THESIS

OPTIMAL LOCAL FOODS PROCUREMENT IN THE NATIONAL SCHOOL LUNCH PROGRAM: AN ANALYSIS OF POTENTIAL IMPACTS OF FARM TO SCHOOL POLICIES ON PROCUREMENT PRACTICES IN THREE NORTHERN COLORADO SCHOOL DISTRICTS

Submitted by

Abigail B. Long

Department of Agricultural and Resource Economics

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Summer 2019

Master's Committee:

Advisor: Becca Jablonski
Co-Advisor: Marco Costanigro

Leslie Cunningham-Sabo

ABSTRACT

OPTIMAL LOCAL FOODS PROCUREMENT IN THE NATIONAL SCHOOL LUNCH PROGRAM: AN ANALYSIS OF POTENTIAL IMPACTS OF FARM TO SCHOOL POLICIES ON PROCUREMENT PRACTICES IN THREE NORTHERN COLORADO SCHOOL DISTRICTS

The most recent Farm to School (FTS) Census reported 23.6 million students in 42,587 schools (representing 42% of surveyed school districts) participated in FTS, with 77% of schools participating by procuring food locally (FNS 2014b). FTS connects K-12 students and local farms in an effort to increase the availability of healthy, local foods in school cafeterias, improve student nutrition, provide health and nutrition education opportunities, and increase market opportunities for small and medium-sized farms. Participation in FTS has been accompanied by legislative support at both the State and Federal levels. Specifically, in Spring of 2019 Colorado joined five other States and the District of Columbia in passing legislation that provides financial incentives for local food procurement (CO HB 19-1132). However, there is little research that assesses the relationship between FTS procurement and typical school food procurement practices carried out by Food Service Managers (FSMs), or quantifies how procurement policies effect procurement decisions by FSMs.

This paper utilizes a unique primary data set to assess the role FTS local food procurement plays in optimal school food procurement and how policies incentivizing local procurement may impact purchasing decisions. To conduct this study, we aggregated and analyzed primary data describing real purchasing decisions made by FSMs in three Northern

Colorado school districts and use the data to parameterize a Linear Programming (LP) optimization model. The optimization model acts as a proxy to examine a portion of FSM decision making regarding FFV purchasing and was then used to simulate how state reimbursements for local food purchases, as described in CO HB 19-1132, may alter FSMs procurement decision-making.

We find that increases in local purchasing associated with reimbursements are nominal at lower reimbursements rates of 1% to 15% of local food purchasing, with substantial increases in local food purchasing and cost savings at higher reimbursement rates of 50% and 100%. When compared to reimbursements provided by CO HB 19-1132 and adjusted for waste we estimate that 20-40% of purchasing of FFV for use on salad bars could be reimbursed in the three districts observed if all reimbursement funds are spent on salad bar FFV exclusively. While promising, our results point to the need for more research that compares cost reductions experienced by schools to overall policy costs to the state, and benefits captured by local farmers.

ACKNOWLEDGEMENTS

This work was funded as part of an USDA AFRI grant: “Rural Community Impacts of Farm to School: Food Supply Chains, Educational Programming, and Household Food Purchases”, award number 2017-67023-26246. I thank the Food Service Managers and their teams who provided invaluable data collection assistance, particularly: Natalie Leffler and Kara Sample of Weld School District 6; Becky Wiggins and Craig Schneider of Poudre School District; and Sarah Tomsic and Lisa Kendall of Thompson School District. Also, thanks to Dr. Melissa Pflugh Prescott for connecting me to the school districts and Kitty Patton-Ilse for invaluable data entry support.

TABLE OF CONTENTS

Introduction

Farm to School (FTS) connects K-12 students and local farms in an effort to increase the availability of healthy, local foods in school cafeterias or classrooms, improve student nutrition, provide health and nutrition education opportunities, and increase market opportunities for small and medium-sized farms (Joshi et al. 2008). In the 2013-2014 school year, 23.6 million students in 42,587 schools (representing 42% of surveyed school districts) participated in one or more of three FTS program areas: 1) procurement of local food, which occurs when local foods are purchased, promoted and served in the school cafeteria, as a snack, or in classroom taste-tests; 2) education activities related to agriculture, food, health or nutrition; 3) school gardens (FNS 2014b). Of these FTS, activities local food procurement is the most common, with 77% of schools participating (FNS 2014b).

Growing participation in FTS has been accompanied by legislative support at both the state and Federal levels (Christensen et al., 2017; NFSN 2017; Ralston et al., 2017). The 2010 Healthy Hunger Free Kids Act created the first mandatory funding program exclusively to support FTS, though other funding programs had been used previously to support FTS efforts (Ralston et al., 2017). Concomitantly, state policies have proliferated (NFSN 2017; Ralston et al., 2017). Of enacted legislation, 11 policies specifically support local food procurement (NFSN 2017).

The overarching aim of prioritizing local procurement is to leverage some of the National School Lunch Program's (NSLP) $13.6 billion annual budget (ERS 2018) to create new market opportunities for U.S. farmers and ranchers, spur regional economic development, and provide healthier, high quality food to students to improve health outcomes (Feenstra and Ohmart 2012; Low et al., 2015; Martinez 2016). While some research addresses FTS' student and economic development goals (e.g. Bontrager Yoder et al., 2015; Bristow et al., 2017; Jones et al., 2015; Christensen et al., 2017; Becot et al., 2017), little research assesses if policies supporting local food procurement change NSLP procurement practices at the school district level (Conner et al., 2011; Conner et al., 2012; Lyson 2016). Understanding how school districts respond to these FTS incentives is critical, as without a shift in procurement the purported farm, community, and student impacts cannot occur.

This paper asks the question: What role does local food purchasing play in cost-minimizing NSLP food procurement decisions, and how may policies that incentivize local food procurement impact purchasing decisions? The two goals of this research are: 1) Identify tradeoffs faced by Food Service Managers (the individuals making NLSP procurement decisions) associated with price, availability and variety that characterize NSLP procurement and 2) model how a Colorado FTS local food reimbursement policy may impact local purchasing of fresh fruits and vegetables (FFV) given identified trade-offs.

To address this question, we utilized a unique primary data set that describes FFV purchases made by Food Service Managers (FSMs) in three Northern Colorado school districts. This data was then used to inform an optimization model that mimics decisions made by FSMs, the individuals who are responsible for NSLP procurement and have been identified as "gatekeepers" to FTS (Joshi et al., 2008). Finally, the model was used to simulate the impacts of Colorado House bill 19-1132: *School Incentives to Use Colorado Food and Producers* on FSM FFV procurement behavior.

We begin this paper with a review of literature that contextualizes FTS as the most recent of a series of goal driven commodity programs, summarizes research on the impacts of FTS, and reviews FSM decision making in the NSLP and links to FTS procurement. Subsequently, we provide a description of the development of our procurement records database, a brief overview of optimization and its appropriateness for this research, and model development. We then present a summary of the results from our model output, as well as a discussion of findings regarding potential impacts of Colorado House bill 19-1132. We conclude with implications for FTS and recommendations for future research.

Literature Review

Procurement has been leveraged to achieve social goals over the course of contemporary U.S. and European history (McCrudden 2004). As large food buyers, governments have the capacity to shape markets, affect public health, and influence the types of products offered to government and individual consumers while increasing market opportunities and reducing risk for producers by providing stable prices (Noonan et al., 2013, McCrudden 2004). Government nutrition programs, including Child Nutrition Programs (CNPs), are one example of how procurement is currently used to achieve such goals.

The NSLP is one example of a CNP, which has dual goals of providing nutritious meals to children and supporting American agricultural markets (FNS 2016). Procurement in the NSLP is conducted through two avenues: 1) commercial food purchases from non-governmental food distributors; and, 2) food purchasing directly from the government through the U.S. Department of Agriculture (USDA) Foods program. USDA Foods are procured by the Agricultural Marketing Service (AMS) and Department of Defense (DoD) to support agricultural commodity program goals and homeland defense (FNS 2016). Specifically, large government purchases of U.S. agricultural products leverage federal dollars to stabilize prices for producers by increasing demand for their products while managing the supply available on the market.

Funding for NLSP procurement comes from two sources: reimbursements, which are used for commercial food purchases, and entitlements used for the purchase of USDA Foods. Reimbursements are cash payments provided based on the number of meals served in the prior month and used to pay commercial vendors while entitlements are calculated based on prior year lunch numbers and provided in the form of a balance that can only be used for the "purchase" of USDA Foods.

It is in this context that FTS has emerged as the newest, and smallest, program focused on leveraging federal dollars to achieve the social goals of improving student health and supporting U.S. farms and ranches (Joshi et al., 2008). While FTS overlaps with the broad NSLP goals of providing nutrition to students and supporting agricultural markets, it stands in contrast to the USDA Foods program in its focus on leveraging reimbursements and commercial supply chain purchasing (rather than entitlements for procurement from government supply chains) to increase market access for farms located proximate to school districts. Further, it includes a focus on student learning and nutrition outcomes that are not part of the USDA Foods program. These differences yield several purported benefits of FTS that distinguish it from the NSLP, and USDA Foods commodity programs focus. Framed by the National Farm to School Network (NFSN) as "Kids Win, Communities Win, Farmers Win" examining these purported benefits have recently garnered attention from researchers. Here we examine the literature regarding each of these claims as well as the relationship between FTS and NSLP operations.

Kids Win, Communities Win: Student Outcomes and Regional Economic Impacts

A portion of FTS research focuses on the impacts of FTS educational programming on student behavior, including: consumption of fruits and vegetables (e.g., Bontrager Yoder et al., 2015; Bristow et al., 2017; Smith et al., 2012; Evans et al., 2012; Moss et al., 2013); knowledge of fruits and vegetables and nutrition attitudes (e.g., Bontrager Yoder et al., 2014; Evans et al., 2012); and willingness to try fruits and vegetables (Jones et al., 2015). Collectively, this work finds moderate to no increase in consumption of FFV, with some improvement in nutrition attitudes, selection of healthy foods, and increasing willingness to try vegetables. Despite these findings a systematic literature review conducted by Prescott et al. (2019) that incorporates the strength of methods used does not provide conclusive evidence linking FTS to changes in student FFV consumption or preferences.

Additional research examines the regional economic impacts of local procurement. Regional food systems can have positive economic impacts (O'Hara 2011; Shideler et al., 2018) in part through farms that sell to schools procuring more of their inputs, including labor, locally than farms not selling to schools (Christensen, Jablonski and O'Hara., 2019). To that end, several studies have assessed the economic impact of specific FTS programs (e.g. Tuck et al., 2010; Kluson 2012; Gunter and Thilmany 2012; Roche et al., 2016). Together these studies report statistically significant, but small, positive regional economic impacts of FTS procurement. However, these studies do not provide generalizable results and are disproportionately focused on the demand side of local procurement (O'Hara and Pirog 2013; Becot et al., 2017; Christensen et al., 2017).

Farmers Win: Small and Mid-Size Farm Viability

FTS as a path to farm viability is founded in the regional food supply chain and intermediated market participation (e.g., selling to institutions such as schools, grocery stores or food aggregators/distributors) literature. Regional supply chains are thought to support farm viability and improve small and mid-size farm survival rates as producers can receive a larger share of retail prices, and secure premiums for products not possible in conventional supply chains (King et al., 2010; Hardesty et al., 2014; Low et al., 2015). The benefits of participating in regional markets are influenced by the market channel (e.g. direct to consumer, intermediated) producers utilize (Low and Vogel 2011; Bauman, McFadden and Jablonski 2018). Intermediated markets, such as schools, are of particular interest as these markets are associated with increased opportunities to achieve economies of scale that support higher sales, lower costs and ultimately profitability. (Low et al., 2015; Bauman, McFadden and Jablonski 2018; Shideler et al., 2018).

Despite evidence that selling through intermediated markets can support improved farm viability, it has been noted that sales to schools represent a relatively small percentage of farmers' sales (Conner et al., 2012; Izumi, Wright and Hamm 2010; Joshi et al., 2008). Several authors attribute the lack of contribution to farm sales to "structural incompatibilities" (i.e. price and seasonality) between FTS procurement and standard NSLP operations (Izumi, Wright and Hamm 2010; Thornburg 2013). Though to date, no peer-reviewed literature looks specifically at farm and ranch profitability impacts of sales through school markets.

FSM Trade-Offs in NSLP and FTS Management

FSMs have challenging positions. They are responsible for balancing a '3-legged stool', including: 1) meeting NSLP nutrition standards, 2) operating break-even or better programs, and 3) maintaining or increasing participation rates of free and reduced (F/R) and full paying students (Ralston et al., 2008; Ralston and Newman 2015). In order to achieve these three goals FSMs must simultaneously meet federal nutrition requirements, satisfy student and parent preferences, and serve a variety of foods, all while navigating shifting availability of products and federal bidding requirements with a limited budget (Izumi, Alaimo and Hamm, 2010; Izumi, Wright and Hamm, 2010; Lambert, Conklin and Johnson 2002; Motta and Sharma 2016; Conner et al., 2012).

Hwang and Sneed (2007) studied the relative importance of these performance criteria by surveying a panel of school foodservice professionals from across the U.S. Their results indicate that achieving customer satisfaction, including keeping students, parents, administrators, and food service staff satisfied, is their first objective followed by financial management, which includes managing limited budgets and maintaining student participation. Meal quality, specifically menu variety, program management (meeting nutrition requirements) and operations management follow in order of importance (Hwang and Sneed 2007). While customer satisfaction is noted as the paramount concern of FSMs, previous research links customer satisfaction directly to both participation rates and program financial viability (Meyer and Conklin 1998; Meyer 2000; Gordon et al., 2007). Hwang and Sneed (2007) also note that customer satisfaction is an "intangible criteria" that though important to FSMs is difficult to quantify. Further, FSM goals are closely intertwined, and none can be achieved without a well-managed program budget.

NSLP budgets are primarily determined by federal reimbursement for meals and entitlements for the purchase of USDA Foods (FNS 2016). Because FTS leverages reimbursement budgets to purchase local foods, we maintain a focus on reimbursements here. The amount of reimbursement per meal received ranges from $0.31 to $3.54 per meal in the contiguous U.S. and is dependent on compliance with USDA nutrition standards for school meals, the percentage of lunches *served* at F/R rates and the percentage of the student population *eligible* for free or reduced rates as summarized in Table 1.

Table 1. NSLP Reimbursement Rates for the Contiguous U.S[1].

Contiguous U.S.	Less than 60% F/R[2]	Less than 60% F/R + 6 cents[3]	60% or more F/R[4]	60% or more F/R + 6 cents
Paid	0.31	0.37	0.33	0.39
Reduce Price	2.91	2.97	2.93	2.99
Free	3.31	3.37	3.33	3.39

[1] FNS 2018
[2]Less than 60% of the U.S. student population is eligible for Free or Reduced (F/R) meals
[3]An additional 6 cents per meal reimbursement is provided for compliance with all USDA nutrition requirements set forth in the 2010 Healthy Hunger Free Kids Act (HHFKA), a subset of which are summarized in Table 4.
[4]More than 60% of the U.S. student population is eligible for Free or Reduced (F/R) meals.

While FSMs have no control over F/R rates, meeting federal nutrition requirements ensures FSMs can obtain reimbursements for meals served and fund their NSLP. Compliance with federal NSLP regulations requires that foods offered in lunches meet certain nutrition requirements (USDA 2012). These requirements received a major overhaul in 2010 as part of the Healthy Hunger Free Kids Act (HHFKA) that required foods in meals to contribute to certain nutrition categories, with a significant increase the in the amount of FFV NSLP lunches must provide (Ralston and Newman 2015). In order to support schools in meeting the new nutrition standards, especially considering concerns over increased costs associated with providing more FFV, two additional rules were established (Ralston and Newman 2015). First, schools that meet the new nutrition standards are eligible to receive an additional six cents per meal reimbursement. Second, meals that utilize Offer vs. Serve (OVS) became eligible for reimbursement (Ralston and Newman 2015). OVS allows for flexibility in meal plan requirements in an effort to reduce waste associated with implementation of new nutrition standards (Ralston and Newman 2015). OVS requires that lunches *offer* foods that fall into the nutrition requirement categories, but students are not required to select all products offered. Rather, students must be *served* at least a half-cup of FFV to form a reimbursable meal (FNS

2015). Yet, the addition of extra reimbursements and OVS still do not ensure financial health of NSLPs considering increased costs associated with the new nutrition standards (Ralston and Newman 2015), particularly in light of evidence that even prior to implementation of the new standards 20 percent of school districts NSLP revenue fell below 85% of costs (May et al., 2014).

Limited reimbursement budgets thus highlight the importance of student participation in NSLPs. Ultimately, participation rates must be maintained to support financial management goals and program viability as the more students who participate, the better able FSMs are to achieve economies of scale in their food purchases (Conner et al., 2012; Ralston and Newman 2015).

Providing meals that satisfy customers and encourage participation is dependent on more than meeting nutrition requirements. Meals characterized by a variety of high-quality food choices, that are attractive, culturally appropriate and perceived to be appealing are essential to maintaining participation rates (Meyer and Conklin 1998; Meyer 2000; Gordon et al., 2007). Yet, producing such meals is costly and hindered by limited budget yielding a “chicken and egg” problem of how FSMs can increase participation rates with a limited budget in order to increase their program budget (Conner et al., 2012).

