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# **A Bilateral Comparison of Fruit and Vegetable Consumption: United States and Canada**

**Timothy J. Richards and Paul M. Patterson**

Many public programs promote diets rich in fruits and vegetables based on evidence of the derived health benefits. Still, produce consumption in the United States lags behind other nations, even its most culturally similar neighbor—Canada. This study uses a structural latent variable model to test the role played by quality and health information in explaining observed differences in produce consumption. The Alchian-Allen effect predicts that higher quality, higher absolute margin produce will be exported, suggesting quality may be an important demand factor in importing nations such as Canada. The results show that dietary health information is significant in expanding demands. Quality also promotes fruit consumption in Canada.

*Key words:* Alchian-Allen effect, fruit and vegetable trade, health information, latent variable, MIMIC model, produce quality

## **Introduction**

Through their “5-A-Day for Better Health” program, the National Cancer Institute (NCI) and the Produce for Better Health Foundation (PBHF) have spent an average of \$1 million per year over the last decade to promote the consumption of fruits and vegetables. The health benefits of increased consumption of these products are clearly documented in the epidemiological literature, both in terms of reduced incidence of various forms of cancer (Block, Patterson, and Subar, 1992), as well other ailments such as stroke, heart disease, and obesity. In fact, the U.S. Department of Agriculture (USDA) estimates the annual cost to the U.S. economy of poor diets in general to be \$5.1 to \$10.6 billion in health care costs, absenteeism, and early death (Frazão, 1999). Despite efforts to promote healthy eating, the number of fruit and vegetable servings per capita per day in the United States lags that in other countries with similar levels of economic development (Waterfield, 1997; Johnson, 1997; Offner, 1999). Of particular concern is the stark difference in consumption between the United States and its largest, and most culturally similar neighbor—Canada. Whereas average consumption of fresh fruits and vegetables in the United States is approximately 3.6 servings per

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capita per day, Canadians consume an average of six to seven servings per day (Burfield, 2003).<sup>1</sup>

If accepted, it is curious this difference persists in spite of the fact that Canada's climate does not allow for widespread production of produce year-round, as in the United States, with the notable exception of greenhouse tomatoes. This restriction necessitates the importation of a large proportion of Canada's produce needs, largely from the United States. In fact, Canada imports approximately 86% of the fruit and 39% of the vegetables it consumes (Statistics Canada, 2001), with the United States accounting for approximately 53% and 80% of these imports, respectively (Industry Canada).

Explanations for the difference in consumption range from differences in ethnic composition, income, relative prices, the propensity to purchase and consume food away from home, knowledge regarding the link between diet and health, and the quality of available produce (Waterfield, 1997; Johnson, 1997; Offner, 1999; Burfield, 2003). Of these factors, ethnicity, income, prices, and the proportion of food consumed away from home are relatively easy to account for econometrically, as demonstrated in other studies on produce consumption (Lutz et al., 1993; McCracken, 1992; Nayga, 1995) and away-from-home food consumption (Capps, Tedford, and Havlicek, 1985; McCracken and Brandt, 1987; Nayga and Capps, 1992). However, knowledge and quality are less straightforward to measure. Nonetheless, it is imperative to do so because quality and knowledge, or more specifically differences in quality and knowledge, are likely to be important determinants of consumption patterns in the United States and Canada. Differences in knowledge may be due to differences in public education or promotion programs. But, can quality of produce be better in a country with relatively little fruit and vegetable production?

Differences in quality may be explained by the Alchian and Allen (1983) theorem, which argues that when goods of different quality incur the same per unit transportation costs, high quality, higher priced goods become relatively less expensive in the destination market than in the production region. Therefore, there is greater demand for the higher quality good in the import region, as consumers substitute higher quality goods for lower quality goods. This leads to the commonly observed practice in the produce industry of "shipping the good apples out" (Borcherding and Silberberg, 1978). As a result, Canadians generally see higher quality produce than consumers nearer the production regions in the United States. This phenomenon was discussed in a Washington State consumer's letter to the *Seattle Times* (October 19, 1975):

Why are Washington apples in local markets so small and old-looking? ... Recently, some apple-picking friends brought some apples they had just picked, and they were at least four times the size of those available for sale here. Where do these big Delicious apples go? Are they shipped to Europe, to the East, or can they be bought here in Seattle? (quoted in Borcherding and Silberberg, 1978, p. 132).

For this consumer, size and freshness are clearly important attributes determining the product's quality. As discussed further below, quality is a multidimensional construct incorporating many attributes that induce consumers to pay more. Marketing studies have shown that consumers often choose their grocery store based on the quality of the

<sup>1</sup> There is some debate over these differences due to the use of alternative methodologies in determining these rates (Burfield, 2003).

produce offered (Arnold, Oum, and Tigert, 1983; Walters and McKenzie, 1988). Consumer surveys have also identified quality as an important factor in influencing produce consumption (Scott, 1998).

