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Exploring Localized Economic Dynamics: Methods-Driven Case Studies of Transformation and Growth in Agricultural and Food Markets

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Abstract

Quantifying the economic impacts and contributions of local and regional food systems and events in these systems has become increasingly common as both public and private entities attempt to justify a commonly held belief that more localized systems lead to positive economic gains in the communities in which they operate. However, many studies are not careful to consider the opportunity costs, complexity of economic linkages, or other subtle dimensions of how regional economies may change in dynamic settings. In this study, the authors use three case studies to explore the important criteria that should be considered when modeling impacts and contributions of activities and events that can be characterized by a variety of supply shocks or customization to account for relocalized linkages in the supply chain.

Keywords

community development, methodology, economic development incentives/tools

Quantifying the economic impacts and contributions of local and regional food systems and events in these systems has become increasingly more common as both public and private entities are attempting to justify a commonly held belief that more localized food and agricultural systems lead to positive economic gains in the communities in which they operate (e.g., Hughes, Brown, Miller, & McConnell, 2008; Sadler, Clark, & Gilliland, 2013; Tuck, Haynes, King, & Pesch, 2010). Although many studies have been conducted on contributions from more localized food economies, drawing overarching conclusions can be difficult because of the diverse scope of projects, methodologies employed, and simplifying assumptions needed to characterize an industry-focused analysis or regionally focused analysis (O'Hara & Pirog, 2013).

The goal of this study is to provide an overview of methods used to evaluate three different types of agricultural and food system shocks and innovations, using different approaches to modify a commonly employed input–output model; specifically, the commercially available software IMpact Analysis for PLANning (IMPLAN) from the IMPLAN Group LLC (Minnesota IMPLAN Group, Inc., 2000). As there is a wide universe of events, innovations, and market transitions that are commonly modeled, the cases here are similarly diverse—from relocalizing a farm to school food procurement program seeking to connect school children with foods from surrounding farms, to an emerging wine sector seeking to relocalize an industry put in dormancy by prohibition, to a traditional weather shock to enterprises operating in traditional commodity markets. In 2016, the U.S. Department of Agriculture Marketing Service released a toolkit to guide economic development assessments. The toolkit was developed by a team of applied researchers who came to a consensus of more standardized approaches, but it notes the scarcity of examples from which to draw and identify as best practices (Thilmany McFadden et al., 2016). This study contributes context-rich examples that integrate the identified best practices, and other considerations, to continue improving the analyses conducted in this field.

Using three Colorado case studies as examples, we explore the criteria that should be considered when modeling impacts and contributions of activities and events that can be characterized by changes in the supply chain. Although these cases provide important context, this contribution intends to generally characterize different approaches to the challenge of modeling emergent, heterogeneous food system innovations using an input–output framework, and how these different contexts inform the discussion on how to carry out

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economic impact analyses. Without delving too deeply into any empirical issues of the individual case studies, we will highlight important factors to consider in study framing, model development, and interpretation of the findings in the context of market and community-specific drivers.

Each case study represents a generalized version of a different innovation or event that may occur in local and regional food systems; the first two focus on shifts in demand to more locally controlled production and supply chains, and the third explores how the locality of inputs and buying sectors may amplify events that negatively affect a specific region. Our conclusions demonstrate that how one chooses to model economic impacts influences results. Specifically, we explore customizing sectors using survey data to modify existing data sources. We use multiple definitions for "local," and recognize that money spent on local farms is money diverted from other sectors, rather than simply characterize the increase in spending as a complete gain for the region.

We also show that careful modeling considerations of spillover effects and backward and forward linkages provide results that are more accurate and more defensible than simply making a change in revenue to the affected sector in IMPLAN and reporting the resulting impacts, a method often used in simple input–output analysis. Local agriculture and food systems are an interesting sector on which to focus. In the past decade, there has been heightened attention to food resiliency—all regions in the United States have some agriculture and food production as a key primary sector of their economy, and there is evidence that demand shocks driven by local food consumers may be misaligned with the current food production systems and supply chains that exist in many areas of the country (Swenson, 2010).

We begin with a review of the literature to survey the previous efforts at modeling economic impacts and contributions in the field of food systems, followed by three Colorado case studies. For each case, the evaluation of economic impacts and contributions will be discussed in the framework of the ownership, governance, and operational model of the value-added enterprise, thereby providing guidance on how to conduct broad categories of analyses conditional on the type of operational model in question. We conclude with a discussion of best practices and recommendations for future research.