<u>FTS procurement</u>

A body of qualitative research has identified several specific challenges associated with FTS procurement in the “structural context” of the NSLP including availability (Izumi, Wright and Hamm 2010; Harris et al., 2011; Boys and Fraser 2019; Thornburg 2013; Gregoire and Strohben 2002; Motta and Sharma 2016; Stokes 2014; Conner et al., 2012); price and budget constraints (Izumi, Wright and Hamm 2010; Harris et al., 2011; Motta and Sharma 2016;

Bateman et al., 2014; Conner et al., 2012); communication barriers between FSMs and producers (Harris et al., 2011); lack of regional supply chain infrastructure (Harris et al., 2011; Feenstra and Ohmart 2012; Thornburg 2013; Voght and Kaiser 2008; Bateman et al., 2014; Conner et al., 2012; Nurse et al., 2011; Bateman et al., 2014; Stokes 2014); and concerns regarding local producers food safety practices(Harris et al., 2011; Thompson et al., 2016; Motta and Sharma 2016). This research is summarized in Table 2 and paired with Botkins and Roe's (2018) analysis of 2012-2013 FTS Census. Of note are challenges associated with price, which 45.3% of schools cite as a barrier to FTS procurement, and availability, which 67.5% of schools indicate is a significant barrier to local food purchasing (Botkins and Roe 2018).

Table 2. Challenges associated with FTS procurement identified in previous literature and FTS Census responses

Challenge	Description	Literature	FTS Census Responses[5]
Availability	School year does not coincide with most of the U.S.'s agricultural production season. Seasonality. Producers do not have high enough production capacity to meet school demand.	Izumi, Wright and Hamm 2010; Harris et al. 2011; Boys and Fraser 2019; Thornburg 2013; Gregoire and Strohben 2002; Motta and Sharma 2016; Stokes 2014; Conner et al. 2012;	67.5% of schools cited product availability as significant barrier to local food purchasing
Price, Budget Constraints	Producers require a price that is too high for FSMs	Izumi, Wright and Hamm 2010; Harris et al., 2011; Motta and Sharma 2016; Bateman et al., 2014; Conner et al., 2012	45.3% cite high prices as a barrier to local purchasing
Communication Barriers	Communicating with producers and finding information about products is difficult.	Harris et al., 2011	19.1% indicate it is hard to get reliable information about products
Lack of Regional Supply Chain Infrastructure	Shortage of aggregation, processing, and distribution resources creates bottlenecks and increases transaction	Harris et al., 2011; Feenstra and Ohmart 2012; Thornburg 2013; Voght and Kaiser 2008; Bateman et al., 2014;	- 36.3% have primary vendors that do not carry local product.

	costs. Too much labor required for food preparation. Local products differ in appearance and size from conventional.	Conner et al., 2012; Nurse et al., 2011; Bateman et al., 2014; Stokes 2014	- 29.5% of schools' local vendors don't offer range of products - 25.3% cite a lack of reliable delivery - 22.3% indicated finding new suppliers is difficult.
Food Safety	With the advent of Food Safety Modernization Act (FSMA) there is nascent concern about safety of local foods.	Harris et al., 2011; Thompson et al., 2016; Motta and Sharma 2016	n/a

[5] Botkins and Roe (2018) provide statistical analysis beyond what the FTS Census provides in report summaries.

The Role of Policy

Considering the complex problems that characterize FTS procurement processes it has been noted that policy, especially at the state and local level, may be able to address barriers to procurement in ways federal policies cannot. Specifically, state and local policies can be more effectively tailored and responsive to local circumstances than federal policies (Martinez 2016; McCarthy et al., 2017). This dynamic, in addition to a lack Federal policy explicitly addressing procurement (the current USDA FTS grant program does not allow funding to directly subsidize FTS procurement FNS CNS 2018), may provide some explanation for recent increases in procurement focused state FTS policies (NFSN 2017), including CO-HB 19-1132.

With HB 19-1132, Colorado joins five other states and the District of Columbia in passing legislation providing financial support for local foods procurement (Table 3). Of the eleven policies passed in these states, eight, including Colorado, provide financial support in the form of grants or reimbursements for the purchase of local foods by schools, school districts or childcare facilities. Two of the policies focus on reimbursements for breakfast, while the remainder do not specify the meal or are focused on lunches. Four policies tie reimbursements to other FTS goals such as nutrition education and school gardens.

Table 3. Summary of Local Food Procurement Reimbursement Legislation in the U.S. as of 2017[6] plus Colorado's 2019 Legislation[7]

State	Bill	Description of Procurement Support	Reimbursement Recipient	Reimbursement Rate or Budget Appropriation (if available)
AK	AK S.B 160, 18, and 119	Encourages school district to purchase nutritious Alaska-grown, caught, or harvested foods. Appropriates funds for fiscal year 2012, 2013 and 2015 respectively.	School districts	$3 million appropriated per year
CA	CA S.B. 19	Increases the amount of money the state reimburses schools for free and reduced-price meals. Allows school districts to convene a committee to increase organic produce in school meals, support school gardens, and collaborate with local farmers markets.	Schools	n/a
CA	CA S.B. 281	Reimburses schools 10 cents for every breakfast that includes an additional fruit or vegetable serving, encourages schools to buy California products and requires that local produce samples be offered as a part of nutrition education.	Schools	10 cent reimbursement per breakfast
DC	DC L.B. 144	Makes breakfast meals eligible for local foods reimbursement.	Unknown	Reimbursement for breakfast
DC	DC L.B. 564	Reimburses schools an additional 5 cents for meals with locally grown, unprocessed foods and 10 cents for meals that meet the nutrition requirements.	Schools	Additional 5 cent per meal reimbursement
DC	DC L.B. 750, L.B. 849, & L.B. 956	Provides additional money for school meals and reimburses childcare facilities an additional 5 cents per meal served when at least one component of a meal is comprised entirely of locally grown, unprocessed foods.	Childcare facilities	Additional 5 cent per meal reimbursement
MI	MI S.B. 801	Helps schools purchase locally grown produce by providing an additional 10 cent reimbursement per meal that includes local fruit, vegetables, or legumes.	Schools	Additional 10 cent per meal reimbursement, $250,000 appropriated

NY	NY A. 2652A/S. 6024A*	Raises the cap on direct purchases (from local producers) from 15 cents to 20 cents per meal. Requires development of regulation that allows schools to pay farmers more than the national wholesale price for locally grown foods.	Schools	n/a
OR	OR H.B. 2649*	Issues grants to reimburse school districts for providing food-based educational activities and for the costs associated with purchasing local food products. At least 80% of the grant money must be used to cover the cost of fresh, Oregon foods, and another 10% funds educational activities.	School Districts	$500,000 appropriated
OR	OR H.B. 2800* (2011)	Awards grants to school districts to help cover the costs incurred purchasing fresh, Oregon food products and providing food-based, agriculture-based, and garden-based educational activities.	School Districts	$200,000 appropriated
CO	CO H.B. 19-1132	Reimburses schools for the purchase of Colorado Foods in the previous school year.	School Districts	2 cent reimbursement per meal. $500,000 appropriated for reimbursements

[6]NFSN Legislative Survey (2017)
[7] CO HB 19-1132. Other than CO legislation all other listed legislation is from the NFSN 2017 Legislative Survey, thus this table may omit policies passed by states since 2017 other than Colorado.

Despite the proliferation of procurement specific policies, research on state FTS policies is focused on the relationship between *rates* of state FTS legislation and FTS programming, rather than impacts of policies on purported FTS outcomes. Specifically, Schneider (2012) and McCarthey et al. (2107) reported that FTS programs are more common, and districts are more likely to serve local products in states with FTS related laws. In contrast, Lyson (2016) found that state legislation had no statistically significant impact on FTS participation rates.

Further, to the authors' knowledge there is no research that quantifies the impact of state level FTS procurement policies on local purchasing, though various authors have noted a need for more research. Conner (2011) provides a general suggestion for research on the impacts of public policies on local food procurement. Likewise, there is an identified need for better data to quantify impacts of FTS (e.g., Christensen et al., 2017; Boys and Hughes 2013). Finally, more research leveraging state-level data (including school food budgets and expenditures) is needed to examine the relationship between specific content of legislation and FTS Rates (Lyson 2016). These calls underscore that the current literature fails to provide evidence of whether the presence of a FTS procurement policy changes purchasing behavior, a question which merits examination especially in light of increasing rates of FTS procurement legislation.

Materials and Methods

Our methodological approach was comprised of three stages. First, we aggregated and analyzed purchase receipts from three Northern Colorado school districts describing FFV procurement decisions made by FSMs. Then, the dataset was used to parameterize an optimization model that solves for a product mix that meets NSLP requirements and mimics FSM decision making considering trade-offs and constraints outlined above. Third, a range of local food reimbursement scenarios were simulated by reducing the price of local products to determine how Colorado House Bill 19-1132 may alter FSMs procurement decision-making and procurement of local FFV.

Optimization

Optimization methods are characterized by an *objective function* that is maximized or minimized; a set of *decision variables*, the levels of which are selected to maximize/minimize the objective function; and *constraints* which represent factors that affect the problem but are external to it. Optimization modeling also provides shadow prices (SP) of constraints and reduced costs (RC) of decision variables. Shadow prices detail how much the value of the objective function would change if a constraint changed by one unit. Similarly, reduced costs show the amount the coefficient on a decision variable must change for an additional unit of that decision variable to be brought into the product mix or, if the RC is negative, reveals the willingness to pay (WTP) for an additional unit of a decision variable.

Optimization is commonly utilized in nutrition and diet research. Many of these studies are part of World Health Organization (WHO) efforts to improve nutrition in malnourished populations while minimizing costs. Similar methodology is used in the United States to determine Supplemental Nutrition Assistance Program (SNAP) allocations, wherein an ideal diet is identified, the cost of which is minimized using current market prices, and the resulting cost is the level of benefits SNAP participants receive (Carlson 2007). It has also been used to develop Food Based Dietary Guidelines (FBDGs) (Ferguson et al., 2004), and determine optimal diets given a limited budget using Cost of Diet (CoD) tools (e.g. Frega et al., 2012; Baldi et al., 2013; and Okuba et al., 2015): a linear programming method that minimizes the cost of theoretical diets given nutrient requirements, cost, availability and price constraints, and such models can be calibrated with actual market price and food purchase frequency data (Biehl et al., 2016).

FSMs grapple with trade-offs and accordingly exhibit optimizing behavior. Optimization modeling thus provides a useful methodology through which to examine FSM procurement decision making. It is tailored to provide quantitative insight (through shadow prices (SPs) and reduced costs (RCs)) to the trade-offs FSMs while revealing how procurement decision may change in response to a policy that impacts prices of some decision variables.

<u>Conceptual Model</u>

Following Hwang and Sneed's (2007) analysis of performance criteria for NLSP management, an ideal optimization model will mimic FSM procurement decision making in: 1) solving for a product mix that meets federal NSLP nutrition (Table 4); and 2) serving quantity requirements via the selection of a products that satisfy quality standards, can be processed with limited labor and combined to form meals that satisfy customers. The objective of the model is to minimize the cost of procurement of products that meet these requirements.

Minimize *the objective function:* the total cost of all pounds (x) of food purchased.

$$min \sum_{p} c_p x_p$$

Subject to:

Quantity: The pounds of product procured must provide an adequate number of servings of products (as determined by subsequent constraints).

$$\sum_{p} x_p \geq \sum_{p} y_p$$

Nutrition: Servings of all products (p) in each nutrition category (n, Table 2) must provide at least as much (or as little) nutrition as is required in each category (n) at grade level (g)

$$\sum_{p} y_{pn} \geq \sum_{g} NutritionRequirements_{ng}$$

$$\sum_{p} y_{pn} \leq \sum_{g} NutritionRequirements_{ng}$$

Quality: The sum of quality (q) of all servings of each product (p) must meet or exceed an FSM designated overall quality standard based on taste, texture and appearance of served products.

$$\sum_{p} q_p y_p \geq Quality_p$$

Satisfaction: Total customer (student, parent, administrator and foodservice staff) satisfaction (s) with each meal (z) served must meet or exceed an FSM designated overall satisfaction standard.

$$\sum_{m} s_m z_m \geq Satisfaction_m$$

Labor: Minutes of labor (l) required to prepare each pound of product (p) must not exceed a maximum amount of labor allowed, as determined by an FSM.

$$\sum_{p} l_p x_p \leq Labor_p$$

Where:

p = product
g = grade level of students (k-5, 6-8, 9-12)
n = nutrition category
m = meal

c_p = price per pound of product (p)
x_p = pounds of product (p) Decision Variables
y_p = servings of product (p)
z_m= number of meals (m)
y_{pn} = servings of product (p) contributing to nutrition category (n)
q_p = quality of each serving of product (p)
s_m = level of customer satisfaction with each meal (m)
l_p = minutes of labor required to process one pound of product (p)

$NutritionRequirements_{ng}$= required servings of product from nutrition category (n) that must be provided at grade level (g)
$Quality_p$ = quality of all served products (p)
$Satisfaction_m$ = customer satisfaction with all meals (m)
$Labor_p$ = labor required to prepare all products (p)

Table 4. NSLP Meal Plan Nutrition Requirements by Nutrition Category and Grade Level[8]

Meal Plan Category	Grade K-5	Grades 6-8	Grades 9-12
	Amount of Food Per Week (Minimum per Day)		
Fruits (cups)	2 ½ (½)	2 ½ (½)	5 (1)
Vegetables (cups)	3 ¾ (¾)	3 ¾ (¾)	5 (1)
Dark Green	½	½	½
Red Orange	¾	¾	1 ¼
Beans/Peas	½	½	½
Starchy	½	½	½
Other	½	½	¾
Additional Veg to Reach Total	1	1	1 ½
Grains (oz eq)	8-9 (1)	8-10 (1)	10-12 (2)
Meat/Meat Alternatives (oz eq)	8-10 (1)	9-10 (1)	10-12 (2)
Fluid Milk (cups)	5 (1)	5 (1)	5 (1)
	Other Specifications		
Min-max calories (kcal)	550-650	600-700	750-850
Saturated Fat (% total calories)	< 10	< 10	< 10

Sodium (mg)	≤ 640	≤ 710	≤ 740

[8]FNS 2015

However, building such a holistic model is not currently feasible for a variety of reasons. First, there is no systematically available data of FSM NSLP procurement decisions across all nutrition categories. Second, neither quality measures of served NLSP foods or metrics regarding customer satisfaction are available. Finally, there is no data available regarding labor required to process specific products. As such we propose a proxy model, for which the data needed is accessible, that provides insight to a portion of FSM procurement decision making.

A proxy model provides the opportunity to focus on FSM FFV procurement decision making, providing a solution that meets a subset of NSLP nutrition requirements, specifically requirements of nutrition categories satisfied by FFV purchases, and serving quantity requirements. A variety constraint is then utilized as a proxy for quality and preference, based on the assumption that variety in FSM purchasing is a vehicle to serving high quality products that satisfy customer preference. The objective of the model is to minimize the total cost of FFV purchases in each Fall semester by selecting pounds of products that may be purchased across a subset of NSLP nutrition categories.

Minimize *the objective function:* the total cost of all pounds (x) of FFV purchased.

$$min \sum_p c_p x_p$$

Subject to:

Quantity: The pounds of FFV product (p) procured must provide an adequate number of servings of FFV products (as determined by subsequent constraints).

$$\sum_p x_p \geq \sum_p y_p$$

Nutrition: Servings of all FFV products (p) in each nutrition category (n) examined must provide at least as much nutrition as is required in each category (n) at grade level (g)

$$\sum_p y_{pn} \geq \sum_g NutritionRequirements_{ng}$$

Variety: the mix of products provided must exhibit certain variety characteristics

$$\sum_p v_p x_p \geq Variety_p$$

Where:

p = product
g = grade level of students (k-5, 6-8, 9-12)
n = nutrition category (Dark Green, Red Orange, Other, Fruit)
m = meal

c_p = price per pound of product (p)
x_p = pounds of product (p) Decision Variables
y_p = servings of product (p)
y_{pn} = quarter cup servings of product (p) contributing to nutrition category (n)
v_p = variety of all pounds of product (p)

$NutritionRequirements_{ng}$= required servings of nutrition category (n) that must be provided at grade level (g) ???
$Variety_p$ = quality of serving of product (p)

<u>Data Collection</u>

To parameterize our proxy model three school districts in Northern Colorado provided data on FFV purchased for use in school lunches from August 2017 through December 2018. The three districts are in adjacent counties, all participate in the NSLP and FTS and utilize OVS when serving lunches. In addition, all districts have access to the same vendors, though each transacts with a unique subset. The districts range in size from 16,278 student enrolled in the 2017/18 school year to 30,019 and are all classified as "urban-suburban" districts by the

Colorado Department of Education (Table 5) (CDE 2019). All have free and reduced lunch rates between 31% and 64% (Table 5) and relatively similar demographic make-ups though the Greeley school district has a significantly higher proportion of minority students (67%) (Table 6) (CDE 2019).

