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Localization effects for a fresh vegetable product supply chain: Broccoli in the eastern United States

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ABSTRACT

What are the costs of increased food system localization in the case of a fresh vegetable product? When production is reallocated across space and seasons, how do supply chain costs and consumer prices change? In this article, we use a production and transportation model to answer these questions, along with illustrative simulation results from increased production of fresh broccoli in the eastern United States. Contrary to previous findings in other industries, we find that localization through reallocation of production may take place at no cost to the consumer, even at a small decrease in price. Localization may also reduce total broccoli supply chain costs and food miles.

Introduction

An alternative food supply system is a priority shared among some consumers, producers and governments. Consumers are increasingly aware of the social and environmental impacts of food systems (e.g. Weatherell et al., 2003; Brown et al., 2009). Growers and retailers constantly innovate to reduce costs while responding to consumer demand for alternative ways to produce and distribute food such as regional and local food systems (e.g. Gilg and Battershill, 1998; Broderick et al., 2011) and to the resulting shifts in public policy (e.g. USDA, 2013 and Kneafsey et al., 2013). Many of these goals may be achieved by diversifying where food is produced. However, the food system localization resulting from production reallocation across space and seasons may have unintended consequences such as increasing supply chain costs and prices paid by consumers. Localization can also alter the supply chain structure, chiefly product flows, in spatially and seasonally unexpected ways. Examination of supply-chain localization impacts requires models and methods that address the spatial and seasonal components of the supply chain, particularly in the case of fresh fruits and vegetables. Efforts to increase production in new areas need to be informed by analyses of the optimal locations of increased production and the effects of localization on production and transportation costs, consumer prices, and product flows.

Such localization effects vary among food commodities. In this paper, we develop an optimization model that depicts the production and transportation of a perishable product, fresh broccoli. We calibrate the model using both primary and secondary data for the United States (U.S.). The model can be solved for the locations and seasons that increase eastern broccoli production while minimizing total costs of production and transportation. We simulate and analyze scenarios of optimal broccoli acreage expansion in the eastern U.S. We measure the resulting changes in system-wide costs by supply segment and season; changes in product marginal costs; increases in the share of eastern-produced broccoli in eastern markets; and decreases in the weighted average source distance (WASD) travelled by the product from farm to demand location (food miles).

The U.S. fresh vegetable sector is an excellent setting for examining the economic and environmental impacts of increased localization of food supply chains. Many vegetables are disproportionally produced in California largely because of its favorable climatic zones and soil (Duxbury and Welch, 1999). This supply concentration is, however, highly dependent on subsidized and limited irrigation water supplies (Peters et al., 2002). Increasing competition for declining water resources between urban and agricultural needs, combined with increasing truck rates,[1] will reinforce the advantages of spatially diversifying vegetable production.

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[1] Real truck rates have increased by 39% between 2003 and 2011 (Prater et al., 2014).

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Broccoli is an interesting case study for examination of the economic consequences of increased localization in fresh vegetable supply chains. Lessons learned from studying broccoli might be generalizable to other fresh crops in the U.S. that share the following characteristics: (1) they are consumed nationally but mostly produced in the western U.S; (2) reallocating some of their production to other regions is possible if new varieties are developed; (3). unless produced in greenhouses, expanding their production in the eastern U.S. would be limited to the summer-fall season. Examples of such crops include carrots, celery, chicory, endive, grapes, strawberries, and lettuce.

Although few locales in the U.S. can supply horticultural commodities year-round as California does, the development of new broccoli varieties adapted to the agroecological conditions of the eastern U.S. is an opportunity for spatial diversification in the national horticultural supply chain. Such diversification might reduce water and energy needs while keeping the industry competitive. Broccoli is a high-volume commodity, with U.S. consumption at about 2 billion pounds per year (USDA, 2010). Warm summer nights make it impossible to produce high quality broccoli in most parts of the eastern U.S. Maine, which enjoys cool summer nights, already produces broccoli for eastern markets in the summer-fall season. Currently, a consortium of public and private institutions is developing new broccoli varieties adaptable to the eastern U.S. in order to satisfy: consumer demand for sustainable, locally-grown, healthy food; grower demand for high-value specialty crop varieties; retailer demand for lower transportation costs, and public sector pressure for reduced carbon emissions and a more reliable food system.[2] This project offers the opportunity to examine the economic impacts of increased localization in a horticultural supply chain. Policy makers supporting local and regional food systems (e.g. USDA, 2013 and Kneafsey et al., 2013) want to identify optimal location-seasons for acreage increases and evidence on localization impacts on costs and prices. Producers and packer–shippers might be interested in anticipating the magnitude, location and seasonality of expected product flows in the wake of acreage expansion in the eastern U.S. Finally, consumers need information on whether localization might increase marginal costs and consumer prices.

