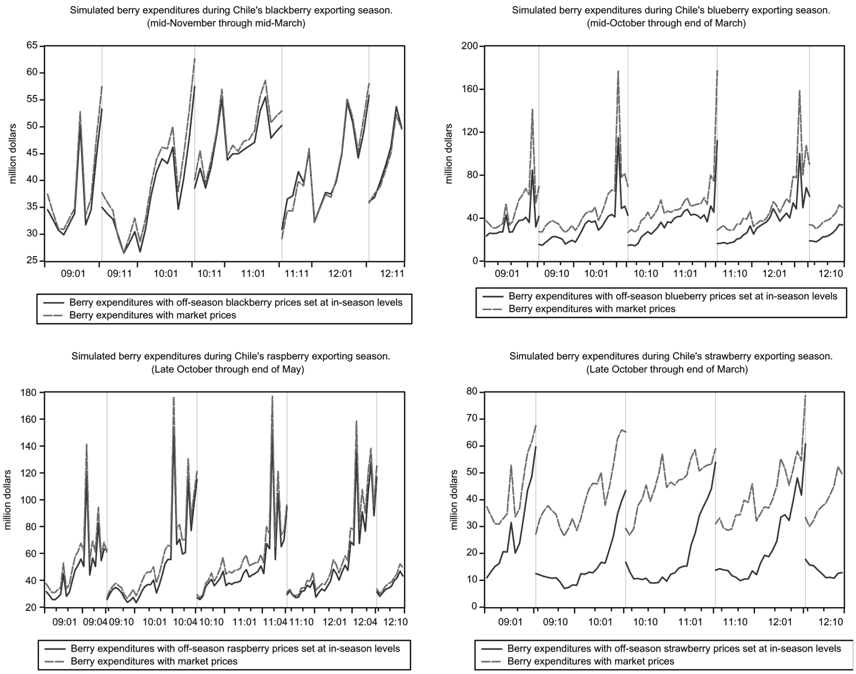

Fig. 4. Simulated berry expenditures during Chile's exporting season. Case 2 – off-season berry prices fall to in-season levels.
Note: These graphs compare expenditures calculated with observed prices with expenditures in which one berry price is set at the choke price. Internal vertical lines denote the end of one Chilean export season and the beginning of another. Periods between export seasons are not shown.
Source: Authors' calculations using IRI InfoScan data.

strawberry compensating variation is far larger than the compensating variation for other berries, largely because the quantity of strawberries is so much larger; the weekly average addition to benefits from strawberries ($106.9 million) is over five times larger than the weekly average for blueberries ($20.6 million).

For Case 2, in-season prices were calculated as the average over the month with highest shipments.[10] Highest monthly shipment numbers occur in June for blackberries, blueberries and raspberries. Shipments of strawberries are highest in May each year. Figure 4 shows the time pattern for off-season 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.

For Case 1, the annual totals of weekly CV estimates, reported in the top half of Table 3, make clear that the consumer benefits arising from increased fall and wintertime availability of berries is relatively high. For example, there is a $2.5

10 US Department of Agriculture, Agricultural Marketing Service, Fruit and Vegetable Programs, Market News Branch. 'Fresh Fruit and Vegetable Shipments By Commodities, States, and Months'. FVAS-4 Calendar Year 2013. Issued February 2014, 62 pp.

billion gain in consumers' surplus arising from making strawberries available in the fall and winter. Of course, this measure of the consumer benefits does not take into account gains that could be attributed to increased competition. If competition from importers led US 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 are 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 34 percent (raspberries) to 53 percent (strawberries). Figures 1 and 2 highlight the situation over the months Chile exports berries (our reference period). Compared with springtime when domestic production is available, the quantity available in fall and winter is relatively small and prices are relatively high. These facts raise the question behind Case 2. Suppose fall and winter prices fell to spring prices. That might occur if other countries began supplying the US market, or from advances in technology, either through improvements in domestic storage or through shipping. Having greater availability of berries at lower prices would benefit consumers, but how much? Case 1 shows consumers benefitted from having some winter berries as opposed to none. If availability increased again and prices fell again, would the benefits be similar or does Case 1 largely exhaust consumers' benefits? In effect, we ask how fast is marginal utility decreasing?

The annual totals for Case 2, reported in the bottom half of Table 3, reveal that additional price decreases do not yield benefits as large as the benefits of initiating trade. 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. Price changes alone are not enough to explain why the benefits seen in Case 2 are so much smaller than Case 1. In Case 1, strawberry prices fell on average 42 percent – dropping from the choke price to the prices in the fall and winter. In Case 2, prices fell 37 percent – dropping from the average fall and winter price to average spring prices when domestic shipments peak. Yet, consumer benefits are much smaller in Case 2. 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 if they could purchase springtime quantities while facing springtime prices in fall and winter. But the latter change adds much less to their well-being than does the former.