Table 5. Student Enrollment and Free and Reduced Price Lunch Rates by District

District	District Setting	PK-12 Student Count	Free Lunch Eligible	Reduced Lunch Eligible	Not Eligible	F/R	Percent Free	Percent Reduced	Percent F/R	OVS	Addtl 6-Cent per Meal
Poudre R-1	Urban-Suburban	30019	7301	1923	20795	9224	24%	6%	31%	Yes	Yes
Thompson R2-J	Urban-Suburban	16278	5044	1485	9749	6529	31%	9%	40%	Yes	Yes
Greeley 6	Urban-Suburban	22325	12166	2098	8061	14264	55%	9%	64%	Yes	Yes

Table 6. Demographic Characteristics of Districts

District	American Indian or Alaskan Native	Asian	Black or African American	Hispanic or Latino	White	Native Hawaiian or Other Pacific Islander	Two or More Races	Percent Minority	Percent Female	Percent Male
Poudre R-1	151	910	362	5,416	22,027	48	1,105	26.6%	48.7%	51.3%
Thompson R2-J	78	182	197	3,360	11,919	23	519	26.8%	47.7%	52.3%
Greeley 6	67	556	529	13,418	7,365	54	336	67.0%	49.1%	50.9%

FFV were selected as the focus of this analysis as FSMs in these districts indicate that most of their local purchases are FFV, a behavior reflected in FTS census responses indicating that FFV are the most common locally procured item in schools participating in FTS (FNS 2014b). Additionally, all three districts indicate they satisfy the majority of four NSLP nutrition category (Dark Green, Red Orange, Other and Fruit) requirements by serving most of the FFV they procure on salad bars. Finally, all districts purchase a similar mix of FFVs (Table 7).

Table 7. FFV Purchased in each district

Product	Poudre	Thompson	Weld
Apples	X	X	X
Asparagus	X		
Bananas	X	X	X
Berry	X	X	
Broccoli	X	X	X
Cabbage	X		X
Carrots	X	X	X
Cauliflower	X	X	X
Celery	X	X	X
Clementines	X	X	
Cucumbers	X	X	X
Grapefruit	X	X	X
Grapes	X	X	X
Kiwi	X	X	X
Lettuce	X	X	X
Melon	X	X	X
Mushroom	X		X
Oranges	X	X	X
Peaches	X	X	X
Pear	X	X	X
Peas	X	X	X
Peppers	X	X	X
Pineapple	X	X	X
Plums	X	X	X
Radishes	X	X	X
Spinach	X	X	X
Squash	X	X	X
Tomatoes	X	X	X

Data was obtained in the form of paper procurement receipts (invoices) covering three semesters of purchasing: Fall 2017, Spring 2018 and Fall 2018. Additionally, each district provided records of the number of reimbursable meals served across the district at all grade levels. Over 650 receipts were aggregated in a database comprised of approximately 7,700 transactions of more than 60 products. Similarities across districts in terms of location, enrollment, FFV purchased and primary use of FFV on salad bars supported combining records from the three districts in to form a regional dataset.

Each entry records the type of product, varietal, level of processing (e.g. whole vs. shredded carrots), purchase price, quantity purchased, pack size, vendor, purchase date and product source (local vs. conventional). Once compiled, all unit purchases were converted to pounds purchased using USDA and vendor provided volume to weight conversions (WSDA 2012; Produce Marketing Association 2018).

The data were organized for modeling in Stata v.15.1. Observations were limited to items served on salad bars that contribute to one of the four nutrition categories of interest. Unique and rarely purchased products (e.g. kumquats, starfruit and other items purchased less than 5 times in a semester) were dropped as well as erroneous items ordered for activities other than student consumption (e.g. carving pumpkins). Product classifications were aggregated to include all products considered substitutes (e.g. red and green cabbage, field greens and spring mix).

Receipt entries were tabulated by product type, varietal, processing, source and purchase month, showing that significant local purchasing occurred only in Fall semesters. As such, Spring semester data was dropped from the analysis. For each unique product, the average price per pound and total quantity purchased was calculated by month. Comparison of prices and products purchased each semester revealed marked seasonality in average product prices and types of products purchased (Table 4). Purchasing was therefore split into two seasons within each semester: August-October and November-December. The seasonal break was delineated where both the number of products purchased locally decreased significantly and the percentage of local purchasing dropped below 5%. Additionally, a significantly lower level of local purchasing was observed in 2018 than 2017, likely due to decreased availability of local products after several local farms closed between the two school years.

Finally, average prices and total purchasing were recalculated by season for use in our parameterize an optimization model that mimics FFV purchasing decisions made by FSMs across the three districts. Modeling was performed in GAMS v. 2.0.35.10 using MINOS LP Solver v. 5.1.

Table 8. Comparison of Local and Total Product Purchasing by Month Across Districts in 2017 and 2018

	2017					**2018**				
	August	**September**	**October**	**November**	**December**	**August**	**September**	**October**	**November**	**December**
Percent Local Purchasing	13.68%	30.41%	2.15%	3.28%	0.60%	9.40%	15.06%	22.08%	0.79%	0.00%
Number of Local Products	11	14	13	6	3	9	10	7	3	1
Total Number of Products	52	57	56	46	43	52	54	50	41	34

<u>Empirical Model</u>

The final empirical model solution is provided in pounds of FFV that meet the nutrition requirements for Dark Green, Red Orange, Other and Fruit nutrition categories and while exhibiting a level of variety informed by observed FSM purchasing.

Compliance with NSLP nutrition requirements is determined by number of servings of FFV provided to students. As such a conversion is conducted that links pounds of raw product purchased to quarter cup servings of products per conversion rates from the USDA Food Buying Guide (USDA 2018). While this conversion accounts for processing (trim) waste it should be noted that the model does not account for pre-consumer waste[9] associated with sub-standard products (rotten or blemished products that cannot be served) or overproduction.

NSLP nutrition requirements are then imposed as lower bounds on the total quantity of products selected along with upper and lower bounds on the proportion of the product mix represented by products from each nutrition category. These constraints are informed by data on the number of meals served in all districts from the Fall 2017 and 2018 semesters and observed purchasing across nutrition categories respectively. Further, variety of products within nutrition categories is imposed as upper and lower bounds to prevent only the least costly product from each nutrition category from being selected. This constraint ensures a more varied product mix than the model would otherwise select and is also informed by observed purchasing ratios in the procurement database.

Finally, upper and lower bounds were imposed on local products. Considering local products are often more expensive than conventional products their selection does not align with the cost-minimizing objective of the model. As such lower bounds of 50% of current purchases were placed on local products to ensure selection of products matched observed purchasing. These bounds are informed by conversations with FSMs indicating that local purchasing is a priority even when it is more expensive than purchasing conventional products. Lower bounds are further supported by evidence that local purchasing in schools is driven by considerations other than cost such as appealing to students or a desire to support the local

[9] Prescott et al. (2019b) define pre-consumer waste as: "occur[ring] before the point of purchase and includes food discarded because of spoilage, contamination, trim waste (ie, food scraps removed during the preparation process), food recalls, product expiration, overproduction, and production mistakes (eg, burning or other quality-control issues). Post-consumer waste, often called plate waste, occurs past the point of purchase." (pg.1)

economy (Izumi, Alaimo and Hamm 2010; Conner et al., 2012). Upper bounds of 150% of observed purchasing were placed on all local products to simulate supply limitations. Upper bounds are informed by FSM corroboration of FTS Census responses revealing that local procurement is constrained by local product availability (FNS 2014b). Unfortunately, no data on local product supply was available to provide more precise bounds.

Minimize *the objective function:* the total cost of FFV from all sources in both seasons selected in a Fall semester.

$$min \sum_{pst} c_{pst} x_{pst}$$

Subject to:

Pounds to Servings Conversion: Number of quarter cup servings of products provided to students (xx_{pt}) must be less than or equal to the pounds of products purchased when converted to quarter cup servings. The right-hand side (RHS) of the equation is summed across source as source does not influence the conversion.

$$y_{pt} \leq \sum_{s} x_{pst} * PoundstoServingsConv_p$$

Required Servings of Fruits and Vegetables: Total servings of products purchased (xx_{pt}) must provide at least ½ cup (2 quarter cup servings) fruit OR vegetable for every meal served. Servings are summed across product as all products contribute to the total quantity requirement. The RHS is summed across grades as the requirement holds irrespective of what grade level the meal was served to.

$$\sum_{p} y_{pt} \geq \sum_{g} 2 * NumMeals_{tg}$$

Nutrition: Servings of products from each nutrition category (y_{nt}) can make up no more/less than a proportion of total purchasing. The first term on the RHS provides the total number of servings of products that must be provided. While the Nutrition term is a table of observed purchasing ratios modified by alpha as a calibration parameter described above. Together the terms force the model to select products across nutrition categories in proportions like those observed in the dataset.

Lower Bound:

$$y_{nt} \geq \sum_{g} 2 * NumMeals_{tg} * \propto * Nutrition_{nt}$$

Upper Bound

$$y_{nt} \leq \sum_{g} 2 * NumMeals_{tg} * ((1 - \propto) + \propto * Nutrition_{nt})$$

Variety: Servings of products (y_{pt}) can make up no more/less than a proportion of products in each nutrition category (y_{nt}). The first term on the RHS provides the total number of servings of products that must be provided. While the variety term is a table of observed purchasing ratios are modified by alpha as a calibration parameter described above. Together the terms force the model to select a variety of products within nutrition categories in proportions like those observed in the dataset.

Lower Bound:

$$y_{pt} \geq \sum_{n} \propto * Variety_{pnt} * y_{nt}$$

Upper Bound:

$$y_{pt} \leq \sum_{n} ((1-\propto)+\propto * Variety_{pnt}) * y_{nt}$$

Where:

p = product
s = source (local or conventional)
g = grade level of students (k-5, 6-8, 9-12)
n = nutrition category (Dark Green, Red Orange, Other, Fruit)
t = season (Aug-Oct, Nov-Dec)

c_{pst} = price per pound of product (p) from source (s) in season (t)
x_{pst} = pounds of product (p) from source (s) in season (t)
y_{pt} = quarter cup servings of product (p) in season (t)
y_{nt} = quarter cup servings of products contributing to nutrition category (n) in season (t)

$\propto$ = a scalar allowing for deviation from observed purchasing ratios

$PoundstoServingsConv_p$ = a table of conversion values that transforms pounds of product (p) to quarter cup servings of product (p)
$NumMeals_{tg}$ = a table of the number of meals served in season (t) in grade level (g)
$NutrCat_{pn}$ = a table that assigns product (p) to the nutrition category (n) they contribute to
$Nutrition_{nt}$ = a table of observed ratios of purchasing of products across nutrition category (n) in season (t)
$Variety_{pnt}$ = a table of observed ratios of purchasing of products (p) within nutrition category (n) in season (t)

<u>Model Calibration</u>

While the model accounts for a significant portion of FSM decision making a lack of data regarding waste and unobserved FSM behaviors requires that the final empirical model be allowed to deviate from observed purchasing. As such a scalar ($alpha$: $\propto$) was added to the nutrition and variety constraints that relaxes the requirement that the model provide solutions that exactly mimic observed purchasing. At alpha = 1 no deviation from observed purchasing is allowed and the model does not provide a solution. Thus, a range of alpha values were tested until the largest alpha value at which the model provides a solution was identified[10] . Once the largest feasible alpha was identified the resulting product mix was analyzed to identify all products selected at levels greater than 200% of observed purchasing. Over-selected items were capped at 100% and 150% of observed purchasing. These caps required the alpha constraint to be reduced for the model to provide a solution. In testing both capping levels, the largest alpha with the smallest Total Relative Deviation (TRD) from observed purchasing was obtained with 100% caps and a product mix within 37%-44% of observed purchasing (Table 9). Ultimately this calibration process allows us to bring the empirical model as close to the ideal model as possible given the data available.

Table 9. Final Alpha Values for Fall 2017/18 Models

Fall Semester	Alpha Nutrition	Deviation from Observed	Alpha Variety	Deviation from Observed
2017	0.63	37%	0.60	40%
2018	0.57	43%	0.56	44%

Policy Testing: Simulating the Impact of Colorado House Bill 19-1132

CO HB 19-1132 was introduced in the Colorado legislature during the Spring 2019 legislative session. The bill establishes a program that reimburses schools for the purchase of "Colorado Foods" for use in school lunches. The bill caps reimbursements at $500,000 per year for the entire state starting in 2020 (CO Fiscal Note 2019). This appropriation is equivalent to providing a $0.02 per meal reimbursement for up to 23.8 million meals, which accounts for 40% of meals served in CO during the 2017-2018 school year (CO Fiscal Note 2019). Beyond 2020

[10] Alpha for each constraint was set at 0.25, 0.5 and 0.75, representing a 75%, 50%, and 25% deviation from observed purchasing ratios respectively. The model did not provide a solution at alpha = 0.75, as such alpha was increased in increments of 0.05 from 0.5 until the model failed to find a solution.

the long-term goal is to reach a $0.05 per meal reimbursement, the total appropriations for which are also based on providing reimbursements for 23.8 million meals (CO Fiscal Note 2019).

In order to contextualize and assess the potential impact of CO HB 19-1132 at the current and goal reimbursement rates we used the calibrated model to test a variety of reimbursement scenarios. The prices of local products were reduced by 1%, 5%, 10%, 15%, 50% and 100% as proxies for a range of reimbursements rates that effectively change the prices faced by FSMs. All pricing scenarios were run for both Fall of 2017 and Fall 2018 purchasing. Finally, the number of meals served in each season were multiplied by the current ($0.02) and long-term ($0.05) reimbursement rates for comparison with model output at various levels of reimbursement.

Results

The final model provides output comparable to observed purchasing[11] (Table 10). Specifically, the model selects approximately the same number of products and local purchasing is within 3% of observed levels of local purchasing. Further the product mix (ratio of purchasing represented by each product) falls within 37-44% of observed purchasing ratios, as reflected in the alpha values described in above. The primary difference between observed purchasing and model output is in total pounds of FFV selected. The model selected less pounds of FFV than FSMs purchased, as pre-consumer waste, was not factored into the model. In Aug-Oct deviation from observed pound of purchasing ranged from 52-57%, in Nov-Dec pounds purchased deviated by 29-33%. Ultimately, the model selects a mix that would satisfy NSLP nutrition requirements (for the subset of FFV categories studied) and provide the same number of meals as served in the districts in the observed seasons.

Table 10. Observed purchasing vs. model output by season and year

	Observed Purchasing			**Model "Purchasing"**		
	Number of Products	Percentage Local Purchasing	Pounds of FFV Purchased	Number of Products	Percentage Local Purchasing	Pounds of FFV Purchased[12]
Aug-Oct						
2017	60	16.5%	439,953.97	58	13.14%	210,136.623
2018	58	16.8%	606,154.35	54	14.9%	256,836.478
Nov-Dec						
2017	48	2.3%	210,136.623	48	3.6%	132,424.483
2018	40	0.5%	419,241.998	41	0.8%	181,092.19

[12]model does not account for pre-consumer waste resulting in model estimates below observed purchasing.

[11] See appendix for full tables of observed purchasing and all model output

Minimizing the objective function (total cost of products selected) without any policy modifications the model selected 58 products in the Aug-Oct season and 48 products in Nov-Dec at a total cost across all three districts of $274,764.89 for the Fall 2017 semester. 13.14% of the total cost of products selected were local in Aug-Oct and 3.6% were local in Nov-Dec. In the Fall 2018 semester, 54 products were selected in the Aug-Oct season and 41 products in Nov-Dec at a cost of $324,654.96. 14.9% of selected products were local in Aug-Oct and 0.8% were local in Nov-Dec. Subsequently a range of local food reimbursement policies were simulated by running the model with the price of all local products reduced by 1%, 5%, 10%, 15%, 50% and 100% respectively[13], results of which are reported in Table 11.

In the 2017 model there was no change in products or quantities selected with a 1% reduction of local product prices. A 5% reduction increased local purchasing from 13.14% to 17.2%, though reducing local product prices by 10% did not change overall purchasing or the percentage of local purchasing. A 15% reduction in local prices increased local purchasing slightly to 17.3%. The local food price reduction scenarios of 50% and 100% resulted in more dramatic changes in model selections for the 2017 season. A 50% price reduction brought local purchasing to 21.9%. Reducing the cost of local products by 100% effectively brought the price per pound for all local products to $0, resulting in selection of all local products to the set upper bounds resulting in 24.5% local purchasing.

In 2018, local purchasing remained at 14.9% when local product prices were reduced by 1%. With 5% and 10% reductions local purchasing remained at 14.9% Reducing local product prices by 15% increased the percentage of local product purchased to 15.1%. A 50% local

[13] See appendix for full tables of model output at all levels of reimbursement.

product price reduction increased local purchasing to 16.4%. Finally, as in 2017, a 100% price reduction resulted in selection of the full quantity of local products available to the upper bounds yielding 26.6% local purchasing.