The Evolution of Economic Impact and Contribution Modeling

The economic literature aimed at quantifying the impacts and contributions of local and regional food systems and events in these systems began with a simple approach.

Assume that an increase (or decrease) in business conducted locally will lead to more (or less) money in the local economy. In subsequent years, a layer of complexity was added by including spillover effects. For example, the extra money spent in a local community at a farmers' market directly affects farmers but also the businesses surrounding the market that might see gains from increased foot traffic and patronage.

After adding spillover effects, researchers began to carefully delineate exactly how much of the spending in local and regional food systems could really be considered an impact (often interpreted as a shock or event) rather than a more locally derived contribution (in essence, saying the net activity is greater if local systems stop leakages to economies outside the region). Incorporating countervailing effects (shifts from nonlocal to local sectors) into the analysis could act to partially mitigate positive gains in a food system. The last innovation in the literature has been to use more complex modeling techniques and hybrid models, the latter of which may combine multiple modeling techniques or modify existing sectors in an input–output analysis, as well as other customization strategies. The remainder of this section will detail the literature, highlighting best practices and methods used to inform the case study portion of this study.

The most straightforward and simple approach to estimate economic impacts and contributions is to assume that spending more money with a local business leads to an economic gain for the community. Brown and Miller (2008) conduct a review of the literature on impacts of farmers' markets and community supported agriculture. They highlight studies in which impacts were estimated by simply plugging farmers market revenue estimates into the economic impact modeling software, IMPLAN, and provide an estimate of the direct and indirect economic impact of a farmers' market to the local community (Henneberry, Whitacre, & Agustini, 2009; Myers, 2004; Otto & Varner, 2005). This review represents the early groundwork for economic impact estimation of local and regional food systems. Yet, given the methods applied, some would argue they could either underestimate or overestimate impacts because of the simplicity of assumptions.

The next evolution in this field of research added a layer of complexity. Spillover effects of economic activity—that is, the dollars spent in a region that are attributable to a given industry, event, or policy can be defined as either the positive or negative impact of a certain activity to members of localities and economic sectors that are not direct beneficiaries (Watson, Wilson, Thilmany McFadden, & Winter, 2007). There are two main types of spillover effects. The first occurs when the economic activity of the industry or event in question drives more (or less) money to surrounding businesses by acting as a catalyst. The second type happens when a business or industry gains enough critical mass to induce supply chain partners (e.g., input suppliers, buyers) to relocate so purchases can be made with more local suppliers and ultimately provide an option for less money to "leak" out of the region.

Most of the research on the economic impacts and contributions of localized food systems has focused on the first type of spillover effects. Oberholtzer and Grow (2003) find that people who visit farmers' markets end up bringing in additional revenue to businesses adjacent to the market. Thilmany McFadden, Kress, and Watson (2006) find that, for the Colorado wine industry, impacts from tourism were larger than those from wine sales because of the amenity-rich regions where the industry was forming.

The second type of spillover effects has been explored in the context of value chain analysis (Barham, 2011; Matson, Sullins, & Cook, 2011; Stevenson, 2009) but has yet to be studied in the economic impact literature. As value chains continue to grow in many communities, supply-chain-related spillover effects (e.g., increased sourcing from local suppliers) will be important when fully measuring the new enterprises' impacts on stakeholders. In essence, these stronger value-chain-based, business-to-business linkages may lessen leakage of economic activity out of the region of interest.

Including spillover effects typically mitigates the potential for underestimating effects, whereas considering countervailing effects mitigates the potential for overestimation. For example, purchasing local food is simply shifting purchasing from one sector to another; it is not fundamentally changing the amount of money being spent in an economy or in any particular sector (although one could collect primary data to determine whether marginal increases occur if local food is considered higher quality and draws a higher share of the region's household spending). In this example, the increased spending in a region, because of local food purchases, is the marketing margins and transactions costs of the food distribution sector that would otherwise "leak" outside the community if governance of such activities did not occur where the raw agricultural products are sourced; in short, it is not gross sales of local food purchases.

Unlike much of the previous research on farmers' markets, Hughes et al. (2008) incorporate countervailing demand effects and report the net impact of farmers' markets rather than the gross impact. The net impact assumes that money spent at the farmers' markets is money not being spent at grocery stores. Therefore, all gains are because of the larger multipliers for the farming sector compared with the retail sector. Similarly, Gunter and Thilmany McFadden (2012) analyze the economic impact of a farm to school program, and Schmitt, Jablonski, and Kay (2013) analyze the economic impact of a regional food hub, assuming demand simply shifts from wholesalers in the region to producers in the region. So, essentially, the only net gains were because of increased labor earnings assumed to be spent locally, retained ownership income, and higher returns to producers.