Differences in dietary knowledge may also exist in the United States and Canada. As in the United States, Canada has a public-private social marketing campaign to promote the consumption of fruits and vegetables. However, Canadians have been promoting this message for at least two decades longer than the United States, and it is reported to air more frequently on television in Canada (Burfield, 2003). The promoted goal in Canada has also surpassed the U.S. goal of "five a day," as Canadian health authorities are now encouraging consumers to "reach for ten" servings of fruits and vegetables. Given these differences in message and the reported differences in the achievement of their proclaimed goals, the availability of information or knowledge on the importance of fruit and vegetables in a healthy diet is likely an important factor explaining U.S.-Canadian differences in produce consumption.

Accounting for the effect of information in econometric models of demand, however, remains a contentious issue. Many studies include various measures of advertising exposure or indices of consumer information in attempting to estimate the effect of information on demand (Ippolito, 1990; Alston et al., 1996; Richards, 1999; Kinnucan et al., 1997; Teisl and Roe, 1998; Brown and Schrader, 1990). The inclusion of information in this manner is often possible in time-series studies on the assumption that all individuals or households receive the same level of exposure to the advertisement or information source through alternative media outlets and that this exposure translates into consumer awareness or concern. In contrast, information-induced changes in demand may be captured by trend variables or dummy variables. Yet, this raises concerns over whether these variables, which agglomerate all time-varying variables, truly identify the impact of the specific information of concern.

Alternatively, appropriately designed surveys may estimate demand as a function of individual awareness or knowledge (Teisl and Roe, 1998). Studies using the USDA's Continuing Survey of Food Intake by Individuals (CSFII) and its companion survey, the Diet and Health Knowledge Survey (DHKS) (U.S. Department of Agriculture, 2000a, b) or similar data (Jensen and Kesavan, 1993; Jensen, Kesavan, and Johnson, 1992; Gould and Lin, 1994; Kim, Nayga, and Capps, 2000) are relatively rich in their ability to measure individual households' level of information regarding both the foods they consume and their links to a healthy diet.

There are three problems with using these data, however. First, such surveys typically do not contain product prices, so one potentially important determinant of variation in demand among households is ignored. Second, there are no comparable data for Canadian households, so a comparison of estimates from such disparate data sets would be tenuous at best. Third, even responses to direct questions regarding dietary knowledge remain only indirect measures of actual knowledge, as knowledge is inherently unobservable and so must be specified as a latent variable (Variyam et al., 1998).

More specifically, the dietary knowledge that consumers hold on the benefits of produce consumption is unobservable. Although U.S. consumers are reminded to eat "five a day," the benefits may not be fully understood. The benefits of produce consumption are complex and multifaceted (the prevention of various forms of cancer, consumption of essential micro-nutrients, or healthy weight maintenance, to name but a few) and

cannot be reduced to a simple claim, as on many packaged goods, which may be substantiated by the information in the nutrition label. Such labeling is generally not available for produce. Thus, measures of information content or exposure are unavailable, much less measures of consumer knowledge acquired through processing this information. Therefore, knowledge must be treated as a latent variable, requiring appropriate methods to capture its impact on demand.

Food quality also poses certain definitional challenges. It is determined by a combination of attributes, such as taste, aroma, texture, color or size, and consistency in these and other attributes on each consumption occasion. Although packaged food products are widely regarded as experience goods (Nelson, 1970) with respect to their quality attributes, they are distinctly different from produce. Today's food manufacturers can, through careful input selection and processing adjustments, deliver products that are nearly uniform over time. Furthermore, an implicit warranty of this quality is often offered through a packaged good's brand name. However, these opportunities elude retail marketers of fresh produce, whose quality attributes are inherently variable, not fully appreciated by the consumer until they are consumed on each occasion, and generally not identifiable through a brand name. As such, produce is more of an experience good than processed foods on the continuum that classifies goods as experience or search goods. Given the variability in product attributes and experiential nature of the product, produce quality also remains an unobservable variable, thereby introducing new difficulties for demand analysis.

Many empirical studies adopt Cox and Wohlgemant's (1986) application of Goldman and Grossman's (1978) hedonic approach to account for differences in product quality. However, the assumption that households of similar demographic or socioeconomic attributes purchase similar products may be of some question. Still, this assumption is often useful, but by no means an exact method of accounting for variation in quality, or for explaining how quality influences quantity demanded. Alternatively, Davis and Hewitt (1996) develop an approach based on the economic theory of index numbers to impute variations in quality of imported goods based on differences between their import unit values and market prices. However, such data are not readily available for domestically produced and consumed goods.

These difficulties in measuring quality and information or knowledge perhaps account for why their role in explaining fruit and vegetable consumption has not been rigorously documented or verified. Accordingly, the objectives of this paper are to: (a) determine whether the accepted difference in U.S. and Canadian consumption of fresh fruits and vegetables is real or an artifact of different measurement systems, and (b) explain the gap as a result of prices, incomes, tastes and preferences, dietary health knowledge, or average produce quality.