Changes in local product prices also decreased the value of the objective function as price reductions increased. These decreases indicate the amount of state expenditure required to provide reimbursements (to the three districts studied) in each scenario by comparing the original objective function value to subsequent objective function values. In the 2017 model simulation, $1,157.74 would support a 1% reimbursement rate, while $2,149.77, $3,421.37 and $4,735.77 provide 5%, 10% and 15% reimbursements respectively. Reimbursement rates of 50% and 100% would require outlays of $15,080.53 and $39,193.24 respectively. In 2018 a 1% reimbursement rate requires $265.20 in state expenditures. 5%, 10% and 15% local food price reductions would require $1,333.60, $2713.73 and $4,101.76 respectively. $13,911.60 would provide a 50% price reduction and $37,570.02 would provide a 100% reduction.

Table 11. Model output of required state expenditures and resulting level of local FFV purchasing at different levels of local product price reductions

2017					
Local Food Price Reduction	**Required State Expenditure for Entire Fall Semester (Aug-Dec)**	**Percentage Local Purchasing Aug Oct**	**Increase in Local Purchasing from Observed (Aug-Oct)**	**Percentage Local Purchasing Nov Dec**	**Increase in Local Purchasing from Observed (Nov-Dec)**
0%	$0	13.10%	-	3.60%	-
1%	$1,157.74	13.10%	0%	3.60%	0%
5%	$2,149.77	17.20%	4.10%	4%	0.40%
10%	$3,421.37	17.20%	0%	4.30%	0.30%
15%	$4,735.77	17.30%	0.10%	4.30%	0%
50%	$15,080.53	21.90%	4.60%	4.80%	0.50%
100%	$39,193.24	24.50%	2.60%	4.80%	0%
2018					
0%	$0	14.90%	-	0.80%	-
1%	$265.20	14.90%	0%	0.80%	0%
5%	$1,333.60	14.90%	0%	1.20%	0.40%

10%	$2,713.73	14.90%	0%	1.20%	0%
15%	$4,101.76	15.10%	0.20%	1.20%	0%
50%	$13,911.60	16.40%	1.30%	1.20%	0%
100%	$37,570.02	26.60%	10.20%	1.20%	0%

Comparison of Model Output to CO HB 19-1132 reimbursements

CO HB 19-1132 currently provides a two-cent per meal reimbursement, with the goal of providing 5-cents per meal in the future, though t intended to cover 40% of meals served in CO (CO Fiscal Note 2019). Based on the number of meals served in the observed Fall semesters, a 2-cent per meal reimbursement for 40% of meals served would provide $ 12,319 in 2017 and $ 17,220 in 2018 in reimbursements for the three districts. Compared to model selection of FFV only, *not observed purchasing of FFV*, this level of reimbursement would cover approximately 30-40% of local FFV purchasing in 2017 and over 50% in 2018 when less local purchasing was observed. At the five-cent reimbursement rate $30,796 and $43,050 would be provided in 2017 and 2018 respectively covering more than 50% of modeled local FFV purchasing in 2017 and over 100% in 2018.

Constraint Shadow Prices and Product Reduced Costs

Optimization modeling also provides SPs of constraints and reduced costs RCs of decision variables. SPs detail how much the value of the objective function would change if a constraint is tightened or loosened by one unit. Similarly, RCs show the amount the coefficient on a decision variable must change for an additional unit of that decision variable to be brought into the product mix or, if the RC is negative, reveals the willingness to pay for an additional unit of a decision variable that is limited.

Within the nutrition constraints the fruit category is binding, meaning the model cannot select an additional serving of fruit without moving away from the optimal objective function value. Specifically, we see that if an additional quarter cup serving of fruit were required (i.e., if the NSLP changed nutrition requirements) the value of the objective function (cost) would increase by $0.181 in Aug-Oct 2017 and $0.178 in Nov-Dec 2017. The fruit constraint is also binding in 2018 with increase of $0.183 in Aug-Oct and $0.137 in Nov-Dec. Though as local product reimbursement rates increase in the model, we see that these increases decrease by 0.3-1.1 cents in the Aug-Oct season (Table 12).

Table 12. Shadow prices of binding nutrition constraints by year and season

Fruit Category Shadow Price				
	Aug-Oct		**Nov-Dec**	
	Baseline	**100% Local Price Reduction**	**Baseline**	**100% Local Price Reduction**
2017	0.181	0.178	0.178	0.178
2018	0.183	0.172	0.137	0.137

SPs of the variety constraints show that the variety requirements for approximately half of the products are binding at upper bounds. As above, the optimized objective function (cost) will increase for every additional quarter cup serving of these products required. These increases range from $0.52 to $0.0008 depending on the product (see appendix). As local product reimbursement rates increase, we see the increase in cost decrease for products that have local substitutes, while the cost increase remains constant for products with conventional only versions.

In the baseline model scenario, the RC of local products are positive, indicating that the cost would have to decrease by the RC for one additional serving of the product to be brought into the optimal model solution. As local product reimbursements increase the RC on local products decrease and ultimately become negative indicating that as local purchasing is subsidized the model exhibits a WTP to bring additional units of local products into the product mix. Conversely, conventional products that upper bounds were placed on have negative RC, also indicating a WTP for additional servings of those products.

Discussion

This research utilized observed prices and quantities of FFV purchased by three Northern Colorado school districts to parameterize an optimization model that simulates FFV procurement and the impact potential of CO HB 19-1132 on FSM decision making. We have provided a generalizable methodology that can be used quantify impacts of specific policy scenarios on NSLP procurement. Our results indicate that the quantity of local products selected for procurement in the model increases in response to a policy reimbursing schools for the purchase of local foods. Increases in local purchasing and cost reductions associated with reimbursements were nominal at the lower reimbursements rates (1%-15%) with substantial increases in local purchasing and cost reductions at higher reimbursement rates of 50% and 100%.

The increases in modeled local purchasing are the result of a substitution effect away from conventional products in favor of Colorado-produced foods, thus there is no net increase in purchasing. At no point did these selections prevent the model from providing a solution, indicating that increasing local purchasing would not come at the expense of meeting other NLSP procurement goals. Specifically, the baseline USDA nutrition requirements are met in all cases, while variety of products selected is maintained and cost is minimized. Though, due to differences between model output and observed purchasing these results are subject to several limitations that have implications for the Colorado policy.

Model Limitations and Implications for CO HB 19-1132

The most significant difference between model output and observed purchasing is that net pounds of FFV "purchased" by the model were significantly lower than the total pounds of observed purchasing. We attribute this difference to the absence of a waste constraint beyond the constraint accounting for trim waste. A study on pre-consumer waste conducted by Prescott et al. (2019) in the same three Northern Colorado School Districts find that post-consumer waste is substantial per student meal served (43.8 g) and is positively related to the use of salad bars. Post-consumer waste comes from a variety of sources, the most significant being overproduction and trim[14]. Trim is accounted for in our model thus subtracting the average trim waste (which is primarily associated with FFV production) identified by Prescott et al. (2019b) results in an average of 37g of pre-consumer waste per meal. Using this estimate and the number of meals served by the three districts studied in the observed semesters model purchasing should increase by 35-40% if waste is incorporated. If purchasing is corrected for waste, we expect the 2 cent per meal reimbursement from CO HB 19-1132 to cover 20-40% of local FFV purchased for use on salad bars from the observed semesters, rather than 30-50% in the modeled scenario. At the policy's goal of 5 cent reimbursement rate, we would expect 30-60% coverage of local FFV purchasing for salad bars. This assumes that the full amount of reimbursements is spent on FFV for salad bars *only* though, yet reimbursements from CO HB 19-1132 may be applied to non-FFV local products as well.

[14] Average grams of waste by source per Prescott et al (2019b). 43.8g per student wasted on average of which 74.2% was edible. Reasons for waster: combo (2), contaminated (1.9), expired (0.1), overproduction (30.6), spoiled (0.3), substandard (2.1), trim (6.8).

The 2-cent reimbursement rate, when compared to model output and assuming all reimbursement money is spent on FFV, would support at least a 15% rate of local FFV purchasing in the three districts studied, this is equivalent to maintaining current levels of local purchasing, observed at approximately 16%. At the 5-cent level a rate of local FFV procurement over 20% may be supported in the study districts. In districts that are not currently participating in FTS though reimbursements could allow for local purchasing increases that bring them in line with the observed districts.

Estimated local purchasing levels are also impacted by a lack of supply side data, which precludes identification of precise upper bounds for local products. The maximum availability of local products has important, and we believe realistic impacts on potential local purchasing, particularly at local food reimbursement rates of 50-100% where most local products are selected to the upper bounds. Further, there are policies at the state and Federal levels that may increase availability of local products through provision of technical assistance to support lengthen the growing season (e.g., NRCS EQUIP) and supporting beginning and veteran farmers and ranchers. To the extent that these efforts are fruitful, we expect reimbursements at both the two and five cent levels to increase local purchasing beyond the levels identified in this research.

Third, it is important to note that this is a pilot case study that models only FFV purchasing, which is just a portion of overall FSM NSLP decision making. While it would be ideal to model all NLSP procurement, particularly trade-offs across food groups, the authors were unable to identify any systematic data publicly available with which to conduct such an analysis. Considering the lack of available data, the methodology for compilation of the procurement records into a database and its descriptive analysis are an important first step in understanding school procurement decisions. Modernizing NSLP procurement management systems would also go a long way to supporting additional analysis, including applying this methodology to analyze a larger scope of FSM decision making in the NSLP and the role of local food procurement.

Implications for FTS

This research contributes to understanding how school FSMs will respond to policy incentives aimed at increasing local procurement. While additional research that links local procurement to student outcomes and overall NSLP program quality is still needed these results do hold implications for the FTS claims that “Kids Win, Communities Win, Farms Win”.

While potential increases in local procurement align with the FTS goal of providing fresher healthier meals to students, our results do not provide additional insight to the opaque relationship between FTS and student FFV related outcomes (Prescott et al. 2019). Rather, it reveals a different avenue through which kids may win. Specifically, shadow prices of nutrition and variety constraints indicate that additional reimbursements provided for procurement of local FFV can decrease cost increases associated with providing additional FFV in school meals. Considering ongoing concerns regarding the cost of meeting new nutritional FFV requirements, especially in smaller districts (Ralston and Newman 2015), it is significant that local food reimbursement policies may support more general NSLP goals.

Our research also has implications for the idea that “Farmers Win” as FTS procurement reimbursement policies may expand the quantity of product farmers are able to sell through school market channels. While it is difficult to link farm and ranch viability directly to increased sales to schools (Conner et al., 2012; Low et al., 2015), our methodological approach provides insight to how sales to schools may be increased. Specifically, the reduced costs revealed in our modeling provides the price point at which a local product becomes cost competitive with a conventional substitute. Access to this information would allow producers to make better informed strategic pricing decisions to access the school food markets with or without a local reimbursement policy in place.

Finally, this research shows that local food procurement policies may increase sales through regional food systems and may, as a result, yield a small, positive economic impact in areas with FTS programming (e.g. Tuck et al., 2010; Kluson 2012; Gunter and Thilmany 2012; Roche et al. 2016). In the interest of expanding analysis of regional economic impacts of FTS though our research provides data with which further economic impact analysis can be conducted. To that end, more work to determine the optimal level of state purchasing support required to realize regional benefits would be particularly interesting.

References

Bagdonis, J. M., C. Clare Hinrichs and Kai A. Schafft (2009). The emergence and framing of farm-to-school initiatives: civic engagement, health and local agriculture. *Agric Hum Values,* 26:107–119.

Baldi, G., Elviyanti Martini, Maria Catharina, Siti Muslimatun, Umi Fahmida, Abas Basuni Jahari, Hardinsyah, Romeo Frega, Perrine Geniez, Nils Grede, Minarto, Martin W. Bloem, and Saskia de Pee (2013). Cost of the Diet (CoD) tool: First results from Indonesia and applications for policy discussion on food and nutrition security. *Food and Nutrition Bulletin*, 34:2 (supplement).

Bateman, J., Teresa Engel and Amy Meinen (2014). Understanding Wisconsin Producer and Distributor Perceptions to Inform Farm to School Programs and Policies. *Journal of Hunger & Environmental Nutrition*, 9:1, 48-63, DOI: 10.1080/19320248.2013.840548

Bauman, A., Dawn Thilmany McFadden and Becca B. R. Jablonski (2018). The Financial Performance Implications of Differential Marketing Strategies: Exploring Farms that Pursue Local Markets as a Core Competitive Advantage. *Agricultural and Resource Economics Review,* 47:3, 477–504.

Becot, F., Kolodinsky, J.M., Roche, E., Zipparo, A.E., Berlin, L., Buckwalter, E. and Mclaughlin, J (2017). Do Farm-to-School Programs Create Local Economic Impacts? *Choices,* 32:1.

Biehl, E., Rolf D. W. Klemm, Swetha Manohar, Patrick Webb, Devendra Gauchan and Keith P West (2016). What Does It Cost to Improve Household Diets in Nepal? Using the Cost of the Diet Method to Model Lowest Cost Dietary Changes. *Food and Nutrition Bulletin*, 37:3, 247-260.

Bontrager Yoder A.B., Foecke L.L. and Schoeller D.A. (2015). Factors affecting fruit and vegetable school lunch waste in Wisconsin elementary schools participating in Farm to School Programmes, *Public Health Nutr*. 18:15, 2855-63.

Bontrager Yoder A.B., Liebhart J.L., McCarty D.J. (2014). Farm to elementary school programming increases access to fruits and vegetables and increases their consumption among those with low intake. *Journal of Nutrion Education and Behavior,* 46:5, 341-349.

Botkins, Elizabeth R., Brian E. Roe (2018). Understanding participation in farm to school programs: Results integrating school and supply-side factors. *Food Policy*, 74:C, 126-137.

Boys K.A. and Fraser A.M. (2019). Linking small fruit and vegetable farmers and institutional foodservice operations: marketing challenges and considerations. *Renewable Agriculture and Food Systems*, 34, 226–238. https://doi.org/10.1017/S1742170518000030

Boys, K. A., & Hughes, D. W. (2013). A regional economics–based research agenda for local food systems. *Journal of Agriculture, Food Systems, and Community Development*, 3:4, 145–150. http://dx.doi.org/10.5304/jafscd.2013.034.012

Bristow K, Jenkins S, Kelly P, and Mattfeldt-Beman M (2017). Does Tasting Local Sweet Potatoes Increase the Likelihood of Selection by High School Students? *Journal of Child Nutrition & Management* 41:1, 8.

Carlson, A., Lino, M., and Fungwe, T (2007). The Low-Cost, Moderate-Cost, and Liberal Food Plans, 2007 (CNPP-20). *U.S. Department of Agriculture, Center for Nutrition Policy and Promotion*.

Christensen, L.O., B.B.R. Jablonski, L. Stephens, and A. Joshi (2017). Economic Impacts of Farm to School: Case studies and assessment tools. *National Farm to School Network*.

Christensen L.O., Jablonski BBR, O'Hara JK (2019). School districts and their local food supply chains. *Renewable Agriculture and Food Systems* 34, 207–215. https://doi.org/10.1017/S1742170517000540

Colorado Department of Education (CDE) (2019), *Colorado Education Statistics*, Retrieved from: https://www.cde.state.co.us/cdereval

Colorado Fiscal Note (2019), HB 19-1132 Revised Fiscal Note, *Legislative Council Staff*.

Colorado House Bill 19-1132 (2019) (enacted).

Conner, David S., Ben King, Christopher Koliba, Jane Kolodinsky and Amy Trubek (2011) Mapping Farm-to-School Networks Implications for Research and Practice, *Journal of Hunger & Environmental Nutrition*, 6:2, 133-152, DOI: 10.1080/19320248.2011.576206

Conner, D. S., Izumi, B. T., Liquori, T., & Hamm, M. W (2012). Sustainable School Food Procurement in Large K-12 Districts: Prospects for Value Chain Partnerships. *Agricultural and Resource Economics Review, 41*(1), 100-113.

Economic Research Service (ERS), National School Lunch Program (2018). Retrieved April 22, 2018, from https://www.ers.usda.gov/topics/food-nutrition-assistance/child-nutrition-programs/national-school-lunch-program.aspx

Evans A., Ranjit N, Rutledge R, Medina J, Jennings R, Smiley A, Stigler M, and Hoelscher D (2012). Exposure to multiple components of a garden-based intervention for middle school students increases fruit and vegetable consumption. *Health Promot Pract*, 13:5, 608-16.

Feenstra, G., and Ohmart, J (2012). The Evolution of the School Food and Farm to School Movement in the United States: Connecting Childhood Health, Farms, and Communities. *Childhood Obesity* (Formerly Obesity and Weight Management), 8:4, 280-289.

Ferguson, Elaine L., Nicole Darmon, André Briend, and Inguruwatte M. Premachandra (2004). Food-Based Dietary Guidelines Can Be Developed and Tested Using Linear Programming Analysis, *The Journal of Nutrition*, 134:4, 951–957, https://doi.org/10.1093/jn/134.4.951.

Food and Nutrition Service (FNS) (2014b), Farm to School Census, *USDA Food and Nutrition Service*. Retrieved from: http://www.fns.usda.gov/farmtoschool/census#/page/about

Food and Nutrition Service (FNS) (2015), Offer vs Serve, *USDA Food and Nutrition Service*. Retrieved from: https://www.fns.usda.gov/updated-offer-vs-serve-guidance-nslp-and-sbp-beginning-sy2015-16.