Similarly, when studying the impacts of increased local vegetable production, acres must shift from one crop to another (considering opportunity costs of a fixed supply of land) rather than assuming new acreage will be created. Swenson (2006, 2010) uses IMPLAN to measure the potential net economic impacts that could accrue to Iowa if the state were to increase fruit and vegetable production for all marketing channels. The study assumes farmland used to grow produce will shift out of corn and soybean production. Conner, Knudson, Hamm, and Peterson (2008) similarly model impacts of local produce sales by Michigan growers, assuming locally sold produce came from acres shifted from other crops.

The last major innovation is to develop models that allow for more dynamic changes to the economy, including modifications to the existing sectors in IMPLAN and more complex models (e.g., equilibrium displacement models). IMPLAN estimates are based on regional and sometimes national averages and most likely represent past economic linkages. To accurately capture the impacts and contributions of local and regional food systems with unique ownership and operational models, modification of IMPLAN sectors is likely necessary. Hughes et al. (2008) modify the IMPLAN farming sectors to more accurately represent the noncorporate structure of small West Virginia farmers. Gunter and Thilmany McFadden (2012) use survey data to customize farming sectors to accurately reflect the much smaller and more diversified local food producer who provides most of the marketing and distribution services themselves.

Similar to models such as IMPLAN, equilibrium displacement models are commonly used to analyze the impacts of exogenous shocks, such as measuring the performance of food programs and policies (Carpio & Isengildina-Massa, 2010; Hu, Onozaka, & Thilmany McFadden, 2011). Because of the inclusion of elasticities, which measure the responsiveness of supply or demand to a change in the economy, equilibrium displacement models are able to estimate changes in welfare (i.e., the implicit monetary gain for producers and consumers in the economy). This is compared with input–output models, such as IMPLAN, that do not include elasticities and are thus unable to estimate changes in welfare.

Evaluating Methods to Model Economic Linkages and Contributions

Using the best practices identified in the literature review (including spillover effects, sector customization, including countervailing effects, and linking IMPLAN with more complex models), the following three case studies explore modeling approaches that can be used to characterize changes in the supply chain for localized food systems. The goal of these case studies is to give specific examples based on an enterprise's ownership, governance, and operational characteristics by showing general steps for researchers to consider that are representative of the best practices now framed in a toolkit for assessing the economic implications of local food systems (Thilmany McFadden et al., 2016).

We will begin with a case study of a farm to school program aimed at measuring the economic impact of a new supply chain model where products are sourced and delivered locally instead of from a traditional distributor, highlighting how to use primary data to customize IMPLAN sectors as well as including countervailing effects. The second case study will analyze the economic contribution of the wine industry to the state of Colorado. This example highlights how primary data can be used to study the economic contribution of an industry through the customization of IMPLAN sectors and including spillover tourism activity. The final case study quantifies the economic impact of the 2011 drought in southern Colorado, using advanced modeling techniques and methods by linking IMPLAN with a more complex model.

Economic Impact of a Supply Chain Innovation: A Case Study of Farm to School

Increased direct sourcing of local food by large wholesale buyers is one key strategy to localize food systems. Farm to school programs, K-12 school meal programs in which schools purchase products directly from farmers or from small-scale distributors, are a popular example, and such programs are now operational in more than 10,000 schools spanning all 50 states—a huge growth from the 400 that existed in 2004 (Farm to School, 2013). Although public health goals are a common motivation for farm to school programs, the focus of this research is on economic development outcomes.

Like many economic studies of local and regional food, we use IMPLAN (Minnesota IMPLAN Group, Inc., 2000) to quantify the economic impact of a farm to school program located in a Northern Colorado school district (Weld-6)—a regional innovation leader in farm to school. Given the planned differences between the ownership and operations of small and midsize aggregation and distribution systems compared with traditional distributors, three modeling categories are customized in the economic impact analysis for this supply chain innovation.

The first question is “How might a supply chain innovation in which purchases are shifted away from traditional distributors to small and midsize producers engaged in their own marketing and distribution affect economic activity?” The small and midsize producers who provide fruits and vegetables for the Weld-6 farm to school program are unlikely to be well characterized by the averages represented by IMPLAN default data. Subsequently, this study chose to customize IMPLAN by creating two new farm sectors (local vegetable and melon farming and local fruit farming) using primary data from a survey of local producers, secondary data collected by the National Agricultural Statistical Service of the U.S. Department of Agriculture, and existing IMPLAN data for the vegetable-, melon-, and fruit-farming sectors. We customize the study area data, industry production, and regional purchase coefficients of these new sectors to more accurately capture the role of farm to school producers in the economy. Survey data and secondary data were used when possible, and IMPLAN data were used when no other data were available, or in cases when there were minor implications of using industry averages (such as minor inputs to the farm businesses).