### **Empirical Model of Fresh Produce Demand**

This study uses a two-stage approach to determine the impact of quality and information on produce demand in Canada and the United States. In the first stage, latent variable models of quality and dietary knowledge are estimated for both the U.S. and Canada. Fitted values for quality and knowledge derived from the first-stage models are then used in a set of second-stage fresh produce demand models to test the impact of quality and information on fruit and vegetable demand in each country. The specific

form of the first-stage latent variable model is based on the structural latent variable approach of Joreskog and Goldberger (1975), who derive a method of identifying and estimating the impact of unobservable variables on observable quantities. Within the general class of structural latent variable models, this study uses a multiple indicator, multiple cause (MIMIC) approach. Gao and Shonkwiler (1993) use a similar method to estimate the impact of changes in tastes and preferences on the demand for various types of meat in the United States, while Patterson and Richards (1999) and Richards, Gao, and Patterson (1999) apply a MIMIC technique to estimate the effect of advertising on the demand for fresh fruit. Variyam et al. (1998) employ a similar, yet somewhat simplified, factor analysis approach in estimating the latent effect of nutritional information on an index of dietary health.

A MIMIC model is appropriate, because latent variables are typically modeled with proxies. Standard proxy variable models, however, are generally unacceptable for several reasons. First, proxy variables are erroneous measures of the true latent variables upon which demand is thought to depend, introducing potentially significant measurement error and, hence, inconsistency. Second, latent variables are likely to be endogenous. Thus, ordinary least squares, or any other limited-information approach, introduces potentially significant simultaneous equations bias. Third, introducing a single proxy variable may provide misleading results simply because there are many other possible proxies for any latent variable, each leading to a different estimate of the true effect. Consequently, measuring product quality and information, as well as their effect on consumption, requires an approach that not only explicitly recognizes the inherent latency of each, but also the many possible ways of measuring them.

A MIMIC model relies on covariance relationships between observable endogenous "indicators" of latent variables and exogenous observable "causes" to identify latent variable values that are otherwise unobservable. Formally, MIMIC models consist of two sets of equations: (a) measurement (or indicator) equations that describe the relationships between indicator variables and latent constructs, and (b) causal or structural equations that show how these latent variables are determined by observable, exogenous economic variables. While measurement equations are used to scale and identify the latent constructs, causal equations provide the parametric estimates that are of key interest to researchers. Formally, and in general notation, structural equations specify relationships between the set of latent variables ( $\eta$ ), their causes ( $\mathbf{z}$ ), and a random error term ( $\zeta$ ):

$$(1) \quad \eta = \Phi\eta + \Gamma\mathbf{z} + \zeta,$$

where  $\Phi$  and  $\Gamma$  are parameter vectors showing the marginal effects of the latent variables on each other and of cause variables on latent variables, respectively. Measurement equations, on the other hand, show how each indicator variable ( $\mathbf{y}$ ) is related to the latent variables, a vector of exogenous factors ( $\mathbf{x}$ ), and a vector of random measurement errors (Joreskog and Goldberger, 1975; Bollen, 1989; Anderson, 1989):

$$(2) \quad \mathbf{y} = \Lambda_y\eta + \beta\mathbf{x} + \varepsilon.$$

In this set of equations, the components of  $\Lambda_y$  are also known as factor loading coefficients. Further, the error terms of (1) and (2) are uncorrelated with each other, have

zero means, and have covariance matrices given by  $\Psi$  and  $\Theta$ , respectively. These covariance matrices are central to the estimation method. Whereas ordinary least squares regression finds parameter estimates by minimizing the sum of squared deviations between the fitted and observed values of  $\mathbf{y}$ , the fact that some of the dependent variables in a MIMIC model are unobserved makes this impossible (Gao and Shonkwiler, 1993; Bollen, 1989). Therefore, estimates of the model parameters are found instead by minimizing the difference between the sample covariance matrix of observed variables ( $\mathbf{S}$ ) and a fitted covariance matrix ( $\Sigma(\theta)$ ) for a parameter vector,  $\theta$  (see Bollen, 1989; Browne, 1984; and Ivaldi, Monier-Dilhan, and Simioni, 1995).

In comparing the demand for fresh produce between the United States and Canada, there are primarily two latent variables: "quality" and "information." Each latent variable requires at least two indicator equations in order to both scale and identify its value. The first set of indicator equations serve to identify quality, and therefore consist of hedonic pricing models for fruits and vegetables in each country. Households of different socioeconomic makeup are assumed to demand variants of the same type of food that differ in terms of their inherent quality (Goldman and Grossman, 1978; Cox and Wohlgenant, 1986). For example, both lower income and higher income households may consume beef, but higher income households are more likely to purchase high quality steaks, while lower income households will buy ground beef. Therefore, regional variations in household characteristics may explain regional differences in price, which may in turn reflect underlying differences in quality. Specifically, the log of price ( $y_i^K$ ) is a function of a vector of household attributes ( $x_{im}^K$ ) that includes household income, household income squared, and family size, and a latent quality variable ( $K$ ) for each type of produce,  $i$ :

$$(3) \quad \ln(y_i^K) = \sum_m \alpha_{im} x_{im}^K + \Lambda_{iK} K + \varepsilon_i.$$

In this model,  $\Lambda_K$  for fruit (vegetables) is normalized to 1.0 for the U.S. (Canadian) model in order to scale the latent variable value.