Food and Nutrition Service (FNS) (2015), Nutrition Standards in School Meals. *USDA Food and Nutrition Service.* Retrieved from: https://www.fns.usda.gov/school-meals/nutrition-standards-school-meals

Food and Nutrition Service (FNS) (2016), USDA Foods in the National School Lunch Program, White Paper, *USDA Food and Nutrition Service*.

Food and Nutrition Service Community Food Systems (FNS CFS) (2018). *USDA Food and Nutrition Service*. Retrieved from: https://www.fns.usda.gov/farmtoschool/farm-school-grant-program

Food and Nutrition Service (FNS) (2018), National School Lunch Program (NSLP), *USDA Food and Nutrition Service*. Retrieved from https://www.fns.usda.gov/nslp/national-school-lunch-program-nslp

Frega, R., Jose Guerra Lanfranco, Sam De Greve, Sara Bernardini, Perrine Geniez, Nils Grede, Martin Bloem, and Saskia de Pee (2012). What linear programming contributes: World Food Programme experience with the "Cost of the Diet" Tool. *Food and Nutrition Bulletin*, 33:3, (supplement).

Gunter, A. and Thilmany, D (2012). Economic Implications of Farm to School for a Rural

Colorado Community, *Rural Connections* 6: 13-16.

Gordon, A., Mary Kay Crepinsek, Renee Nogales, and Elizabeth Condon (2007). School Nutrition Dietary Assessment Study–III: Vol. II Student Participation and Dietary Intakes. *USDA Food and Nutrition Service*.

Gregoire, Mary B. and Strohbehn, Catherine H. (2002), Benefits and Obstacles to Purchasing Food from Local Growers and Producers, *Apparel, Events and Hospitality Management Publications*, 90.

Hardesty, S., Gail Feenstra, David Visher, Tracy Lerman, Dawn Thilmany-McFadden, Allison Bauman, Tom Gillpatrick, and Gretchen Nurse Rainbolts (2014). Values-Based Supply Chains: Supporting Regional Food and Farms. *Economic Development Quarterly* 2014, 28:1, 17–27.

Harris, D., Megan Lott, Velma Lakins, Brian Bowden and Joel Kimmons (2012), Farm to Institution: Creating Access to Healthy Local and Regional Foods, *Advances in Nutrition*, 3:3, 343–349. https://doi.org/10.3945/an.111.001677

Hwang, J. H., and Sneed, J. (2007). Developing a Performance Criteria Model for School Foodservice. *Journal of Hospitality & Tourism Research*, 31:1, 111–129. https://doi.org/10.1177/1096348006296715

Izumi B.T., Alaimo K., Hamm M.W (2010). Farm-to-School Programs: Perspectives of School Food Service Professionals. *Journal of Nutrition Education and Behavior*, 42:2, 83-91.

Izumi, B. T., Wright, D. W., & Hamm, M. W (2010). Market Diversification and Social Benefits: Motivations of Farmers Participating in Farm to School Programs. *Journal of Rural Studies,* 26, 374-382.

Jones S.J., Childers C, Weaver AT, Ball J (2015). SC Farm-to-School Programs Encourages Children To Consume Vegetables. *J Hunger Environ Nutr*, 10:4, 511-25.

Joshi, A., Azuma, Andrea M., and Feenstra, Gail (2008). "Do farm-to-school programs make a difference? Findings and future research needs." *Journal of Hunger Environment and Nutrition*, 3:(2–3), 229–246.

King, R., Hand, M., Digiacomo, G., Clancy, K., Gomez, M., Hardesty, S., Lev, L. and Mclaughlin, E (2010). Comparing the Structure, Size, and Performance of Local and Mainstream Food Supply Chains. Washington, DC: USDA Economic Research Service.

Kluson, R.A (2012). Regional and Local Economic Impacts of the Sarasota County Farm to

School Program. *University of Florida Agriculture/Natural Resource Extension Fact Sheet*.

Lambert, L., Martha T. Conklin and J.T. Johnson (2002), Parental Beliefs Toward the National School Lunch Program Related to Elementary Student Participation, *The Journal of Child Nutrition & Management*, 26:1.

Low, Sarah A., and Stephen Vogel (2011). Direct and Intermediated Marketing of Local Foods in the United States, *USDA Economic Research Service*, ERR-128.

Low, S., Adalja, A., Beaulieu, E., Key, N., Martinez, S., Melton, A., Perez, A., Ralston, K., Stewart, H. and Suttles, S (2015). Trends in US Local and Regional Food Systems. Washington, D.C. *USDA Economic Research Service*.

Lyson, Helena C. (2016). National policy and state dynamics: A state-level analysis of the factors influencing the prevalence of farm to school programs in the United States, *Food Policy*, 63:C, 23-35.

Martinez S.W. (2016) Policies Supporting Local Food in the United States, *Agriculture*, 6:3, 43.

McCarthy, Ashley C., Abigail S. Steiner and Robert F. Houser (2017), Do State Farm-to-School Related Laws Increase Participation in Farm-to-School Programs*?, Journal of Hunger & Environmental Nutrition*, 12:4, 466-480. DOI: 10.1080/19320248.2017.1284026

Maillot, Matthieu & Vieux, Florent & Amiot, Marie Josèphe and Darmon, Nicole (2010). Individual diet modeling translates nutrient recommendations into realistic and individual-specific food choices. *The American journal of clinical nutrition*. 91, 421-30.

May, L., Kim Standing, Adam Chu, Joe Gasper, and Jarnee Riley (2014). Special Nutrition Program Operations Study: State and School Food Authority Policies and Practices for School Meals Programs School Year 2011-12. *USDA Food and Nutrition Service*.

Meyer, M.K., and Martha T. Conklin (1998), Variables Affecting High School Students' Perceptions of School Foodservice, *Journal of the American Dietetic Association*, 98: 12, 1424 – 1431

Meyer, M. K. (2000). Top Predictors of Middle/Junior High School Students' Satisfaction with School Foodservice and Nutrition Programs. *Journal of the American Dietetic Association*, 100:1, 100-103.

McCrudden, C. (2004). Using Public Procurement to Achieve Social Outcomes. *Natural Resources Forum,* 28, 257-267.

Moss, A., Smith, S., Null, D., Long Roth, S., and Tragoudas, U. (2013). Farm to School and Nutrition Education: Positively Affecting Elementary School-Aged Children's Nutrition Knowledge and Consumption Behavior. *Childhood obesity*, 9:1, 51–56. doi:10.1089/chi.2012.0056

Motta, V., and Sharma, Amit (2016). Benefits and transaction costs of purchasing local foods in school districts. *International Journal of Hospitality Management*. 55, 81-87.

National Farm to School Network (NFSN) (2017). State Farm to School Legislative Survey: 2002 2017, *National Farm to School Network.*

Noonan, K., Miller, D., Sell, K., and Rubin, D. (2013). A procurement-based pathway for promoting public health: Innovative purchasing approaches for state and local government agencies. *Journal of Public Health Policy*, 34:4, 528-537. Retrieved from http://www.jstor.org/stable/43288150

Nurse, G., Dawn Thilmany McFadden and Allie Gunter (2011), Understanding the Effectiveness of Farm to School Programs through Food Service Professionals, *Colorado State University Agricultural and Resource Policy Report*, Report No.1.

O'Hara, Jeffrey K. (2011) Market Forces: Creating Jobs through Public Investment in Local and Regional Food Systems*, Union of Concerned Scientists*. www.jstor.org/stable/resrep00058.

O'Hara, J. K., and Pirog, R (2013). Economic impacts of local food systems: Future research priorities. *Journal of Agriculture, Food Systems, and Community Development,* 3:4, 35–42.

Okubo, H., Satoshi Sasaki, Kentaro Murakami, Tetsuji Yokoyama, Naoko Hirota, Akiko Notsu, Mitsuru Fukui and Chigusa Date (2015). Designing optimal food intake patterns to achieve nutritional goals for Japanese adults through the use of linear programming optimization models. *Nutrition Journal*, 14:57.

Prescott, M.P., Cameron Herritt, Marisa Bunning, and Leslie Cunningham-Sabo (2019), Resources, Barriers, and Tradeoffs: A Mixed Methods Analysis of School Pre-Consumer Food Waste, *Journal of the Academy of Nutrition and Dietetics*.

Prescott, M.P., Rebecca Cleary, Alessandro Bonanno, Marco Costanigro, Becca BR Jablonski and Abigail B. Long (2019). *Presentation: Farm to School Activities and Student Outcomes: A Systematic Review*.

Produce Marketing Association of America (2018). *Fresh Produce Yields*.

Ralston, K., Constance Newman, Annette Clauson, Joanne Guthrie, and Jean Buzby (2008). The National School Lunch Program: Background, Trends, and Issues*, USDA Economic Research Service*, ERR-61.

Ralston, K. and Constance Newman (2015). School Meals in Transition, *USDA Economic Research Service*, EIB-143.

Ralston, K., E. Beaulieu, J. Hyman, M. Benson, and M. Smith (2017). Daily Access to Local Foods for School Meals: Key Drivers*, USDA Economic Research Service*, EIB-168.

Roche, E., Conner, D., and Kolondinsky, J. (2015). Increasing Local Procurement in Farm-To School Programs: An Exploratory Investigation. *Journal of Agriculture, Food Systems, and Community Development* 5:2, 81-90.

Roche, E., Florence Becot, Jane Kolodinsky, and David Conner (2016), Economic Contribution and Potential Impact of Local Food Purchases Made by Vermont Schools, *University of Vermont Center for Rural Studies*.

Schneider L., Chriqui J, Nicholson L, Turner L, Gourdet C and Chaloupka F (2012). Are farm-to school programs more common in states with farm-to-school-related laws? *J Sch Health*, 82, 210-216.

Shideler, D., Allie Bauman, Dawn Thilmany and Becca B.R. Jablonski (2018), Putting Local Food Dollars to Work: The Economic Benefits of Local Food Dollars to Workers, Farms and Communities, *Choices*, 33:3.

Smith C.A., Corriveau N, and Aaronson S (2012). "School Intervention Incorporates Farm to School Programs To Highlight Healthy Eating: A Report from Project Healthy Schools." *Childhood Obesity*, 8:6, 584-587.

Stokes, N.M. (2014), Investigating barriers and keys to success when implementing and maintaining farm to school programs: Perspectives of hourly school foodservice employees, *Graduate Theses and Dissertations*, 13657.

Thompson, J.J., A. June Brawner and Usha Kaila, (2017). "You can't manage with your heart": risk and responsibility in farm to school food safety, *Agriculture and Human Values*, 34:3, 683-699.

Thornburg, G. K (2013). Embeddedness, Marketness, and Economic Instrumentalism in the Oklahoma Farm-to-School Program. *Journal of Rural and Community Development, 8*:3, 321-334.

Tuck, B., Haynes, M., King, R. and Pesch, R (2010). The Economic Impact of Farm-to-School Lunch Programs: A Central Minnesota Example. Minneapolis, MN: University of Minnesota Extension Center for Community Vitality and University of Minnesota Department of Applied Economics.

USDA School Meal Patterns (2012). *USDA Food and Nutrition Service*, Retrieved from: https://fns-prod.azureedge.net/sites/default/files/dietaryspecs.pdf

USDA Release 292.15 (2015). Retrieved from: https://www.fns.usda.gov/pressrelease/2015/029215

USDA Small and Mid-Size Farmer Resources (2019). Retrieved from: https://www.usda.gov/topics/farming/resources-small-and-mid-sized-farmers accessed 6.4.19

Vogt, Rainbow A., Lucia L. Kaiser (2008). Still a time to act: A review of institutional marketing of regionally-grown food. *Agriculture and Human Values* 25, 241–255

Washington State Department of Agriculture, WSDA (2012). Standard Pack Size – Weight-Count Converter Chart for Fruit.

Appendices

Appendix Table A. Table of decision variables with associated nutrition category and description

Product (p)	Nutrition Category (n)	Description
BrocCrw	Dark Green	Broccoli Crowns
BrocFl	Dark Green	Broccoli Florets
Brocc	Dark Green	Whole Head Broccoli
GrnLf	Dark Green	Green Leaf Lettuce
Romain	Dark Green	Romaine
RomainCh	Dark Green	Chopped Romaine
SpMx	Dark Green	Spring Mix
Spnch	Dark Green	Spinach
Apple	Fruit	Whole Apples
Banana	Fruit	Whole bananas
BrBlk	Fruit	Blackberries
BrBlu	Fruit	Blueberries
BrRasp	Fruit	Raspberries
BrStraw	Fruit	Strawberries
Clem	Fruit	Clementines/Tangerines
Grpft	Fruit	Grapefruit
Oran	Fruit	Oranges
Grp	Fruit	Grapes (Red and Green)
Kiwi	Fruit	Whole Kiwis
MlCant	Fruit	Cantaloupe
MlHny	Fruit	Honeydew
MlWtr	Fruit	Watermelon
Peach	Fruit	Whole Peaches
Pear	Fruit	Whole Pears
Pnapl	Fruit	Whole Pineapples
Plum	Fruit	Whole Plums
Aspar	Other	Asparagus
Cab	Other	Whole Head Cabbage (Red and Green)
CaulFl	Other	Cauliflower Florets
Caul	Other	Whole Head Cauliflower

CelStk	Other	Celery Sticks
Cel	Other	Whole Head Celery
Cuke	Other	Cucumbers (English and Slicing)
Mshrm	Other	Mushrooms
OthrPepp	Other	Green or Yellow Bell Peppers
SnPea	Other	Whole Sno/Snap Peas
Rdsh	Other	Whole Radishes
SldMx	Other	Salad Mix
LetShr	Other	Shredded Iceberg Lettuce
Sqsh	Other	Summer Squashes (Yellow and Zucchini)
CrrtBb	Red Orange	Baby Carrots
Crrt	Red Orange	Whole Carrots
RdOrPepp	Red Orange	Red or Orange Bell Peppers
TomSl	Red Orange	Slicing Tomatoes
TomCh	Red Orange	Cherry/Grape Tomatoes

Appendix Table B. Average price and total quantity of FFV by season and source purchased by three Northern Colorado school districts

		Fall 2017				Fall 2018			
Raw Product	**Source**	**Avg Price per Pound Aug-Oct**	**Pounds Purchased Aug-Oct**	**Avg Price per Pound Nov-Dec**	**Pounds Purchased Nov-Dec**	**Avg Price per Pound Aug-Oct**	**Pounds Purchased Aug-Oct**	**Avg Price per Pound Nov-Dec**	**Pounds Purchased Nov-Dec**
Broccoli Crowns	Conventional	1.27	1700	1.47	640	1.13	3220	1.32	1080
Broccoli Florets	Conventional	1.94	2742	1.74	2544	1.62	5244	1.95	2832
Whole Head Broccoli	Local	2.50	124.4	-	0	-	0	-	0
Whole Head Broccoli	Conventional	-	0	-	0	-	0	-	0
Green Leaf Lettuce	Local	0.77	286	0.91	264	-	0	-	0
Green Leaf Lettuce	Conventional	0.73	286	0.91	22	0.95	704	-	0
Romaine	Local	0.45	160	0.83	665	0.52	530	-	0
Romaine	Conventional	0.45	2920	0.60	955	0.46	10280	0.80	2285

Chopped Romaine	Conventional	1.38	4656	1.30	2112	1.37	3348	1.50	540
Spring Mix	Conventional	2.07	816	2.06	517	2.00	888	2.65	459
Spinach	Conventional	1.89	2219	1.53	590	2.18	4030	2.38	878
Whole apples	Local	0.01	45360	-	0	0.07	63520	-	0
Whole apples	Conventional	0.01	53960	0.01	27440	0.01	68600	0.01	55160
Whole bananas	Conventional	0.66	33160	0.66	17300	0.57	61100	0.50	29040
Blackberries	Conventional	4.99	2241	4.41	1404	5.75	4657.5	4.59	2380.5
Blueberries	Conventional	5.22	3001.5	6.63	1845	5.42	4086	-	0
Raspberries	Local	6.67	102	-	0	-	0	-	0
Raspberries	Conventional	5.85	2506.5	7.10	1818	7.51	5616	6.21	2308.5
Strawberries	Conventional	2.17	8424	3.70	6448	2.03	15328	2.71	8136
Clementine	Conventional	1.75	5940	1.21	9740	1.63	14580	1.27	6960
Grapefruit	Conventional	0.69	2040	0.74	1280	0.68	2520	0.58	1320
Oranges	Conventional	0.81	32880	0.63	12160	1.27	43200	0.57	35440
Grapes (Red and Green)	Conventional	1.38	29196	1.43	19458	1.20	44892	1.15	22788
Kiwi	Conventional	1.43	15252	1.28	6400	1.12	20680	1.08	9980
Cantaloupe	Local	0.85	4139.9	-	0	1.52	1667.5	-	0
Cantaloupe	Conventional	0.46	10626.6	0.59	6301.2	0.46	15863.15	0.52	9353.35
Honeydew	Conventional	0.67	8057.2	0.69	4377.6	0.72	10248.2	0.56	4560.4
Watermelon	Local	0.43	8470.4	0.42	2000	0.39	12660	-	0
Watermelon	Conventional	0.42	20617.6	0.46	7956	0.42	23983.2	0.37	11328.8
Peaches	Local	1.21	3410	-	0	1.41	10892	-	0
Peaches	Conventional	0.98	6417.5	1.05	175	1.50	940	-	0
Pears	Conventional	0.80	7272	0.89	7868	0.77	9614	0.63	5184
Pears	Local	-	0	-	0	0.72	4652	-	0
Pineapple	Conventional	0.13	12760	0.11	7440	0.12	13400	0.10	7260
Plums	Conventional	0.74	4116	-	0	0.83	3752	-	0
Asparagus	Conventional	2.66	814	2.71	649	2.38	363	2.83	264
Whole Head Cabbage (Red and Green)	Local	0.69	445.9	0.57	190	0.70	90	-	0