Two main modifications were necessary. The first was to determine the total output of the two new sectors created and subtract this same amount from the related IMPLAN food sector industries to avoid double counting: Related industries include the nonlocal vegetable and melon farmers, and nonlocal fruit farmers, retailers, and distributors. The second modification was to change production functions for the newly created sectors. We moved the marketing activities that typically are handled outside the farm (with wholesale food distributors) and integrated them with the new farm sector to capture the idea that the locally marketing farmers act as both their own distributor and retailer. Thus, the production functions for the newly created sectors were a hybrid of existing fruit and vegetable farming, wholesale trade and distribution, and retail food sectors (Gunter & Thilmany McFadden, 2011).

Once customized sectors were created, the next questions we ask are, how do you define regional and how does your chosen definition affect results? Though “local” has a geographic connotation, definitions vary by regions, companies, and local food markets, and these subtle differences affect how economic impacts are measured (Gunter & Thilmany McFadden, 2012). Given the disjointed discussion of local, we chose to define local in two different ways: the hyperlocal region and a local region more representative of the business trade area. The hyperlocal region includes two counties: the county in which the school district is located and the neighboring county. To evaluate a more regional impact with a business trade area, the local region includes the hyperlocal region plus the five counties in Colorado with the highest dollar value of direct sales, which also align with intended suppliers to the district.

The last modeling issue to address is how to incorporate countervailing effects, because purchases made in the farm to school program shifted sales activity from a traditional distributor to a local producer. To operationalize this effect, the same positive shock to business activity occurring in the newly created farm to school sectors is offset with a negative change in the wholesale sector, producing a net rather than gross impact (see Figure 1).

The first scenario is the most simplistic; it includes only the hyperlocal region, no modifications to the IMPLAN model, and assumes that all purchases made by the farm to school program are all new demand. The second scenario evaluates a more realistic, regionalized impact by including a six-county region. As seen in Table 1, estimated impacts increase when moving to a larger region as more of the local

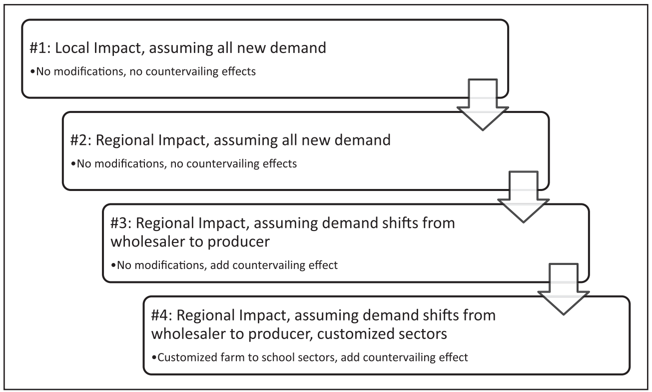

Figure 1. Map of modeling scenarios, changing assumptions with each step.
Source. Gunter and Thilmany McFadden (2012).

products purchased in the farm to school program are incorporated into the modeling framework. But given the larger region, the third scenario assumes money being spent on the farm to school procurement program is most likely taken away from other sectors in the region: a countervailing effect because demand shifts from wholesalers to producers in the region, resulting in a net rather than gross impact.

The final scenario includes the countervailing effect of demand shifting from wholesalers to producers in the newly created sectors, more accurately representing the operational and ownership structure of the farm to school farm enterprise. Estimated impacts increase from the previous scenario but are still well below those estimated in scenarios one and two, for which countervailing effects were not considered.

The direct impact is the change associated with the initial economic change that is being measured (e.g., a school district purchases fruits and vegetables from local farms). The indirect impact is the resulting change in spending because of local industries buying goods and services from other local industries (e.g., purchases of fruits and vegetables from local farms stimulates purchases by other industries). And, the induced impact is the respending of income that occurs because of the new earnings retained in the region because of the initial economic change (e.g., workers spend the wages they have earned).