Literature review

The U.S. supply of fruits and vegetables may be increasingly vulnerable because much of the nation's horticultural supply is concentrated in water-scarce, drought-prone California (Duxbury and Welch, 1999). Climate changes are likely to further reduce the availability of irrigation water in California (Weare, 2009). Recent droughts in California have caused groundwater depletion to become unsustainable at current recharge rates (Scanlon et al., 2012).

One strategy to reduce supply vulnerability consists of relocating some production to areas with higher rainfall and fewer droughts. However, spatial diversification of supply in the U.S. can be a challenge because most horticultural crops are harvested from hybrid cultivars specifically developed for California production environments (Björkman, 2010). Broccoli, one of the top dollar vegetables produced domestically with a farm-gate value of $800 million (USDA, 2010) is no exception. Although some new broccoli cultivars have been tested in the eastern U.S., adaptation to eastern production conditions has not been an objective of U.S. breeding programs until recent years (Björkman, 2010).

Aside from the obvious challenge that broccoli cannot grow during winter months in much of the eastern U.S., relatively warm summer evenings can reduce its marketable yield. In response, the U.S. Vegetable Laboratory and Cornell University are breeding broccoli cultivars adapted to summer conditions of the eastern U.S. (Farnham and Bjorkman, 2011). One project currently aims at developing new varieties tailored to year-round eastern production from northern Florida to Maine. Although current U.S. production is largely centered in California, eastern production in Maine is well established, and there is increased interest in growing broccoli in other eastern states.

While new broccoli cultivars are developed, regional testing takes place, and hybrid seed production starts, effects of a regional production increase on the supply chain need to be better understood. The recent literature on food system localization focuses mostly on understanding consumer demand (Onozaka et al., 2010; Sirieix et al., 2008; Toler et al., 2009) and willingness to pay for locally-grown food (Conner et al., 2009; Khan and Prior, 2010; Toler et al., 2009). Another stream of the literature, however, deals with supply chains and the response to food system localization and the economic and environmental consequences that follow. The most common concept or metric used to quantify food system localization is the one of food miles; it represents the distance traveled from field to consumer (Coley et al., 2009; Hein et al., 2006). Using this measure, three Iowa case studies showed that food produced within local or regional food systems travels fewer miles than the food produced within a conventional system (Pirog and Benjamin, 2005). Localization effects can, however, sometimes go in the other direction. King et al. (2010) show that, for some food products, fuel use per unit of food product can be higher in local supply chains compared to mainstream supermarket supply chains which often enjoy higher efficiencies in transportation, storage, and distribution. Few studies provide more comprehensive estimates of the changes in supply chain costs due to localization. In the foodservice sector, Hardesty (2008) shows that transaction costs in localized supply chains are larger than in mainstream chains. Studying U.S. dairy supply chain segments beyond the farm gate for multiple products, Nicholson et al. (2011) found that, while localization cost impacts can be modest, they can impose relatively large cost re-allocations across supply chain segments, regions and products.

Methods

In this paper, we develop a mathematical programming, production–transportation model to identify the current optimal supply chain structure for fresh broccoli in the U.S. We then simulate increased localization by optimally expanding eastern production and analyzing the resulting seasonally- and spatially-disaggregated changes in the supply chain.

Production–transportation problems consist of deriving the production and transport patterns that minimize total production and transportation costs. Production needs to meet consumer demand, constrained by production capacity. In this study, we seasonally and spatially disaggregate the economic model. The model specifies seasonal supply and demand, regional production costs, and seasonal transportation costs. Given these inputs, the model solves for the production quantities and product flows that minimize the total cost of producing and shipping broccoli in each season. The model solution also provides, for each season, the resulting shadow prices for land at each supply location and the marginal costs of broccoli at the demand locations. We analyze the impact of a short-run eastern U.S. broccoli acreage expansion on production and transportation costs, the spatial–seasonal reorganization associated with optimal production and flows, and the reduction in weighted average distance travelled by the product.

We choose a supply chain approach because it allows us to analyze comparative advantages in both the production (yield,

[2] For more details on the eastern broccoli project: http://www.hort.cornell.edu/bjorkman/lab/broccoli/easternindustrymain.php.