Whole Head Cabbage (Red and Green)	Conventional	0.36	150	-	0	0.39	600	0.50	300
Cauliflower Florets	Conventional	2.31	8540	2.61	912	2.19	1008	2.86	540
Whole Head Cauliflower	Conventional	0.78	2484	0.98	1014	0.72	3902.8	1.22	1438
Celery Sticks	Conventional	1.23	6540	1.35	2000	1.51	10900	1.27	5180
Whole Head Celery	Conventional	0.62	1231.25	0.58	1046	0.40	2891	0.42	1002
Cucumbers (English and Slicing)	Local	1.43	1288.2	0.00	0	1.29	295	-	0
Cucumbers (English and Slicing)	Conventional	0.61	10365	0.58	5825	0.63	25690	0.42	11280
Mushrooms	Conventional	2.13	1544	2.19	432	2.27	1262	1.98	484
Green or Yellow Bell Peppers	Local	2.36	1242	-	0	1.23	830	-	0
Green or Yellow Bell Peppers	Conventional	0.88	1899	0.85	1084	0.75	6292	1.13	1470
Sno/Snap Peas	Conventional	3.13	590	4.20	490	3.04	1954	3.16	160
Whole Radishes	Conventional	1.90	558	1.51	324	1.40	724	1.37	324
Salad Mix	Conventional	1.00	7755	0.70	4840	0.75	9200	1.08	8345
Shredded Iceberg Lettuce	Conventional	0.75	25548	0.70	1140	0.72	2200	0.97	1320
Summer Squashes (Yellow and Zucchini)	Local	1.36	1233	-	0	0.90	65	-	0
Summer Squashes (Yellow and Zucchini)	Conventional	0.79	670	0.65	965	0.90	2401	0.62	1500
Baby Carrots	Local	0.63	2400	0.70	480	0.63	3680	0.57	720
Baby Carrots	Conventional	0.78	15745	0.68	8360	0.74	27780	0.66	13060
Whole Carrots	Local	0.39	75	0.39	225	-	0	-	0
Whole Carrots	Conventional	-	0	-	0	0.84	225	-	0
Red or Orange Bell Peppers	Local	3.25	410.5	-	0	0.00	0	-	0
Red or Orange Bell Peppers	Conventional	1.32	3221	1.45	2136	1.37	4507	1.39	1444

Slicing Tomatoes	Local	2.56	2210	1.60	375	1.39	2275	1.50	705
Slicing Tomatoes	Conventional	0.75	1788	1.48	1388	0.74	6100	0.86	2691
Grape Tomatoes	Local	4.12	1332.52	-	0	2.87	384	-	0
Grape Tomatoes	Conventional	2.02	4015	4.09	2735	1.70	5840	2.03	2540

Appendix Table C. Baseline model output Fall 2017 and Fall 2018 with no policy testing

Raw Product	Source	Pounds Selected Aug-Oct 17	Pounds Selected Nov-Dec 17	Pounds Selected Aug-Oct 18	Pound Selected Nov-Dec 18
Apple	Local	10509.89	0	0	0
Apple	Conventional	0	4727.271	12034.26	7575.365
Asparagus	Conventional	542.778	678.566	242.583	259.594
Banana	Conventional	9634.937	12980.26	23970.29	20800.63
Blackberries	Conventional	294.929	300.821	527.617	406.595
Blueberries	Conventional	395.016	395.31	462.875	0
Raspberries	Conventional	337.62	383.086	625.683	387.78
Strawberries	Conventional	1256.47	1565.755	1967.926	1574.935
Broccoli Crown	Conventional	3400	824.838	2637.06	2160
Broccoli Floret	Conventional	5400.915	2429.292	6184.272	4327.468
Whole Head Broccoli	Local	186.162	0	0	0
Whole Head Cabbage (Red and Green)	Local	668.85	285	135	0
Whole Head Cabbage (Red and Green)	Conventional	300	0	1200	600
Baby Carrots	Local	3600	240	5520	1080
Baby Carrots	Conventional	8457.856	5183.536	8286.747	7611.116
Carrots	Local	112.5	337.5	450	0
Cauliflower Florets	Conventional	1493.641	250.111	176.687	139.275
Cauliflower	Conventional	646.377	413.734	1017.808	551.805
Celery	Conventional	2462.5	2092	5782	2004
Celery Sticks	Conventional	1495.165	716.953	2497.43	1746.36
Clementine	Conventional	1550.452	4139.004	3275.811	2357.757

Cucumbers (English and Slicing)	Local	644.1	0	147.5	0
Cucumbers (English and Slicing)	Conventional	12543.03	2784.167	7790.814	10677.66
Grapefruit	Conventional	705.269	720.443	749.92	592.266
Grapes (Red and Green)	Conventional	4354.689	6663.201	5763.578	6680.837
Kiwi	Conventional	2850.4	3493.182	3326.741	2420.625
Green Leaf Lettuce	Local	429	396	0	0
Green Leaf Lettuce	Conventional	572	44	1408	0
Romaine	Local	240	332.5	265	0
Romaine	Conventional	4729.532	1902.759	5425.32	3981.824
Chopped Romaine	Conventional	5891.907	2650.137	5304.109	1080
Salad Mix	Conventional	940.193	2650.137	1117.838	1491.95
Spring Mix	Conventional	551.477	300.916	328.43	918
Shredded Lettuce	Conventional	5891.907	1185.655	2363.384	2152.678
Cantaloupe	Local	2069.95	0	833.75	0
Cantaloupe	Conventional	21008.14	10380.36	25591.63	16634.33
Honeydew	Conventional	2575.201	8755.2	2819.447	1891.681
Watermelon	Local	4235.2	3000	18990	0
Watermelon	Conventional	14063.84	8469.444	10207.87	18379.57
Mushroom	Conventional	264.268	115.939	216.477	122.162
Orange	Conventional	15145.23	9118.906	17128.42	21186.33
Peaches	Local	1705	0	3544.526	0
Peaches	Conventional	1715.217	99.155	0	0
Pears	Local	0	0	6978	0
Pears	Conventional	4973.264	8760.259	1420.065	4601.194
Plums	Conventional	1291.808	0	1013.619	0
Sno/Snap Peas	Conventional	165.648	215.715	549.812	66.244
Green or Yellow Bell Peppers	Local	621	0	415	0
Green or Yellow Bell Peppers	Conventional	62.896	370.084	6283.774	471.989
Red or Orange Bell Peppers	Local	205.25	0	0	0
Red or Orange Bell Peppers	Conventional	6442	4759.429	5457.817	2888

Pineapple	Conventional	24304.12	10931.81	26800	14520
Radishes	Conventional	116.73	106.278	151.79	99.951
Spinach	Conventional	1639.032	1308.395	1263.442	1756
Summer Squashes (Yellow and Zucchini)	Local	616.5	0	0	0
Summer Squashes (Yellow and Zucchini)	Conventional	1340	1930	553.161	2569.303
Slicing Tomatoes	Local	1105	187.5	1137.5	352.5
Slicing Tomatoes	Conventional	3576	1338.877	12200	5382
Cherry Tomatoes	Local	666.26	0	192	0
Cherry Tomatoes	Conventional	7139.506	1510.996	2103.693	6592.411
Objective Function Value		**274764.89**		**324654.96**	

Appendix Table D. Model output with prices of local products reduced by 1% and 5%.

		1% Reduction Fall '17		1% Reduction Fall '18		5% Reduction Fall '17		5% Reduction Fall '18	
Raw Product	**Source**	**Pounds Selected Aug-Oct**	**Pound Selected Nov-Dec**	**Pounds Selected Aug-Oct**	**Pound Selected Nov-Dec**	**Pounds Selected Aug-Oct**	**Pound Selected Nov-Dec**	**Pounds Selected Aug-Oct**	**Pound Selected Nov-Dec**
Apple	Local	10509.89	0	0	0	10509.89	0	0	0
Apple	Conventional	0	4727.271	12034.26	7575.365	0	4727.271	12034.26	7575.365
Asparagus	Conventional	542.778	678.566	242.583	259.594	542.778	678.566	242.583	259.594
Bananas	Conventional	9634.937	12980.26	23970.29	20800.63	9634.937	12980.26	23970.29	20800.63
Blackberries	Conventional	294.929	300.821	527.617	406.595	294.929	300.821	527.617	406.595
Blueberries	Conventional	395.016	395.31	462.875	0	395.016	395.31	462.875	0
Raspberries	Conventional	337.62	383.086	625.683	387.78	337.62	383.086	625.683	387.78
Strawberry	Conventional	1256.47	1565.755	1967.926	1574.935	1256.47	1565.755	1967.926	1574.935
Broccoli Crown	Conventional	3400	824.838	2637.06	2160	3400	824.838	2637.06	2160
Broccoli Florets	Conventional	5400.915	2429.292	6184.272	4327.468	5400.915	2429.292	6184.272	4327.468
Whole Head Broccoli	Local	186.162	0	0	0	186.162	0	0	0

Whole Head Cabbage (Red and Green)	Local	668.85	285	135	0	668.85	285	135	0
Whole Head Cabbage (Red and Green)	Conventional	300	0	1200	600	300	0	1200	600
Baby Carrots	Local	3600	240	5520	1080	3600	720	5520	1080
Baby Carrots	Conventional	8457.856	5183.536	8286.747	7611.116	8457.856	4703.536	8286.747	7611.116
Carrots	Conventional	0	0	450	0	0	0	450	0
Carrots	Local	112.5	337.5	0	0	112.5	337.5	0	0
Cauliflower Florets	Conventional	1493.641	250.111	176.687	139.275	1493.641	250.111	176.687	139.275
Cauliflower	Conventional	646.377	413.734	1017.808	551.805	646.377	413.734	1017.808	551.805
Celery	Conventional	2462.5	2092	5782	2004	2462.5	2092	5782	2004
Celery Sticks	Conventional	1495.165	716.953	2497.43	1746.36	1495.165	716.953	2497.43	1746.36
Clementine	Conventional	1550.452	4139.004	3275.811	2357.757	1550.452	4139.004	3275.811	2357.757
Cucumbers (English and Slicing)	Local	644.1	0	147.5	0	644.1	0	147.5	0
Cucumbers (English and Slicing)	Conventional	12543.03	2784.167	7790.814	10677.66	12543.03	2784.167	7790.814	10677.66
Grapefruit	Conventional	705.269	720.443	749.92	592.266	705.269	720.443	749.92	592.266
Grapes (Red and Green)	Conventional	4354.689	6663.201	5763.578	6680.837	4354.689	6663.201	5763.578	6680.837
Kiwi	Conventional	2850.4	3493.182	3326.741	2420.625	2850.4	3493.182	3326.741	2420.625
Green Leaf Lettuce	Local	429	396	0	0	429	396	0	0
Green Leaf Lettuce	Conventional	572	44	1408	0	572	44	1408	0
Romaine	Local	240	332.5	265	0	240	332.5	265	0
Romaine	Conventional	4729.532	1902.759	5425.32	3981.824	4729.532	1902.759	5425.32	3981.824
Chopped Romaine	Conventional	5891.907	2650.137	5304.109	1080	5891.907	2650.137	5304.109	1080
Salad Mix	Conventional	940.193	2650.137	1117.838	1491.95	940.193	2650.137	1117.838	1491.95
Spring Mix	Conventional	551.477	300.916	328.43	918	551.477	300.916	328.43	918
Shredded Lettuce	Conventional	5891.907	1185.655	2363.384	2152.678	5891.907	1185.655	2363.384	2152.678
Cantaloupe	Local	2069.95	0	833.75	0	2069.95	0	833.75	0
Cantaloupe	Conventional	21008.14	10380.36	25591.63	16634.33	21008.14	10380.36	25591.63	16634.33

Honeydew	Conventional	2575.201	8755.2	2819.447	1891.681	2575.201	8755.2	2819.447	1891.681
Watermelon	Local	4235.2	3000	18990	0	12705.6	3000	18990	0
Watermelon	Conventional	14063.84	8469.444	10207.87	18379.57	5593.438	8469.444	10207.87	18379.57
Mushrooms	Conventional	264.268	115.939	216.477	122.162	264.268	115.939	216.477	122.162
Oranges	Conventional	15145.23	9118.906	17128.42	21186.33	15145.23	9118.906	17128.42	21186.33
Peaches	Local	1705	0	3544.526	0	1705	0	3544.526	0
Peaches	Conventional	1715.217	99.155	0	0	1715.217	99.155	0	0
Pears	Local	0	0	6978	0	0	0	6978	0
Pears	Conventional	4973.264	8760.259	1420.065	4601.194	4973.264	8760.259	1420.065	4601.194
Plums	Conventional	1291.808	0	1013.619	0	1291.808	0	1013.619	0
Sno/Snap Peas	Conventional	165.648	215.715	549.812	66.244	165.648	215.715	549.812	66.244
Green or Yellow Bell Peppers	Local	621	0	415	0	621	0	415	0
Green or Yellow Bell Peppers	Conventional	62.896	370.084	6283.774	471.989	62.896	370.084	6283.774	471.989
Red or Orange Bell Peppers	Local	205.25	0	0	0	205.25	0	0	0
Red or Orange Bell Peppers	Conventional	6442	4759.429	5457.817	2888	6442	4759.429	5457.817	2888
Pineapple	Conventional	24304.12	10931.81	26800	14520	24304.12	10931.81	26800	14520
Radishes	Conventional	116.73	106.278	151.79	99.951	116.73	106.278	151.79	99.951
Spinach	Conventional	1639.032	1308.395	1263.442	1756	1639.032	1308.395	1263.442	1756
Summer Squashes (Yellow and Zucchini)	Local	616.5	0	97.5	0	616.5	0	97.5	0
Summer Squashes (Yellow and Zucchini)	Conventional	1340	1930	455.661	2569.303	1340	1930	455.661	2569.303

Slicing Tomatoes	Local	1105	187.5	1137.5	352.5	1105	187.5	1137.5	1057.5
Slicing Tomatoes	Conventional	3576	1338.877	12200	5382	3576	1338.877	12200	5382
Cherry Tomatoes	Local	666.26	0	192	0	666.26	0	192	0
Cherry Tomatoes	Conventional	7139.506	1510.996	2103.693	6592.411	7139.506	1510.996	2103.693	6095.415
	Objective Function Value	**273607.2**		**324389.8**		**272615.1**		**323321.4**	

Appendix Table E. *Model output with prices of local products reduced by 10% and 15%.*

		10% Reduction Fall '17		10% Reduction Fall '18		15% Reduction Fall '17		15% Reduction Fall '18	
Raw Product	**Source**	**Pounds Selected Aug-Oct**	**Pound Selected Nov-Dec**	**Pounds Selected Aug-Oct**	**Pound Selected Nov-Dec**	**Pounds Selected Aug-Oct**	**Pound Selected Nov-Dec**	**Pounds Selected Aug-Oct**	**Pound Selected Nov-Dec**
Apple	Local	10509.89	0	0	0	10509.89	0	0	0
Apple	Conventional	0	4727.271	12034.26	7575.365	0	4727.271	12034.26	7575.365
Asparagus	Conventional	542.778	678.566	242.583	259.594	542.778	678.566	242.583	259.594
Bananas	Conventional	9634.937	12980.26	23970.29	20800.63	9634.937	12980.26	23970.29	20800.63
Blackberry	Conventional	294.929	300.821	527.617	406.595	294.929	300.821	527.617	406.595
Blueberries	Conventional	395.016	395.31	462.875	0	395.016	395.31	462.875	0
Raspberry	Local	0	0	0	0	153	0	0	0
Raspberry	Conventional	337.62	383.086	625.683	387.78	184.62	383.086	625.683	387.78
Strawberry	Conventional	1256.47	1565.755	1967.926	1574.935	1256.47	1565.755	1967.926	1574.935
Broccoli Crowns	Conventional	3400	824.838	2637.06	2160	3400	824.838	2637.06	2160
Broccoli Florets	Conventional	5400.915	2429.292	6184.272	4327.468	5400.915	2429.292	6184.272	4327.468
Whole Head Broccoli	Local	186.162	0	0	0	186.162	0	0	0
Whole Head Cabbage (Red and Green)	Local	668.85	285	135	0	668.85	285	135	0