In scenario one, the simplistic notion of all new demand in the hyperlocal region would lead one to conclude that the $20,900 spent by Weld-6 (direct impact) created an additional $5,400 of indirect impact and $6,800 of indirect impact, for a total impact of $33,100. In scenario two, the region is expanded to include more counties and thus captures a higher portion of the spending by the Weld-6 school district, so all impacts increase compared with the previous scenario because of modeling a larger region.

Scenario three includes the same region as scenario two, but now we address the idea of countervailing effects. The school district's $39,100 purchase is offset by decreasing purchases to wholesalers in the region by the same amount, assuming that the full amount of purchases from local suppliers was shifted away from traditional distributors and to local food producers. This results in a direct impact of zero, a negative indirect impact of $500, and a positive induced impact of $1,500, resulting in a very small total economic impact. In essence, we are offsetting a positive shock to a farmer sector with a negative shock to a wholesale sector.

But in reality, local food producers selling directly to schools spend their money very differently than traditional distributors, and more important, they are likely to create different economic impacts. In scenario four, we customize sectors to more accurately represent economic activity patterns of local food farmers. In this case, direct impacts remain zero, but indirect and induced impacts (retained ownership income and local business spending) improve the impact to the local economy. Results demonstrate the impact that modeling choices can have on results of an economic impact study. Customizing sectors to more accurately represent the direct marketing food sector and recognizing that money spent on local farms is money not being spent in other sectors provides results that are more accurate and more defensible than the simple "plug and chug" method often used in economic impact studies.

Economic Contribution and Spillover Effects to Allied Sectors: A Case Study of the Colorado Wine Industry and Its Tourism Effects

As with many U.S. states, wine production and consumption in Colorado has been steadily increasing in recent years; sales volume (by value) has increased by more than 350% in the first decade of the 2000s. Because it is supported through a checkoff on all wine sales (regardless of source) through the Colorado Wine Industry Development Board, the industry is occasionally asked to quantify the growth in the economic contribution of this industry to the state's economy, as well as spillover effects from wine-related tourism as a means to justify this public policy. The objective of this case study is to highlight how primary data can be used to study the economic contribution of an industry through the customization of IMPLAN sectors and to study the economic impacts of an industry through consideration of spillover effects (see Figure 2).

A survey of wineries and wine consumers at wine festivals, winery tasting rooms, and liquor stores were the source of primary data. Winery surveys were used to rebuild IMPLAN sectors and a combination of winery and consumer surveys was used to estimate spillover effects resulting from wine-related tourism. The winery survey had a response rate of 30% and included revenue and expenditure information, with a focus on where those expenditures occurred (which would prevent the leakage that more generalized averages might assume).[1] For the consumer survey, more than 200

Table 1. Economic Impact of Weld-6 Farm to School Program in Four Scenarios.

	Scenario #1: Local impact (all new demand), $	Scenario #2: Regional gross impact (all new demand), $	Scenario #3: Regional net impact (offset to wholesale sector), $	Scenario #4: Regional net impact (offset to wholesale sector, customized sectors), $
Direct	20,900	39,100	0	0
Indirect	5,400	8,300	-500	300
Induced	6,800	12,300	1,500	7,600
Total	33,100	59,700	1,000	7,900

Source. Gunter and Thilmany McFadden (2012).

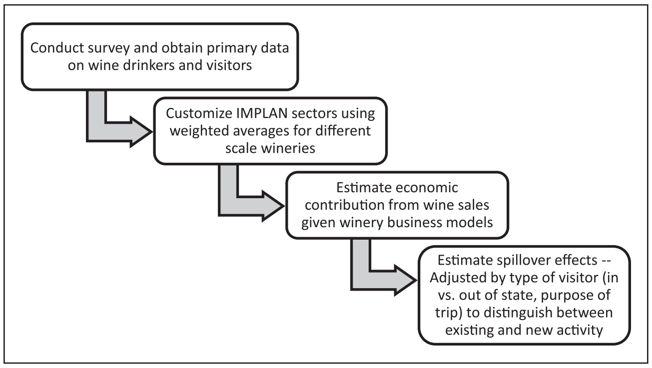

Figure 2. Wine industry modeling assumptions, refining and augmenting sales, and tourism activity.
Note. IMPLAN = IMpact Analysis for PLANning.

Table 2. Economic Contribution of Colorado's Wine Sector.

Contribution type	Default data, $	Customized wine sector, $
Direct	18,807,900	24,800,700
Indirect + induced	11,302,000	15,000,000
Total	30,109,900	39,800,700

Source. Thilmany McFadden et al. (2013).

surveys were completed at five locations including a wine festival, a wine and cheese festival, a tasting room, and two liquor stores. The consumer survey focused on buying behavior, visits to wineries and wine events, and perceptions of Colorado wine (see Thilmany McFadden, Costanigro, Tegegne, Hines, & Bauman, 2013, for details).