Information indicators, on the other hand, should reflect the extent of consumer knowledge of the health benefits of a diet rich in fruits and vegetables. Revealed consumption behavior is a logical choice, as consumers who are well informed are more likely to choose to buy fruits and vegetables if they are concerned about the quality of their diet. Indeed, analysis of the "5-A-Day Baseline Survey" shows that higher fruit and vegetable consumption is related to consumer perceptions on the required number of servings they should consume to maintain good health (Krebs-Smith et al., 1995). Also, education level has been shown to be an important factor in influencing how health information is incorporated into the dietary behavior of consumers (Van Duyn et al., 2001; Krebs-Smith et al., 1995). More educated consumers are able to access health-related dietary information more readily and to process available information more effectively. Therefore, the set of information indicators includes total produce consumption and educational expenditures by region.

Additional exogenous variables ( $\mathbf{x}$ ) entering these indicator equations include demographic variables and an index measure of available dietary information on fruit and vegetable consumption constructed using the *Reader's Guide to Periodicals*. This index is similar to the one used by Brown and Schrader (1990) in their analysis of cholesterol awareness, and it enters the produce consumption, information indicator equation. Since

produce consumption is influenced by race or ethnicity and income (Nayga, 1995; Lutz et al., 1993; McCracken, 1992; Subar et al., 1995), these variables also enter the produce consumption, information indicator equation. However, unlike prior studies, these demographic variables are not being used as proxy variables in a demand or expenditure function; rather, they are being used to help identify the latent information variable. The exogenous variables in the education expenditures, information indicator equation include educational attainment, women in the workforce, and income. Educational attainment and income have been shown to be important factors influencing produce consumption and dietary knowledge (Krebs-Smith et al., 1995). These variables and the percentage of women in the workforce may also directly influence public decision on investments in education (Bergstrom, Rubinfeld, and Shaprio, 1982).

In general notation, these information measurement (indicator) equations are written as:

$$(4) \quad y_k^I = \sum_j \beta_{jk} x_{jk}^I + \Lambda_{kI} I + \varepsilon_k,$$

where  $I$  is the latent information construct and  $k$  indexes either education expenditure or total produce consumption. Identifying each latent variable with the measurement model, however, does not necessarily explain variation in quality and information over panel observations.

Structural, or causal, equations serve this purpose. The structural equation for information includes other exogenous, causal factors that may contribute to a consumer's access to and use of nutritional information. Previous research on the role of dietary knowledge on food choices suggests that race is an important determinant of the extent to which available information is taken into account in making food choices (Gould and Lin, 1994) or is associated with differences in dietary health knowledge (Kim, Nayga, and Capps, 2001; USDA, 2000b). Also, consumers who tend to eat many meals away from home necessarily lack the same type of detailed information regarding the nutritional content of their meals. Some studies have shown that the overall quality of an individual's diet may be negatively affected by the frequency with which meals are eaten away from home (Eck-Clemens, Slawson, and Klesges, 1999; Prentice and Jebb, 2003). Eating away from home or the demand for convenience is also associated with the number of women in the workforce (Capps, Tedford, and Havlicek, 1985; Manrique and Jensen, 1997), which could also affect dietary health knowledge. Therefore, causal information variables include the size of the minority population in a region, expenditures on food away from home, and participation by women in the workforce ( $z_k^I$ ). Again in general notation, the structural equation is written as:

$$(5) \quad I = \sum_k \gamma_k z_k^I + \xi_1,$$

where  $I$  varies over all panel observations.

With respect to quality, the causal variables reflect other demographic factors that are more likely to determine quality choices directly, and not through prices as in the measurement model. Here, the effects of the average number of children per household, the proportion of women in the workforce, and the amount of expenditure on food away from home on consumer preferences for quality are evaluated. Households with children are likely to choose higher quality foods out of concern for their children's health



outcomes, so this effect is expected to be positive. Nayga (1995) found the presence of children to be an important factor influencing consumer household expenditures on processed fruits. He speculates, though, that this may be due more to the children's preference for sweet, processed products. Women's participation in the workforce, however, is likely to be associated with lower quality food purchases as the demand for convenience (Manrique and Jensen, 1997; Capps, Tedford, and Havlicek, 1985) takes precedence over nutritional goals, or demand for "nonconvenience" goods (fresh produce; Capps, Tedford, and Havlicek's terminology) diminishes. Finally, for many people, restaurant meals represent a means by which they are able to diversify their personal menus, so new dietary trends often begin in restaurants and find their way into home-prepared meals. McCracken and Brandt (1987) draw a distinction between restaurant dining and eating at fast food restaurants, where restaurant dining is sought as a recreational diversion and is positively influenced by income. Therefore, expenditures on food away from home could be expected to have a positive effect on the demand for quality. Combining each of these causal factors, the structural equation for quality becomes:

$$(6) \quad K = \sum_l \gamma_l z_l^K + \xi_2,$$

where quality ( $K$ ) again varies over all panel observations. Parameterizing each latent variable in this way is necessary because it allows for the calculation of fitted information and quality indices.