Whole Head Cabbage (Red and Green)	Conventional	300	0	1200	600	300	0	1200	600
Baby Carrots	Local	3600	720	5520	1080	3600	720	5520	1080
Baby Carrots	Conventional	8457.856	4703.536	8286.747	7611.116	8457.856	4703.536	8286.747	7611.116
Carrots	Local	112.5	337.5	0	0	112.5	337.5	0	0
Carrots	Conventional	0	0	450	0	0	0	450	0
Cauliflower Florets	Conventional	1493.641	250.111	176.687	139.275	1493.641	250.111	176.687	139.275
Cauliflower	Conventional	646.377	413.734	1017.808	551.805	646.377	413.734	1017.808	551.805
Celery	Conventional	2462.5	2092	5782	2004	2462.5	2092	5782	2004
Celery Sticks	Conventional	1495.165	716.953	2497.43	1746.36	1495.165	716.953	2497.43	1746.36
Clementine	Conventional	1550.452	4139.004	3275.811	2357.757	1550.452	4139.004	3275.811	2357.757
Cucumbers (English and Slicing)	Local	644.1	0	147.5	0	644.1	0	147.5	0
Cucumbers (English and Slicing)	Conventional	12543.03	2784.167	7790.814	10677.66	12543.03	2784.167	7790.814	10677.66
Grapefruit	Conventional	705.269	720.443	749.92	592.266	705.269	720.443	749.92	592.266
Grapes (Red and Green)	Conventional	4354.689	6663.201	5763.578	6680.837	4354.689	6663.201	5763.578	6680.837
Kiwi	Conventional	2850.4	3493.182	3326.741	2420.625	2850.4	3493.182	3326.741	2420.625
Green Leaf Lettuce	Local	429	396	0	0	429	396	0	0
Green Leaf Lettuce	Conventional	572	44	1408	0	572	44	1408	0
Romaine	Local	240	332.5	265	0	240	332.5	795	0
Romaine	Conventional	4729.532	1902.759	5425.32	3981.824	4729.532	1902.759	4895.32	3981.824
Chopped Romaine	Conventional	5891.907	2650.137	5304.109	1080	5891.907	2650.137	5304.109	1080
Salad Mix	Conventional	940.193	2650.137	1117.838	1491.95	940.193	2650.137	1117.838	1491.95
Spring Mix	Conventional	551.477	300.916	328.43	918	551.477	300.916	328.43	918
Shredded Lettuce	Conventional	5891.907	1185.655	2363.384	2152.678	5891.907	1185.655	2363.384	2152.678
Cantaloupe	Local	2069.95	0	833.75	0	2069.95	0	833.75	0

Cantaloupe	Conventional	21008.14	10380.36	25591.63	16634.33	21008.14	10380.36	25591.63	16634.33
Honeydew	Conventional	2575.201	8755.2	2819.447	1891.681	2575.201	8755.2	2819.447	1891.681
Watermelon	Local	12705.6	3000	18990	0	12705.6	3000	18990	0
Watermelon	Conventional	5593.438	8469.444	10207.87	18379.57	5593.438	8469.444	10207.87	18379.57
Mushroom	Conventional	264.268	115.939	216.477	122.162	264.268	115.939	216.477	122.162
Oranges	Conventional	15145.23	9118.906	17128.42	21186.33	15145.23	9118.906	17128.42	21186.33
Peaches	Local	1705	0	3544.526	0	1705	0	3544.526	0
Peaches	Conventional	1715.217	99.155	0	0	1715.217	99.155	0	0
Pears	Local	0	0	6978	0	0	0	6978	0
Pears	Conventional	4973.264	8760.259	1420.065	4601.194	4973.264	8760.259	1420.065	4601.194
Plums	Conventional	1291.808	0	1013.619	0	1291.808	0	1013.619	0
Sno/Snap Peas	Conventional	165.648	215.715	549.812	66.244	165.648	215.715	549.812	66.244
Green or Yellow Bell Peppers	Local	621	0	415	0	621	0	415	0
Green or Yellow Bell Peppers	Conventional	62.896	370.084	6283.774	471.989	62.896	370.084	6283.774	471.989
Red or Orange Bell Peppers	Local	205.25	0	0	0	205.25	0	0	0
Red or Orange Bell Peppers	Conventional	6442	4759.429	5457.817	2888	6442	4759.429	5457.817	2888
Pineapple	Conventional	24304.12	10931.81	26800	14520	24304.12	10931.81	26800	14520
Radishes	Conventional	116.73	106.278	151.79	99.951	116.73	106.278	151.79	99.951
Spinach	Conventional	1639.032	1308.395	1263.442	1756	1639.032	1308.395	1263.442	1756
Summer Squashes (Yellow and Zucchini)	Local	616.5	0	97.5	0	616.5	0	97.5	0
Summer Squashes (Yellow and Zucchini)	Conventional	1340	1930	455.661	2569.303	1340	1930	455.661	2569.303

Slicing Tomatoes	Local	1105	562.5	1137.5	1057.5	1105	562.5	1137.5	1057.5
Slicing Tomatoes	Conventional	3576	963.877	12200	5382	3576	963.877	12200	5382
Cherry Tomatoes	Local	666.26	0	192	0	666.26	0	192	0
Cherry Tomatoes	Conventional	7139.506	1510.996	2103.693	6095.415	7139.506	1510.996	2103.693	6095.415
	Objective Function Value	**271343.53**		**321941.22**		**270029.12**		**320553.198**	

Appendix Table F. Model output with prices of local products reduced by 50% and 100%

		50% Reduction Fall '17		50% Reduction Fall '18		100% Reduction Fall '17		100% Reduction Fall '18	
Raw Product	**Source**	**Pounds Selected Aug-Oct**	**Pound Selected Nov-Dec**	**Pounds Selected Aug-Oct**	**Pound Selected Nov-Dec**	**Pounds Selected Aug-Oct**	**Pound Selected Nov-Dec**	**Pounds Selected Aug-Oct**	**Pound Selected Nov-Dec**
Apple	Local	10509.89	0	0	0	10509.89	0	12034.26	0
Apple	Conventional	0	4727.271	12034.26	7575.365	0	4727.271	0	7575.365
Asparagus	Conventional	542.778	678.566	242.583	259.594	542.778	678.566	242.583	259.594
Bananas	Conventional	9634.937	12980.26	23970.29	20800.63	9634.937	12980.26	15281.46	20800.63
Blackberry	Conventional	294.929	300.821	527.617	406.595	294.929	300.821	527.617	406.595
Blueberry	Conventional	395.016	395.31	462.875	0	395.016	395.31	462.875	0
Raspberry	Local	153	0	0	0	153	0	0	0
Raspberry	Conventional	184.62	383.086	625.683	387.78	184.62	383.086	625.683	387.78
Strawberry	Conventional	1256.47	1565.755	1967.926	1574.935	1256.47	1565.755	1967.926	1574.935
Broccoli Crown	Conventional	3400	824.838	2637.06	2160	3400	824.838	2637.06	2160
Broccoli Floret	Conventional	5400.915	2429.292	6184.272	4327.468	5400.915	2429.292	6184.272	4327.468
Whole Head Broccoli	Local	186.6	0	0	0	186.6	0	0	0
Whole Head Cabbage (Red and Green)	Local	668.85	285	135	0	668.85	285	135	0

Whole Head Cabbage (Red and Green)	Conventional	300	0	1200	600	300	0	1200	600
Baby Carrots	Local	3600	720	5520	1080	3600	720	5520	1080
Baby Carrots	Conventional	8457.856	4703.536	8286.747	7611.116	8457.856	4703.536	8286.747	7611.116
Carrots	Conventional	0	0	450	0	0	0	450	0
Carrots	Local	112.5	337.5	0	0	112.5	337.5	0	0
Cauliflower Florets	Conventional	1493.641	250.111	176.687	139.275	1493.641	250.111	176.687	139.275
Cauliflower	Conventional	646.377	413.734	1017.808	551.805	646.377	413.734	1017.808	551.805
Celery	Conventional	2462.5	2092	5782	2004	2462.5	2092	5782	2004
Celery Sticks	Conventional	1495.165	716.953	2497.43	1746.36	1495.165	716.953	2497.43	1746.36
Clementine	Conventional	1550.452	4139.004	3275.811	2357.757	1550.452	4139.004	3275.811	2357.757
Cucumbers (English and Slicing)	Local	644.1	0	147.5	0	1932.3	0	442.5	0
Cucumbers (English and Slicing)	Conventional	10863.8	2784.167	7790.814	10677.66	7924.856	2784.167	7495.814	10677.66
Grapefruit	Conventional	705.269	720.443	749.92	592.266	705.269	720.443	749.92	592.266
Grapes (Red and Green)	Conventional	4354.689	6663.201	5763.578	6680.837	4354.689	6663.201	5763.578	6680.837
Kiwi	Conventional	2850.4	3493.182	3326.741	2420.625	2850.4	3493.182	3326.741	2420.625
Green Leaf Lettuce	Local	429	396	0	0	429	396	0	0
Green Leaf Lettuce	Conventional	572	44	1408	0	572	44	1408	0
Romaine	Local	240	997.5	795	0	240	997.5	795	0
Romaine	Conventional	4729.532	1237.759	4895.32	3981.824	4729.532	1237.759	4895.32	3981.824
Chopped Romaine	Conventional	5891.907	2650.137	5304.109	1080	5891.907	2650.137	5304.109	1080
Salad Mix	Conventional	940.193	2650.137	1117.838	1491.95	940.193	2650.137	1117.838	1491.95
Spring Mix	Conventional	551.477	300.916	328.43	918	551.477	300.916	328.43	918
Shredded Lettuce	Conventional	5891.907	1185.655	2363.384	2152.678	5891.907	1185.655	2363.384	2152.678
Cantaloupe	Local	6209.85	0	833.75	0	6209.85	0	2501.25	0
Cantaloupe	Conventional	16868.24	10380.36	25591.63	16634.33	16868.24	10380.36	23924.13	16634.33

Honeydew	Conventional	2575.201	8755.2	2819.447	1891.681	2575.201	8755.2	2819.447	1891.681
Watermelon	Local	12705.6	3000	18990	0	12705.6	3000	18990	0
Watermelon	Conventional	5593.438	8469.444	10207.87	18379.57	4343.188	8469.444	8447.572	18379.57
Mushrooms	Conventional	264.268	115.939	216.477	122.162	264.268	115.939	216.477	122.162
Oranges	Conventional	15145.23	9118.906	17128.42	21186.33	15145.23	9118.906	17128.42	21186.33
Peaches	Local	3420.217	0	3544.526	0	5115	0	16338	0
Peaches	Conventional	0	99.155	0	0	0	99.155	0	0
Pears	Local	0	0	6978	0	0	0	6978	0
Pears	Conventional	4973.264	8760.259	1420.065	4601.194	4973.264	8760.259	1420.065	4601.194
Plums	Conventional	1291.808		1013.619		1291.808		1013.619	
Sno/Snap Peas	Conventional	165.648	215.715	549.812	66.244	165.648	215.715	549.812	66.244
Green or Yellow Bell Peppers	Local	621	0	1245	0	1863	0	1245	0
Green or Yellow Bell Peppers	Conventional	62.896	370.084	5453.774	471.989		370.084	5453.774	471.989
Red or Orange Bell Peppers	Local	615.75	0	0	0	615.75	0	0	0
Red or Orange Bell Peppers	Conventional	6442	4759.429	4137.698	2888	6442	4759.429	4137.698	2888
Pineapple	Conventional	24304.12	10931.81	26800	14520	24304.12	10931.81	26800	14520
Radishes	Conventional	116.73	106.278	151.79	99.951	116.73	106.278	151.79	99.951
Spinach	Conventional	1638.696	1308.395	1263.442	1756	1638.696	1308.395	1263.442	1756
Summer Squashes (Yellow and Zucchini)	Local	1849.5	0	97.5	0	1849.5	0	97.5	0
Summer Squashes (Yellow and Zucchini)	Conventional	1340	1930	455.661	2569.303	1340	1930	455.661	2569.303
Slicing Tomatoes	Local	3315	562.5	3412.5	1057.5	3315	562.5	3412.5	1057.5
Slicing Tomatoes	Conventional	3576	963.877	12200	5382	3576	963.877	12200	5382

Cherry Tomatoes	Local	666.26	0	576	0	1998.78	0	576	0
Cherry Tomatoes	Conventional	5082.84	1510.996	1719.693	6095.415	3750.32	1510.996	1719.693	6095.415
	Objective Function Value	**259684.4**		**310743.36**		**235571.65**		**287084.94**	

Appendix Table G. Nutrition constraint shadow prices (SP) across local product price reduction scenarios

Year and Constraint	No Reduction		1% Reduction		5% Reduction		10% Reduction		15% Reduction		50% Reduction		100% Reduction	
	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Nov-Dec
2017 Fruit	0.181	0.178	0.181	0.178	0.181	0.178	0.181	0.178	0.181	0.178	0.18	0.178	0.178	0.178
2018 Fruit	0.183	0.137	0.183	0.137	0.183	0.137	0.183	0.137	0.182	0.137	0.181	0.137	0.172	0.137

Appendix Table H. Variety constraint shadow prices (SP) in 1%, 5% and 10% local price reduction scenarios for 2017

Product	No Reduction		1% Reduction		5% Reduction		10% Reduction	
	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Nov-Dec	SP Nov-Dec
Apple	0.396	0.15	0.396	0.396	0.15	0.395	0.150	0.15
Asparagus	0.503	0.52	0.503	0.503	0.52	0.503	0.520	0.52
Bananas	0.053	-	0.053	0.053	-	0.053	-	-
Blackberries	0.351	0.23	0.351	0.351	0.23	0.351	0.230	0.23
Blueberries	0.37	0.417	0.37	0.37	0.417	0.37	0.417	0.417
Raspberries	0.415	0.446	0.415	0.415	0.446	0.415	0.446	0.446
Strawberries	0.138	0.212	0.138	0.138	0.212	0.138	0.212	0.212
Broccoli Crown	0.062	0.059	0.062	0.062	0.059	0.062	0.059	0.059
Whole Head Broccoli	0.188	-	0.185	0.175	-	0.162	-	-
Cauliflower Florets	0.076	0.097	0.076	0.076	0.097	0.076	0.097	0.097

Cauliflower	0.012	0.035	0.012	0.012	0.035	0.012	0.035	0.035
Celery	-	0.002	-		0.002		0.002	0.002
Celery Sticks	0.037	0.051	0.037	0.037	0.051	0.037	0.051	0.051
Clementine	0.222	0.06	0.222	0.222	0.06	0.222	0.060	0.06
Cucumbers (English and Slicing)	0.008	0.01	0.008	0.008	0.01	0.008	0.010	0.01
Grapefruit	0.084	0.023	0.084	0.084	0.023	0.084	0.023	0.023
Grapes (Red and Green)	0.063	-	0.063	0.063	-	0.063	-	-
Kiwi	0.102	0.012	0.102	0.102	0.012	0.102	0.012	0.012
Chopped Romaine	0.018	-	0.018	0.018	-	0.018	-	-
Salad Mix	0.013	4.53359E-18	0.013	0.013	4.53E-18	0.013	EPS	4.53E-18
Spring Mix	0.062	0.046	0.062	0.062	0.046	0.062	0.046	0.046
Shredded Lettuce	0.003	-	0.003	0.003	-	0.003	-	-
Honeydew	0.067	-	0.067	0.067	-	0.067	-	-
Mushrooms	0.064	0.072	0.064	0.064	0.072	0.064	0.072	0.072
Oranges	0.168	0.045	0.168	0.168	0.045	0.168	0.045	0.045
Peach	0.149	0.093	0.149	0.149	0.093	0.149	0.093	0.093
Pear	0.279	0.249	0.279	0.279	0.249	0.279	0.249	0.249
Plum	0.079	-	0.079	0.079	-	0.079	-	-
Sno/Snap Peas	0.224	0.323	0.224	0.224	0.323	0.224	0.323	0.323
Green or Yellow Bell Peppers	0.009	0.013	0.009	0.009	0.013	0.009	0.013	0.013
Radishes	0.074	0.053	0.074	0.074	0.053	0.074	0.053	0.053
Spinach	0.04	0.011	0.04	0.04	0.011	0.04	0.011	0.011
Cherry Tomatoes	0.077	0.164	0.077	0.077	0.164	0.077	0.164	0.164

Appendix Table I. Variety constraint shadow prices (SP) in 15%, 50% and 100% local price reduction scenarios for 2017

Product	**15% Reduction**		**50% Reduction**		**100% Reduction**	
	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Nov-Dec