Comparing a sector that is relatively small in Colorado, such as wine, to leading states such as California and Washington, data provided by IMPLAN are not likely to provide an accurate representation of the wine sector in a state like Colorado. But how is customization of an industry sector composed of a diverse set of business and operational models accurately characterized? For example, in Colorado, production (in terms of volume) is dominated by the three largest wineries, but in terms of tourism-related spending, the smaller wineries play a significant role.

As in the farm to school study, sector customization leads to a more accurate representation. Using a weighted average of winery survey responses (based on industry structure) allow us to accurately modify production functions. For example, because the majority of the volume of wine produced in Colorado is dominated by large firms, an average more heavily weighted toward the responses from the large firms was used to calculate the production function for the Colorado wine industry. It should be noted that the default IMPLAN wine sector was structured more like retail stores selling wines procured through wholesalers; therefore, only the margins were valued.

In this customized, Colorado-based wine sector, total revenues were used because the supermajority of wines sold by a winery (more than 90%) were from their own production. In essence, this newly built sector was a hybrid of wine grape, wine production, and wine retail sales embedded in one production function. Table 2 shows the findings of the economic contribution of the Colorado wine industry to the state's economy using the default IMPLAN wine sector as well as a customized Colorado wine sector. Direct impact estimation is simplified by the fact that the Colorado wine industry does not yet export. Using default IMPLAN data and gross wines sales reported by the Colorado Wine Industry Development Board as the direct contribution, the resulting total economic contribution of the Colorado wine industry to the state's economy is $30.1 million.

When the wine sector is customized to more accurately reflect expenditures by Colorado wineries, and survey data confirm a higher average price (and subsequent profit margin) per bottle (Thilmany McFadden et al., 2013), the resulting total economic contribution of Colorado's wine industry is $39.8 million. Results demonstrate that the default IMPLAN data representing an "average" industry often do not accurately characterize those firms participating in local and regional food systems.

The economic contribution from wine sales only tells a part of the story; wine-related tourism is an important spillover effect for these enterprises. We considered two main factors in modeling spillover effects: What are the average daily expenditures of a wine tourist, and to what extent did the visit to the winery or wine-based event drive their travel plans? The latter is important to consider so as to not overestimate

Table 3. Tourism Impacts, Divided by In-State and Out-of-State Visitor Contributions.

Impact type	In-state winery visit, $	Out-of-state winery visit, $
Direct	26,367,700	26,269,200
Indirect	7,904,700	7,899,400
Induced	10,774,800	10,431,900
Total	45,047,200	44,600,500

Source. Thilmany McFadden et al. (2013).

spillover effects by incorrectly attributing activity to the wine industry that was driven by other tourism sectors.

To calculate the spillover effect of wine-based tourists to the local economies, we calculated an average daily expense: average expenditures reported per day on hotel ($148.39), regional transportation ($78.78), food ($95.96), Colorado-produced goods ($52.43), shopping ($34.69), entertainment ($74.25), and spending on other goods ($31.36) were considered spillover effects. To avoid double counting, we exclude wine purchases because they would already be considered in the direct contributions.

A rough estimate of total expenditure is then calculated by multiplying the total number of visitors by the average length of trip and by average daily expenditures (Table 3). To avoid overestimating, the results are calibrated so that, for the local respondents and those who did not travel to the wine event as the primary purpose of the trip, only that day's expenditure was counted. If the visit was not a planned part of the trip, a much smaller set of activities was credited to the industry (entrance fees and purchases at the location). For tourism estimates related to winery visitors, the sample was considered in the context of the all wineries in Colorado.

In-state tourism accounted for a direct impact of $26.4 million, resulting in a total economic impact of $45 million, whereas out-of-state tourism's direct impact was estimated at $26.3 million, translating to a $44.6 million total economic impact. In total, the Colorado wine industry could be credited for $89.6 million in economic impact, about twice the size of the contribution from wine sales alone. These results demonstrate the importance of including spillover effects, particularly in industries with a large tourism component.