In the second stage, these latent indices are used in a model of fresh produce demand. Because there are no comparable data for other food categories, the demand model is specified as a set of quantity-dependent, Cobb-Douglas demand equations. Specifically, the demand equations for produce type  $i$  are therefore written as:

$$(7) \quad \ln(q_{it}) = \beta_0 + \beta_1 \ln(p_{it}^r) + \sum_j \beta_{2j} \ln(P_{jt}^r) + \beta_3 \ln(X_t) + \beta_4 I_t + \beta_5 K_t + \varepsilon_{it}$$

for each country, where  $q_{it}$  is the quantity of fruit or vegetables purchased per capita,  $p_{it}^r$  is the price of fruits or vegetables measured as a weighted average of all the products purchased,  $P_{jt}^r$  are prices of substitute and complementary products in demand,  $X_t$  measures weekly expenditures on produce, and  $I_t$  and  $K_t$  are the latent information and quality variables. Given that the objective of this analysis is to explain observed differences in the total demand for fruits and vegetables, data on individual products are aggregated into two broad categories. These aggregates are defined for a number of regions within both countries and are recorded on a weekly basis, as explained in greater detail in the next section.

### Data Description and Estimation Methods

Clearly, much of the controversy over apparent differences in U.S. and Canadian produce consumption lies in defining comparable data sources. Because official government data sources differ widely in their definition of what constitutes fresh fruits and vegetables, private data sources are more likely to be able to provide similar data for both countries. Consequently, this study uses relatively high frequency, retail-scanner data gathered

**Table 1. U.S. Panel Data Summary Statistics (N = 416)**

Variable	Mean	Std. Dev.	Minimum	Maximum
Fresh Fruit Quantity (lbs./capita, weekly)	0.987	0.213	0.595	1.923
Fresh Vegetable Quantity (lbs./capita, weekly)	0.969	0.181	0.599	1.580
Fresh Fruit Price (\$/lb.)	0.931	0.115	0.616	1.324
Fresh Vegetable Price (\$/lb.)	0.886	0.080	0.685	1.524
Meat Price (index)	154.705	2.291	150.062	160.122
Dairy Price (index)	160.753	0.968	158.793	162.487
Grain Price (index)	188.479	2.031	185.530	196.453
Canned Fruit Price (index)	106.900	1.420	104.726	110.967
Canned Vegetables Price (index)	106.932	1.879	102.797	114.610
Produce Expenditure (¢/capita, weekly)	0.103	0.020	0.062	0.180
Household Income (\$1,000s, annual)	42.231	3.254	37.506	47.493
Family Size (number of persons)	3.141	0.125	3.016	3.430
Education Expenditure (\$/pupil, annual)	4.139	0.737	3.524	5.938
College Graduates (proportion)	0.242	0.021	0.217	0.275
Households with Children (proportion)	0.330	0.017	0.311	0.358
Women in Workforce (proportion)	0.578	0.024	0.549	0.624
Food-Away-from-Home Consumption (proportion)	0.613	0.013	0.594	0.643
Income (\$1,000s/capita)	21.326	1.453	18.786	23.881
Produce Consumed (lbs./capita, weekly)	1.956	0.345	1.194	3.277
African-American Population (proportion)	0.126	0.070	0.028	0.227
Hispanic Population (proportion)	0.127	0.096	0.034	0.324
Asian Population (proportion)	0.034	0.029	0.015	0.109
Article Index (index)	4.827	3.290	1.000	14.000

Notes: The data were collected for the year 2000. All values are recorded in U.S. dollars.

from same-format grocery outlets. In order to incorporate regional socioeconomic data, the scanner data are aggregated from a store level to a regional level on a weekly basis for the year 2000. For the U.S. model, the data are provided by FreshLook Marketing of Chicago, Illinois. Sales by grocery retailers are available on 35 fresh fruit and 51 fresh vegetable products for eight regions in the United States (Great Lakes, Midsouth, Northeast, Plains, South Central, Southeast, West, and California), and account for approximately 90% of the retail sale of produce in these regions. Prices for other food products were obtained from the U.S. Department of Labor/Bureau of Labor Statistics. Regional sociodemographic variables are developed using state-level data available from the 2000 U.S. Census. Data on retail grocery and restaurant sales were used to develop a weekly measure of away-from-home food consumption expenditures. Table 1 provides summary statistics for each variable in the U.S. model.

The Canadian retail data, supplied by A. C. Nielsen Canada, provides sales on 71 fruit products and 107 vegetable products from six regions defined as individual provinces or combinations of provinces—Alberta, British Columbia, Ontario, Quebec, the Maritime provinces (Newfoundland, Prince Edward Island, Nova Scotia, and New Brunswick), and a combination of Manitoba and Saskatchewan. Like the U.S. data vendor, A. C. Nielsen Canada also achieves approximately 90% account coverage and develops weekly projections for each region. Only sales data on fruits and vegetables are available in this sample, so price indices for substitute food products were developed from Statistics