For the other berries, Case 1 benefits are larger than Case 2 benefits. Case 1 simulates a 34 percent decrease in the price of raspberries and Case 2 simulates a second 34 percent decrease. The former yields an annual benefit of $235.2 million while the latter yields a benefit of $231.6 million. For blueberries, the case 1 and 2 percentage changes in prices are also similar, falling 53 and 55 percent, respectively. Still, the case 1 CV is larger than the case 2 CV. Blackberries show case 1 benefits approximately five times larger than that in Case 2. But the price decline simulated in Case 1 is also almost four times larger than in Case 2.

The CV calculations for strawberries are consistent with diminishing marginal utility over the range of the price changes. This finding 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 fall and winter levels and too low to reflect spring. As such, the model would likely fail to capture the high values consumer place on newly available goods when those goods appear seasonally.

6. Conclusions

This research makes three novel contributions. First, there is a new contribution economists can make to trade policy analyses. It is obvious that when food production is seasonal, north–south trade that relies on the shifting comparative advantage in production will be valuable to consumers: having some springtime fruits in winter, even at retail prices that incorporate long-distance shipping costs, can be better than doing without. Importers are creating a benefit for consumers by filling what would otherwise be a seasonal void in their consumption. But, despite the certainty that off-season availability of produce is a benefit to consumers, economists have not been able to fully account for this benefit. There was no way to account for the market reality that additions to availability when supplies are seasonally low are especially valuable to consumers. That is, the benefit–cost analysis that often accompanies policy discussions about proposed reductions in tariffs and trade barriers has been incomplete. Proposed policies that would make off-season trade rewarding and make unprecedented consumption patterns possible can now be addressed in terms of the dollar value of benefits consumers would receive. Economists can quantify seasonal trade benefits that accrue to consumers even when trade does nothing to increase domestic price competition. That is, seasonal trade adds to the variety of products available to consumers, and that benefit can be estimated. When estimating the benefits consumers receive from trade, estimates of the variety effect can be added to the price effect calculations that are usually the focus of trade models.

Second, the paper reveals that the benefits consumers receive (or prospectively, might receive) from increased trade during periods when trading partners have a seasonal comparative advantage are not trivial. This paper focused attention on purchases of individual berry varieties during a relatively small portion of the year. As such, if the calculations of compensating variation had been trivially small the gains of interhemispheric trade would be inaccurately estimated. Namely, the CV estimates might have been small because our focus was narrow. Instead, CV calculations show the opposite: offering consumers relatively small quantities of produce at prices that peak at two to three times in-season levels for small windows of time yields annual benefits that range from \$105 million for blackberries to \$2.5 billion for strawberries. These results highlight 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 range of benefits across berries is wide partially because the market sizes are so different. Compared with other types of produce, berries are a small market. Even so, results can be characterised as finding large benefits from small changes in seasonal access to fruit.

The idea that exporters (or perhaps domestic suppliers taking advantage in improvements in domestic storage technology) might someday be able to match prices of in-season suppliers is admittedly speculative. But the market reveals that it is financially feasible to grow and harvest produce in one hemisphere and market that same produce in the other hemisphere. So, imagining that the off-season price might fall to a half or a third of current levels is not impossible, but a function of storage and transportation technology. The CV calculations make clear that the largest benefits are already being reaped: for the strawberry market, the CVs calculated for the initiation of trade are mostly larger than the CVs calculated for the possibility of importers matching in-season prices.

Although our estimated welfare benefits are high, there is reason to suspect that the reported benefits in Table 3 represent a lower bound. For one, import competition may force US producers to lower prices in the domestic season, improve storage and expand sales into other seasons. This represents the price effect discussed in traditional trade models and is not included here. And, as Ferrier and Zhen (2014) have shown, year-round availability allows consumers to form consumption habits and thus 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 paper.

The third contribution made by this paper is to recognise that a policy of removing barriers to seasonal trade can have a public health benefit and thus be an alternative to more costly subsidies. Comparisons of food consumption (National Health and Nutrition Examination Survey 2007–2010) with *Dietary Guidelines for Americans 2010* (USDA and USDHHS, 2010) indicate where Americans' diets raise concerns. For adults on a 2,000 calorie daily diet, typical consumption of fruit is 50 percent of the recommended level. Vegetable consumption is 61 percent of recommendations, with lower levels for dark green vegetables and for red and orange vegetables. Alternatively, consumption of added sugars is 216 percent of recommendations and consumption of solid fats is 213 percent of recommendations (USDA, Economic Research Service, 2014a). It is not surprising that the key recommendations in the *Dietary Guidelines for Americans 2010* include controlling calorie intake while increasing fruit and vegetable intake and eating a variety of vegetables.

Numerous public sector education programs have been implemented with the hope of changing consumers' preferences. The *Guidelines* are the foundation for consumer materials including *MyPlate* and other educational materials distributed by the USDA and other Federal agencies. But an education programme, with goal of convincing consumers to adopt healthier diets, is not the only way to increase fruit and vegetable consumption. As an alternative, it may be possible to give consumers an incentive to increase their fruit and vegetable consumption. If fruit and vegetables were always available at lower prices, consumers would likely consume more. The notion that increased variety yields large dollar benefits to consumers is perfectly aligned with public health dietary recommendations.

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