Modeling an External Shock to a Supply Chain: A Case Study of Drought in Colorado

During the summer of 2011, 17 counties in Colorado were designated as disaster areas because of severe drought conditions in the region (U.S. Department of Agriculture Farm Service Agency, 2012). Drought events can have large impacts on the economies of rural communities; not only do they directly affect producers they also have an indirect effect on entities throughout the supply chain. This case addresses four modeling challenges encountered when modeling the economic impact of a drought. Although the IMPLAN framework is designed to estimate the economic impact of an event, the challenge with situations such as droughts (or animal disease or other natural events) is that it is a more interesting exercise to model the impact of the lost potential revenue (considering opportunity costs) rather than actual lost revenue. These subtler inquiries enable one to answer the question, "How much would producers have earned had the drought not occurred?"

To calculate the direct impact of the drought to producers in the region, we find the difference between actual, reported revenue and the revenue-impacted producers would have earned had the drought in Colorado not occurred (i.e., potential revenue). Using National Agricultural Statistical Service data, we assume potential revenue is calculated using the current number of planted acres, historical adjusted averages for both yield and the percentage of planted acres that are harvested, and current cash market prices. Using current prices assumes price is exogenous, but this is a reasonable assumption as the region is not large enough to influence the domestic market nor regional prices (see Bauman, Goemans, Pritchett, & Thilmany McFadden, 2013).

Equation (1) is the Potential Revenue calculation for each crop in each region.

$$\begin{aligned}&\textit{Potential Revenue} = \\ &\textit{Planted Acres}_{2011} * \textit{Adj Ave\% Harvested}_{1998-2010} \\ &* \textit{Adj Ave Yield}_{1998-2010} * \textit{Price}_{2011}\end{aligned} \tag{1}$$

A common practice in economic impact studies is to use the change in revenue as a proxy for the change in final demand, which is the figure used to calculate the direct economic impact in IMPLAN. Technically speaking, a change in final demand and a change in revenue are not the same because final demand includes only goods and services sold to final users, whereas a change in revenue could also include those who use the goods and services in their production process (Leontief, 1936).

For example, if we were to use lost potential revenue (i.e., a change in revenue) as a proxy for final demand, we would be double counting the portion of the output that is used as an input to another production process in the region, thus overstating the impact of the drought. In this case, many crops are used as livestock feed, so the primary adjustment is across those sectors. To avoid double counting, we effectively make the multiplier on affected crops equal to one by excluding the indirect and induced impacts to the directly affected industries in the calculation of the multiplier (Bauman et al., 2013).

The third modeling challenge concerns the indirect impacts; that is, impacts along the supply chain. A typical economic impact analysis traces a direct impact backward through the supply chain, modeling the impact to all input suppliers. Yet using IMPLAN, only backward-linked impacts can be modeled. But in an event like the drought in Colorado, not only are input suppliers affected so are output users; namely, the livestock industry. Given this challenge, how can we also accurately incorporate impacts to forward-linked industries into our study?

In our study of the drought in Colorado, we used an equilibrium displacement mathematical programming (EDMP) model in addition to IMPLAN to model impacts to forward-linked industries. The EDMP model was originally developed by the U.S. Department of Agriculture Economic Research Service (Harrington & Dubman, 2008) to provide a sector-wide comparative static analysis of the U.S. agricultural sector (e.g., changes in production, domestic demand, imports, and exports), combining an equilibrium displacement modeling approach (Muth, 1964) with positive mathematical programming (Howitt, 1995). Unlike an input–output model, the EDMP model is able to capture economic relationships such as managerial responses (e.g., the substitution of inputs), forward-linked industries, responsiveness of the quantity supplied or demanded to a change in price, returns to scale, and changes in costs.

Impacts of the drought were demonstrated using the EDMP model by first calibrating it to reflect what would have occurred had Colorado experienced normal climatic conditions. This output was compared with model output that was generated by assuming the changes in yields and percentage of acres harvested that resulted from drought conditions. Then, because the EDMP model is limited in scope to the agricultural industry only, we use IMPLAN to extend impacts to industries outside of agriculture.

The two models are linked using estimates of the change in economic activity in the agricultural sector from the EDMP as inputs into the IMPLAN model to determine the change in economic activity across nonagricultural sectors in the region. One shortcoming of this approach is that although the EDMP model does include fixed elasticities (i.e., responsiveness of supply produced or demand consumed to a change in price), because we did not have information on how those elasticities might have changed because of the drought, elasticities remained constant when comparing drought conditions with nondrought conditions. The mechanics of the linking approach are detailed in Figure 3.