**Table 2. Canada Panel Data Summary Statistics (N = 300)**

Variable	Mean	Std. Dev.	Minimum	Maximum
Fresh Fruit Quantity (lbs./capita, weekly)	2.828	0.558	1.235	4.416
Fresh Vegetable Quantity (lbs./capita, weekly)	2.745	0.478	1.631	5.098
Fresh Fruit Price (\$/lb.)	0.888	0.101	0.497	1.109
Fresh Vegetable Price (\$/lb.)	0.946	0.135	0.494	1.276
Meat Price (index)	115.749	14.094	16.190	128.167
Dairy Price (index)	111.650	13.124	12.090	118.299
Grain Price (index)	112.826	3.379	107.377	121.285
Processed Fruit Price (index)	105.184	5.370	95.115	116.224
Processed Vegetables Price (index)	103.032	3.545	93.887	114.369
Produce Expenditure (¢/capita, weekly)	0.129	0.020	0.078	0.188
Household Income (\$1,000s, annual)	47.305	5.084	41.289	54.291
Family Size (number of persons)	3.064	0.048	3.000	3.119
Education Expenditure (\$/pupil, annual)	1.353	0.207	1.058	1.678
College Graduates (proportion)	0.126	0.016	0.105	0.149
Households with Children (proportion)	0.648	0.021	0.608	0.672
Women in Workforce (proportion)	59.864	3.229	56.060	65.600
Food-Away-from-Home Consumption (proportion)	0.278	0.030	0.230	0.325
Income (\$1,000s/capita)	16.427	1.112	14.747	17.943
Produce Consumed (lbs./capita, weekly)	5.573	0.839	3.211	8.330
Minority Population (proportion)	0.096	0.058	0.019	0.179
Article Index (index)	4.753	3.382	1.000	14.000

Notes: The data were collected for the year 2000. All values are recorded in Canadian dollars (\$1 US = \$1.487 CAN, 2000).

Canada's (2002) *CANSIM II* database. These prices are available on a monthly basis for each region. A cubic spline extrapolation technique was used to develop weekly measures of these variables for use with the scanner data. The *CANSIM* database also provides regional socioeconomic measures used in the measurement and structural equations for quality and information. These data, which measure regional characteristics (e.g., population, women's participation in the workforce, the presence of children in the household), are available only on an annual basis. The Canada data are summarized in table 2.

Each demand model is estimated using a two-stage procedure. In the first stage, the MIMIC model is estimated, and fitted index values for both the quality and information latent variables are calculated. Each of these indices is then substituted into the second-stage demand models. While the second-stage model is estimated using least squares, the MIMIC model is estimated with maximum likelihood methods using the Amos software package (SmallWaters Corporation, 1997). In the following section, we first compare fruit and vegetable consumption levels before describing and interpreting the results obtained for each stage of the analysis.

## Results and Discussion

Based on the official government data for each country, Canadians consumed 414 pounds of fruits and vegetables per capita on average over the sample period, while Americans consumed only 274 pounds (Statistics Canada, 2001; USDA, 2000a). However, this comparison is misleading due to the differences in how the data are recorded in the two

countries. For example, Canadian officials record consumption of frozen potatoes (French fries) as a fresh vegetable. Such discrepancies are not encountered, however, when comparing produce sales in each country using the panel data. Indeed, these data allow us to literally compare apples to apples and oranges to oranges, thereby providing several noteworthy differences. For example, the apparent annual per capita consumption of bananas in the United States and Canada is 13.6 and 27.6 pounds, respectively. A similar disparity in consumption levels is observed between U.S. and Canadian apple consumption (7.1 pounds versus 15.1 pounds), and oranges (5.8 pounds versus 13 pounds). Explaining these differences in consumption, however, requires more formal statistical analysis to control for other intervening factors.

Recall that, for each country, the quality measurement model consists of hedonic specifications wherein variations in fruit and vegetable prices, used as indicators of quality, are explained by household income and family size (table 3). The latent quality variable coefficient is normalized to 1.0 in the fruit (vegetable) price equation for the U.S. (Canada), but the factor loading coefficient is positive and significant in the other price equation, suggesting that the hedonic models serve as a good indicator for quality. The results for the structural equation show that quality is, in turn, positively related to the presence of children in the household, but negatively related to increased work-force participation by women in the United States. Both of these results are as expected. In Canada, increases in away-from-home food consumption also resulted in higher levels of quality, as hypothesized.

Two indicators of information or knowledge of the dietary health benefits of produce consumption are used in the U.S. and Canadian models. Because aggregate education spending is an endogenous public policy choice, per pupil expenditure on schools is used as a knowledge indicator. Based on the results reported in table 3, educational expenditures decline in the number of college graduates in a region, but rise with income in the U.S. The latent information variable coefficient is normalized to 1.0 in this equation for the U.S., but is unrestricted in the other indicator equation, where the total pounds of produce sold per capita serves as an indicator of dietary health information. As expected, information also has a positive and significant impact on produce consumption in the United States. However, the structural equation for information shows that dietary health information is negatively related to the proportion of minorities in the population. This result is generally consistent with the findings of the 1994–96 Diet and Health Knowledge Survey (USDA, 2000b). In their study using data from the 1995 Diet and Health Knowledge Survey, Kim, Nayga, and Capps (2001) also find that minority status is negatively related to health knowledge. These results emphasize the continued need for dietary health information campaigns targeted at minority population segments (table 3). In general, these results show that the MIMIC models used to identify the latent quality and information constructs are very similar for the United States and Canada in a qualitative sense. However, the relative magnitudes of the fitted values for these latent variable indices are quite different.