Apple	0.395	0.150	0.394	0.150	0.393	0.15
Asparagus	0.503	0.520	0.503	0.520	0.503	0.52
Bananas	0.053	-	0.053	-	0.053	-
Blackberries	0.351	0.230	0.351	0.230	0.351	0.23
Blueberries	0.37	0.417	0.37	0.417	0.37	0.417
Raspberries	0.415	0.446	0.415	0.446	0.415	0.446
Strawberries	0.138	0.212	0.138	0.212	0.138	0.212
Broccoli Crowns	0.062	0.059	0.062	0.059	0.062	0.059
Whole Head Broccoli	0.15	-	0.06	-	-	-
Cauliflower Florets	0.076	0.097	0.076	0.097	0.076	0.097
Cauliflower	0.012	0.035	0.012	0.035	0.012	0.035
Celery		0.002	-	0.002	-	0.002
Celery Sticks	0.037	0.051	0.037	0.051	0.037	0.051
Clementine	0.222	0.060	0.222	0.060	0.222	0.06
Cucumbers (English and Slicing)	0.008	0.010	0.008	0.010	0.008	0.01
Grapefruit	0.084	0.023	0.084	0.023	0.084	0.023
Grapes (Red and Green)	0.063	-	0.063	-	0.063	-
Kiwi	0.102	0.012	0.102	0.012	0.102	0.012
Chopped Romaine	0.018	-	0.018	-	0.018	-
Salad Mix	0.013	-	0.013	-	0.013	4.53E-18
Spring Mix	0.062	0.046	0.062	0.046	0.062	0.046
Shredded Lettuce	0.003	EPS	0.003	EPS	0.003	-
Honeydew	0.067	-	0.067	-	0.067	-
Mushroom	0.064	0.072	0.064	0.072	0.064	0.072
Oranges	0.168	0.045	0.168	0.045	0.168	0.045
Peach	0.149	0.093	0.066	0.093	-	0.093
Pear	0.279	0.249	0.279	0.249	0.279	0.249
Plum	0.079	-	0.079	-	0.079	-
Sno/Snap Peas	0.224	0.323	0.224	0.323	0.224	0.323
Green or Yellow	0.009	0.013	0.009	0.013		0.013

Bell Peppers						
Radishes	0.074	0.053	0.074	0.053	0.074	0.053
Spinach	0.04	0.011	0.04	0.011	0.04	0.011
Cherry Tomatoes	0.077	0.164	0.077	0.164	0.077	0.164

Appendix Table J. Variety constraint shadow prices (SP) in 1% and 5% local price reduction scenarios for 2018

Product	**No Reduction**		**1% Reduction**		**5% Reduction**	
	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Nov-Dec
Apple	0.284	0.275	0.284	0.275	0.284	0.275
Asparagus	0.444	0.546	0.444	0.546	0.444	0.546
Blackberries	0.378	0.276	0.378	0.276	0.378	0.276
Blueberries	0.35		0.35		0.35	
Raspberries	0.515	0.403	0.515	0.403	0.515	0.403
Strawberries	0.088	0.149	0.088	0.149	0.088	0.149
Broccoli Crowns	0.015		0.015		0.015	
Cauliflower Florets	0.069	0.113	0.069	0.113	0.069	0.113
Cauliflower	0.007	0.056	0.007	0.056	0.007	0.056
Celery Sticks	0.057	0.048	0.057	0.048	0.057	0.048
Clementine	0.167	0.102	0.167	0.102	0.167	0.102
Cucumbers (English and Slicing)	0.009		0.009		0.009	
Grapefruit	0.045	0.019	0.045	0.019	0.045	0.019
Grapes (Red and Green)	0.009		0.009		0.009	
Kiwi	0.029	0.02	0.029	0.02	0.029	0.02
Salad Mix	0.000894743	0.004	0.000895	0.004	0.000895	0.004
Spring Mix	0.04		0.04		0.04	
Honeydew	0.042	0.006	0.042	0.006	0.042	0.006
Mushrooms	0.07	0.063	0.07	0.063	0.07	0.063

Oranges	0.269	0.059	0.269	0.059	0.269	0.059
Peach	0.208		0.205		0.192	
Pear	0.231	0.164	0.231	0.164	0.231	0.164
Plum	0.062		0.062		0.062	
Sno/Snap Peas	0.215	0.234	0.215	0.234	0.215	0.234
Green or Yellow Bell Peppers		0.034		0.034		0.034
Radishes	0.041	0.047	0.041	0.047	0.041	0.047
Spinach	0.033		0.033		0.033	
Squash (Yellow and Zucchini)	0.012		0.012		0.012	
Cherry Tomatoes	0.047		0.047		0.047	

Appendix Table K. Variety constraint shadow prices (SP) in 10%, 15%, 50% and 100% local price reduction scenarios for 2018

Product	**10% Reduction**		**15% Reduction**		**50% Reduction**		**100% Reduction**	
	SP Aug-Oct	SP Nov-Dec	SP Aug-Oct	SP Nov-Dec	SP Nov-Dec	SP Aug-Oct	SP Aug-Oct	SP Nov-Dec
Apple	0.284	0.275	0.284	0.275	0.284	0.275	0.391	0.275
Asparagus	0.444	0.546	0.444	0.546	0.444	0.546	0.444	0.546
Blackberries	0.378	0.276	0.378	0.276	0.378	0.276	0.036	
Blueberries	0.35		0.35		0.35		0.414	0.276
Raspberries	0.515	0.403	0.515	0.403	0.515	0.403	0.386	
Strawberries	0.088	0.149	0.088	0.149	0.088	0.149	0.551	0.403
Broccoli Crowns	0.015		0.015		0.015		0.124	0.149
Cauliflower Florets	0.069	0.113	0.069	0.113	0.069	0.113	0.015	
Cauliflower	0.007	0.056	0.007	0.056	0.007	0.056	0.069	0.113
Celery Sticks	0.057	0.048	0.057	0.048	0.057	0.048	0.007	0.056
Clementine	0.167	0.102	0.167	0.102	0.167	0.102	0.057	0.048
Cucumbers (English and Slicing)	0.009		0.009		0.009		0.203	0.102

Grapefruit	0.045	0.019	0.045	0.019	0.045	0.019	0.009	
Grapes (Red and Green)	0.009		0.009		0.009		0.081	0.019
Kiwi	0.029	0.02	0.029	0.02	0.029	0.02	0.045	
Salad Mix	0.000895	0.004	0.00089474	0.004	0.000895	0.004	0.065	0.02
Spring Mix	0.04		0.04		0.04		0.000895	0.004
Honeydew	0.042	0.006	0.042	0.006	0.042	0.006	0.04	
Mushrooms	0.07	0.063	0.07	0.063	0.07	0.063	0.078	0.006
Oranges	0.269	0.059	0.269	0.059	0.269	0.059	0.07	0.063
Peach	0.177		0.161		0.051		0.305	0.059
Pear	0.231	0.164	0.231	0.164	0.231	0.164	0.267	0.164
Plum	0.062		0.062		0.062		0.098	
Sno/Snap Peas	0.215	0.234	0.215	0.234	0.215	0.234	0.215	0.234
Green or Yellow Bell Peppers		0.034		0.034		0.034		0.034
Radishes	0.041	0.047	0.041	0.047	0.041	0.047	0.041	0.047
Spinach	0.033		0.033		0.033		0.033	
Squash (Yellow and Zucchini)	0.012		0.012		0.012		0.012	
Cherry Tomatoes	0.047		0.047		0.047		0.047	

Appendix Table K. Decision variable reduced costs (RC) in 0%, 1%, 5% and 10% local price reduction scenarios for 2017

		Original Output		**1% Reduction**		**5% Reduction**		**10% Reduction**	
Product	**Source**	RC Aug-Oct 17	RC Nov-Dec 17	RC Aug-Oct 17	RC Nov-Dec 17	RC Aug-Oct 17	RC Nov-Dec 17	RC Aug-Oct 17	RC Nov-Dec 17
Apple	Conventional	0.002		0.002		0.002		0.002	
Raspberries	Local	0.815		0.748		0.481		0.148	
Broccoli Crown	Conventional	-0.182		-0.182		-0.182		-0.182	
Whole Head Cabbage (Red and Green)	Local	-0.79	-0.786	-0.797	-0.791	-0.825	-0.814	-0.859	-0.843

Whole Head Cabbage (Red and Green)	Conventional	-1.126		-1.126		-1.126		-1.126	
Baby Carrots	Local	-0.147	0.011	-0.154	0.005	-0.179	-0.023	-0.211	-0.058
Carrots	Local	-1.428	-1.501	-1.432	-1.505	-1.448	-1.521	-1.467	-1.540
Celery	Conventional	-0.093	-0.071	-0.093	-0.071	-0.093	-0.071	-0.093	-0.071
Cucumbers (English and Slicing)	Local	0.816		0.802		0.745		0.673	
Green Leaf Lettuce	Local	-1.543	-0.961	-1.551	-0.970	-1.582	-1.006	-1.62	-1.052
Green Leaf Lettuce	Conventional	-1.582	-0.961	-1.582	-0.961	-1.582	-0.961	-1.582	-0.961
Romaine	Local	-0.002	0.228	-0.006	0.219	-0.024	0.186	-0.046	0.145
Cantaloupe	Local	0.388		0.379		0.345		0.303	
Honeydew	Conventional		-0.057		-0.057		-0.057		-0.057
Watermelon	Local	0.004	-0.033	0.000215	-0.037	-0.017	-0.054	-0.038	-0.075
Peach	Local	0.229		0.217		0.168		0.108	
Peach	Conventional								
Green or Yellow Bell Peppers	Local	1.481		1.457		1.363		1.245	
Green or Yellow Bell Peppers	Conventional								
Red or Orange Bell Peppers	Local	0.796		0.763		0.633		0.471	
Red or Orange Bell Peppers	Conventional	-1.131		-1.131		-1.131		-1.131	
Squash (Yellow and Zucchini)	Local	0.524		0.51		0.456		0.388	
Squash (Yellow and Zucchini)	Conventional	-0.045	-0.111	-0.045	-0.111	-0.045	-0.111	-0.045	-0.111
Slicing Tomatoes	Local	1.134	0.119	1.108	0.103	1.006	0.039	0.878	-0.041
Slicing Tomatoes	Conventional	-0.679		-0.679		-0.679		-0.679	
Cherry Tomatoes	Local	2.104		2.063		1.898		1.692	

Appendix Table L. Decision variable reduced costs (RC) in 15%, 50% and 100% local price reduction scenarios for 2017

		15% Reduction		50% Reduction		100% Reduction	
Product	**Source**	RC Aug-Oct	RC Nov-Dec	RC Aug-Oct	RC Nov-Dec	RC Aug-Oct	RC Nov-Dec
Apple	Conventional	0.003		0.004		0.007	
Raspberries	Local	-0.185		-2.519		-5.852	
Broccoli Crown	Conventional	-0.182		-0.182		-0.182	
Whole Head Broccoli	Local			-0.201		-1.451	
Whole Head Cabbage (Red and Green)	Local	-0.894	-0.871	-1.137	-1.071	-1.483	-1.357
Whole Head Cabbage (Red and Green)	Conventional	-1.126		-1.126		-1.126	
Baby Carrots	Local	-0.242	-0.093	-0.463	-0.336	-0.779	-0.684
Carrots	Local	-1.487	-1.560	-1.624	-1.697	-1.82	-1.893
Celery	Conventional	-0.093	-0.071	-0.093	-0.071	-0.093	-0.071
Cucumbers (English and Slicing)	Local	0.602		0.103		-0.611	
Green Leaf Lettuce	Local	-1.659	-1.097	-1.93	-1.415	-2.317	-1.870
Green Leaf Lettuce	Conventional	-1.582	-0.961	-1.582	-0.961	-1.582	-0.961
Romaine	Local	-0.069	0.103	-0.226	-0.186	-0.45	-0.600
Cantaloupe	Local	0.26		-0.038		-0.463	
Honeydew	Conventional		-0.057		-0.057		-0.057
Watermelon	Local	-0.059	-0.097	-0.208	-0.244	-0.421	-0.456
Peach	Local	0.047				-0.31	
Peach	Conventional			0.376		0.671	
Green or Yellow Bell Peppers	Local	1.127		0.299		-0.855	
Green or Yellow Bell Peppers	Conventional					0.028	
Red or Orange Bell Peppers	Local	0.308		-0.829		-2.454	

Red or Orange Bell Peppers	Conventional	-1.131		-1.131		-1.131	
Squash (Yellow and Zucchini)	Local	0.32		-0.154		-0.832	
Squash (Yellow and Zucchini)	Conventional	-0.045	-0.111	-0.045	-0.111	-0.045	-0.111
Slicing Tomatoes	Local	0.75	-0.121	-0.145	-0.681	-1.424	-1.481
Slicing Tomatoes	Conventional	-0.679		-0.679		-0.679	
Cherry Tomatoes	Local	1.485		0.042		-2.02	

Appendix Table M. Decision variable reduced costs (RC) in 0%, 1%, 5% and 10% local price reduction scenarios for 2018

		Original Output		**1% Price Reduction**		**5% Reduction**		**10% Reduction**	
Product	**Source**	RC Aug-Oct	RC Nov-Dec	RC Aug-Oct	RC Nov-Dec	RC Aug-Oct	RC Nov-Dec	RC Aug-Oct	RC Nov-Dec
Apple	Local	0.066		0.065		0.062		0.059	
Broccoli Crown	Conventional		-1.589		-1.589		-1.589		-1.589
Whole Head Cabbage (Red and Green)	Local	-0.607		-0.614		-0.642		-0.677	
Whole Head Cabbage (Red and Green)	Conventional	-0.915	-0.601	-0.915	-0.601	-0.915	-0.601	-0.915	-0.601
Baby Carrots	Local	-0.103	-0.082	-0.109	-0.088	-0.135	-0.111	-0.166	-0.139
Carrots	Conventional	-0.176		-0.176		-0.176		-0.176	
Celery	Conventional	-0.226	-0.110	-0.226	-0.110	-0.226	-0.110	-0.226	-0.110
Cucumbers (English and Slicing)	Local	0.661		0.648		0.597		0.532	
Green Leaf Lettuce	Conventional	-0.677		-0.677		-0.677		-0.677	
Romaine	Local	0.063		0.058		0.037		0.011	
Chopped Romaine	Conventional		-2.823		-2.823		-2.823		-2.823
Spring Mix	Conventional		-0.898		-0.898		-0.898		-0.898
Cantaloupe	Local	1.060		1.045		0.984		0.908	
Watermelon	Local	-0.029		-0.033		-0.049		-0.068	

Peach	Conventional	0.088		0.102		0.158		0.229	
Pear	Local	-0.051		-0.059		-0.087		-0.123	
Green or Yellow Bell Peppers	Local	0.472		0.459		0.410		0.349	
Red or Orange Bell Peppers	Conventional		-1.077		-1.077		-1.077		-1.077
Pineapple	Conventional	-0.557	-0.599	-0.557	-0.599	-0.557	-0.599	-0.557	-0.599
Spinach	Conventional		-1.810		-1.810		-1.810		-1.810
Squash (Yellow and Zucchini)	Local	0.003		-0.006		-0.042		-0.087	
Slicing Tomatoes	Local	0.600	0.066	0.586	0.051	0.530	-0.009	0.460	-0.084
Slicing Tomatoes	Conventional	-0.050	-0.575	-0.050	-0.575	-0.050	-0.575	-0.050	-0.575
Cherry Tomatoes	Local	1.170		1.141		1.027		0.883	

Appendix Table N. Decision variable reduced costs (RC) in 15%, 50% and 100% local price reduction scenarios for 2018

		15% Reduction		**50% Reduction**		**100% Reduction**	
Product	**Source**	RC Aug-Oct	RC Nov-Dec	RC Aug-Oct	RC Nov-Dec	RC Aug-Oct	RC Nov-Dec
Apple	Local	0.055		0.030			
Apple	Conventional					0.005	
Broccoli Crown	Conventional		-1.589		-1.589		-1.589
Whole Head Cabbage (Red and Green)	Local	-0.712		-0.957		-1.307	
Whole Head Cabbage (Red and Green)	Conventional	-0.915	-0.601	-0.915	-0.601	-0.915	-0.601
Baby Carrots	Local	-0.198	-0.168	-0.420	-0.369	-0.737	-0.656
Carrot	Conventional	-0.176		-0.176		-0.176	
Celery	Conventional	-0.226	-0.110	-0.226	-0.110	-0.226	-0.110
Cucumbers (English and Slicing)	Local	0.468		0.016		-0.629	
Green Leaf Lettuce	Conventional	-0.677		-0.677		-0.677	

Romaine	Local	-0.015		-0.197		-0.456	
Chopped Romaine	Conventional		-2.823		-2.823		-2.823
Spring Mix	Conventional		-0.898		-0.898		-0.898
Cantaloupe	Local	0.832		0.298		-0.463	
Watermelon	Local	-0.088		-0.225		-0.422	
Peach	Local					-0.311	
Peach	Conventional	0.299		0.793		1.186	
Pear	Local	-0.159		-0.411		-0.770	
Green or Yellow Bell Peppers	Local	0.288		-0.141		-0.753	
Red or Orange Bell Peppers	Conventional		-1.077		-1.077		-1.077
Pineapple	Conventional	-0.557	-0.599	-0.557	-0.599	-0.327	-0.599
Spinach	Conventional		-1.810		-1.810		-1.810
Squash (Yellow and Zucchini)	Local	-0.132		-0.447		-0.897	
Slicing Tomatoes	Local	0.391	-0.159	-0.096	-0.321	-0.792	-1.434
Slicing Tomatoes	Conventional	-0.050	-0.575	-0.050	-0.575	-0.050	-0.575
Cherry Tomatoes	Local	0.740		-0.264		-1.697	