The mean values of these indices are given at the bottom of table 3. Although each index is scaled differently in each country, the relative values of the indices provide some evidence on the importance of each in potentially influencing demand. In the U.S., the information index is nearly three times the magnitude of the quality index, while the quality index is more than twice the magnitude of the information index in Canada. This finding indicates that the quality embodied in the produce in Canada, when scaled

**Table 3. MIMIC Model Estimates for the United States and Canada**

Equation / Variable	United States		Canada	
	Estimate	<i>t</i> -Ratio	Estimate	<i>t</i> -Ratio
<b>Quality Structural Equation</b>				
Household with Children	0.731*	1.892	4.291**	3.766
Women in Workforce	-6.743**	-2.318	0.010	1.557
Food-Away-from-Home Consumption			9.678**	6.734
<b>Quality Measurement Equation: Log Fruit Price</b>				
Household Income	0.937**	68.708	-0.256**	-11.066
Household Income Squared	-0.011**	-79.004	0.003**	10.562
Family Size	1.162**	12.965	-0.402**	-2.989
Quality (latent)	1.000		0.280**	128.990
<b>Quality Measurement Equation: Log Vegetable Price</b>				
Household Income	0.440**	27.392	-0.553**	-7.523
Household Income Squared	-0.005**	-31.066	0.006**	7.451
Family Size	-0.071	-0.453	0.866**	2.215
Quality (latent)	3.623**	2.211	1.000	
<b>Information Structural Equation</b>				
Minority Population	-1.844**	-7.205	-1.627**	-4.030
Food-Away-from-Home Consumption	30.790**	37.240		
Women in Workforce			0.047**	8.857
<b>Information Measurement Equation: Education Expenditures</b>				
College Graduates	-21.941**	-16.798	-1.092	-1.086
Women in Workforce	0.485	0.686		
Income	0.509**	27.705		
Information (latent)	1.000		0.463**	9.502
<b>Information Measurement Equation: Produce Consumption</b>				
African American	-2.545**	-11.844		
Hispanic	2.985**	7.194		
Asian	-12.449**	-7.079		
Income	0.036	1.481	0.144**	6.978
Article Index	0.007*	1.868	0.017**	3.128
Information (latent)	0.201**	7.107	1.000	
<b>Latent Variable Indices (<i>K</i>, <i>I</i>)</b>				
Quality (mean and standard deviation)	9.852	0.023	6.069	0.230
Information (mean and standard deviation)	28.428	0.419	2.657	0.149
$H_0: K_{US}/I_{US} - K_{Canada}/I_{Canada} = 0$	-1.944**	-226.825		

Note: Single and double asterisks (\*) denote statistical significance at the 10% and 5% levels, respectively.

by the available information, is higher than in the United States. Indeed, this is verified using a test on the differences in the means of the ratios of quality to information. This provides some primary evidence that quality is higher in Canada and adds considerable support to the Alchian-Allen hypothesis. It remains, however, to determine the role these variables play in produce demand in each country.

The fit of all four demand models is relatively good, as indicated by the high coefficients of determination, which range from 0.80 to 0.89 (table 4). Furthermore, the signs

**Table 4. Per Capita Produce Demand in the United States and Canada**

Variable	United States		Canada	
	Fruit	Vegetables	Fruit	Vegetables
Log Fruit Price	-0.672** (-13.47)	-0.306** (-5.83)	-0.860** (-19.00)	-0.134** (-3.02)
Log Vegetable Price	-0.115** (-2.44)	-0.886** (-17.86)	-0.148** (-3.58)	-0.869** (-21.49)
Log Meat Price	4.643** (6.21)	-5.276** (-6.71)	1.347** (7.72)	-1.414** (-8.30)
Log Dairy Price			-1.185** (-7.80)	1.238** (8.34)
Log Grain Price	-10.785** (-9.07)	11.246** (8.99)	-0.995** (-4.31)	0.982** (4.35)
Log Processed Fruit Price	2.268** (5.40)	-2.636** (-5.97)	0.110 (0.81)	0.056 (0.42)
Log Processed Vegetable Price	1.464** (5.30)	-1.556** (-5.36)	-0.707** (-3.28)	0.427** (2.03)
Log Produce Expenditure per Capita	1.090** (41.07)	0.859** (30.77)	1.132** (33.66)	0.870** (26.48)
Log Quality Index	1.274 (0.73)	-1.625 (-0.88)	1.224** (6.11)	-1.225** (-6.26)
Log Information Index	-0.133 (-0.64)	0.376* (1.72)	0.478** (4.30)	-0.520** (-4.80)
$R^2$	0.86	0.80	0.89	0.84
F-Value	268.82**	179.60**	235.60**	154.46**

Notes: Single and double asterisks (\*) denote statistical significance at the 10% and 5% levels, respectively. Numbers in parentheses are *t*-values.

of the estimated parameters are consistent with prior expectations. Each model has significant, negative own-price coefficients and positive, significant expenditure coefficients, each of which are interpreted as elasticities in this double-log specification. The pattern of these elasticities is quite similar across countries as well. With price and expenditure elasticities similar across each country, differences in consumption may be related to the influence of quality and information. Since the demand variables were estimated using fitted quality and information variables, these variables are also specified in log form. However, the results in table 4 show that quality does not have a significant effect on fresh fruit or vegetable demand in the U.S. Quality, though, has a significant and strong effect on fruit demand in Canada. This provides strong support for the effect of the Alchian-Allen theorem on quality, and hence differences in consumption. This result is also consistent with prior findings obtained by estimating a similar MIMIC model using aggregate, time series, per capita fruit and vegetable consumption data, and so is clearly robust to both model specification and data definition.

Contrary to the quality results, information has a significant, positive effect on vegetable demand in the United States. Therefore, while changes in prices or incomes in the U.S. have only a modest impact on vegetable consumption, information such as that provided by the "5-A-Day" campaign may play a significant role in supporting vegetable demand. Information also plays a significant role in promoting fruit consumption in Canada. However, vegetable demand is adversely affected by both quality and

information in Canada. Given the way quality was measured, the negative effect on vegetable demand may partly reflect a confounding price effect, as the measurement model may not have created an index that is entirely orthogonal to the price series. It may also be the case that the quality of U.S.- and Canadian-consumed vegetables simply does not differ as much as it does with fruit. Many vegetables are now grown in greenhouses in Canada, so there is little need to import higher value products, and lower value products such as potatoes or carrots are inherently less variable in terms of taste and consistency. In contrast, despite a significant domestic apple supply, most Canadian fruit is imported. Nonetheless, taken together, these results do provide a very clear indication of the true cause of observed differences in fruit consumption between the United States and Canada.

Given this study's finding of a significant impact of quality on fruit demand in Canada, and because fruit is largely imported from the U.S. and elsewhere, there is considerable support for the Alchian-Allen effect as an explanation for observed differences in produce consumption between the United States and Canada. Indeed, if fresh fruit is costly to import, with lengthy inspection, long transport routes, and expensive refrigeration technology, the best quality fruit is likely to be sent to export markets, since these costs are invariant to quality. Our findings in this regard are not only consistent with the Alchian-Allen hypothesis, but also with the conventional wisdom in industry. Consequently, the "produce consumption gap" referred to in the introduction should be of little surprise. Information is also important in explaining Canadian fruit demand, but plays a smaller role than quality. Given the relative intensity of the "Reach for It" campaign in Canada, it may be the case that although the information elasticity value is lower than the quality elasticity, the underlying information variable is rising at a faster rate. This would go a long way toward explaining observed consumption trends in Canada relative to the United States, but requires corroboration to be completely convincing.

### **Conclusions and Implications**

This research seeks to explain the source of the observed difference in fruit and vegetable consumption between the United States and Canada. Despite their demographic and socioeconomic similarity, Canadians consume far more servings of fruits and vegetables each day compared to their U.S. counterparts—an observation that, although challenged by some, is confirmed using retail-level scanner data on produce sales in each country. Because prices tend to be higher in Canada, and incomes lower, we hypothesize that this difference in consumption levels is due in part to the superior quality of imported Canadian produce. Canadian produce is generally believed to be of higher quality because consumers in import regions tend to substitute toward higher quality products, once transportation charges and other shipping costs, which are invariant to quality, are applied—as predicted by the Alchian-Allen effect. Econometric tests of the Alchian-Allen effect, however, have been rare due to the fact that measures of quality are not generally available.

Consequently, we test the Alchian-Allen hypothesis by estimating structural latent variable (MIMIC) models of fresh produce quality, information, and consumption. In this way, we account for as many other explanations for the observed difference in U.S. and Canadian produce consumption as possible and then test for the independent effect of

quality. With a MIMIC approach, implied latent-variable values are estimated and then used as explanatory variables in models of produce demand in order to test the impact of quality and information on fruit and vegetable consumption. Thus we are able to account for the potentially confounding effects of price and expenditure differences between the two countries while estimating the independent effect of quality and information. Estimates of the entire two-stage MIMIC/demand model are obtained using a retail scanner data set made up of weekly observations during a one-year period across a number of regions in each country.

The empirical results show that information explains very little of the trend in U.S. fruit consumption, and is only weakly responsible for changes in the demand for vegetables. In Canada, however, information has had a strong positive effect on fruit consumption. Quality appears to have had no effect on the demand for either fruits or vegetables in the United States, but a significant impact on the demand for fruits in Canada. Consequently, much of the gap between Canadian and U.S. fruit consumption appears to derive from the higher average quality of fruit imported by, and consumed in, Canada. Thus, the Alchian-Allen effect is partly responsible for some of the observed difference in produce consumption rates between the two countries.

The implications of this research for academic, public policy, and commercial interests are many. Given their mandate to promote fruit and vegetable consumption, public health officials at the National Cancer Institute and allied state health agencies clearly have an interest in the information we provide on the factors influencing fruit and vegetable consumption. Understanding the role of information in increasing fruit and vegetable consumption can help public health officials design more effective public awareness programs and, potentially, secure higher funding for these programs in the future. Growers and shippers in the United States need marketing research such as this in order to better understand the dynamics underlying not only export markets, but the domestic market as well. Because the U.S. and Canadian markets are relatively homogeneous in terms of their socioeconomic makeup, it is likely the case that quality can be made to be as important in the United States as it is in Canada if consumers are given the choice of high quality produce over a period of time. The importance of this issue in the produce industry press is not surprising, given that moving from the current estimated consumption level of about 3.5 servings per day to the "5-A-Day" goal would result in a 30% increase in shipments for growers.

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