Given some of the shortcomings of IMPLAN (such as lack of flexibility and an inability to fully model market-based impacts), combining or linking IMPLAN with more complex models, such as an EDMP model, offers a more accurate picture. Whereas a detailed description of the linking approach used is available in Bauman et al. (2013), the goal of this study is to introduce the concept of linking IMPLAN with a more complex model as one option that allows researchers to more accurately model economic impacts of events such as drought, without the need to collect and model the allied impacts to the larger economy. As a point of comparison, results of the impact of the drought

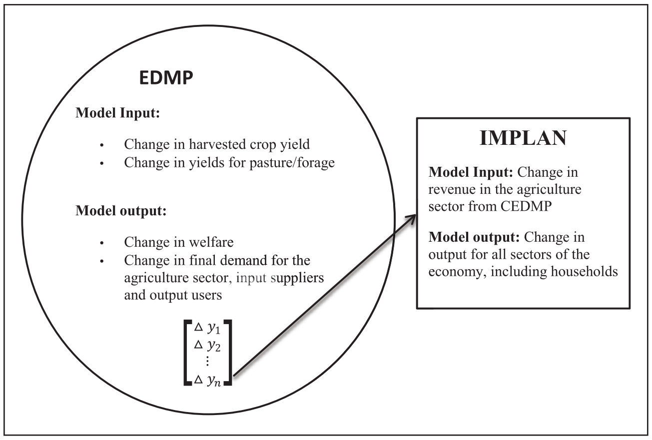

Figure 3. Overview of Approach 3: Linking the input–output model and EDMP.
Note. EDMP = equilibrium displacement mathematical programming; IMPLAN = IMpact Analysis for PLANning; CEDMP = Colorado equilibrium displacement mathematical programming.
Source. Bauman et al. (2013).

using each approach (IMPLAN only, EDMP only, and using both models together) are presented in Table 4.

Economic impacts vary across approaches as well as across crops in each approach. Using only IMPLAN or only the EDMP model, the total economic impact of the drought is approximately $100 million and $69 million, respectively, whereas linking the two models results in an economic impact of $83 million. These differences reflect two factors. First, the scope of the IMPLAN model includes all sectors in each of the regions, whereas the EDMP only traces the impact of lost productivity through the agricultural sector. Second, unlike the case with IMPLAN, the EDMP allows prices to adjust and producers to mitigate impacts by changing their input mixes, both of which act as mitigating factors, dampening the response embedded in the linking approach.

Comparing results of economic impacts across crops, we see impacts vary dramatically as some crops are irrigated (e.g., potatoes) and some are not (e.g., wheat). Drought impacts resulting in the potato sector were positive, ranging between $3 and $16.6 million, a positive change that could be attributed to favorable growing conditions (warmer and sunnier weather) and high commodity prices. Moreover, there is little negative impact because producers did not face any shortage of irrigation water and most acreage is irrigated. In contrast, drought impacts resulting from wheat production, dominated by dry land acres, were negative, ranging between $16.8 and $26.5 million.

The final modeling challenge occurs because IMPLAN only considers changes in revenue, not changes in profit; as a specific case, impacts of the drought on the Colorado livestock sector illustrate the problem. The cow–calf producers experienced an increase in input costs because of higher feed costs but not a change in revenue and are thus not captured

Table 4. Total Economic Impacts in the Arkansas and Rio Grande River Basins for Each Modeling Approach.

	Input–output, $	EDMP, $	Linking input–output and EDMP, $
Barley	-753,700	261,300	313,600
Corn	-48,087,300-	-46,000,000	-55,468,900
Hay	-32,908,100	-3,942,000	-5,085,900
Potatoes	16,579,000	2,293,800	3,050,700
Sorghum	-14,750,400	-716,900	-864,400
Sunflowers	-3,178,100	996,400	1,198,800
Wheat	-16,888,400	-22,000,000	-26,528,600
Total	-99,987,000	-69,107,400	-83,384,700

Note. EDMP = equilibrium displacement mathematical programming.
Source. Bauman et al. (2013).

well by the IMPLAN analysis. Once again, the equilibrium displacement model was used to model changes in profits for that allied sectors as a partial solution.

Conclusions and Future Research

Concerns about the appropriate use of economic assessments of food system dynamics were strong enough to catalyze the U.S. Department of Agriculture Marketing Service to commission a Toolkit to Evaluate the Economic Implications of Local Food System Initiatives (Thilmany McFadden et al., 2016). Whereas the Toolkit provides a more standardized framework, this study offers a complement for applied researchers to show how place-based economic assessments can thoughtfully customize and integrate regional economic models using three case studies. Specifically, the cases illustrate that careful modeling considerations of countervailing and spillover effects, sector customization, and backward and forward linkages provide results that are both more accurate and defensible than the "plug and chug" method used by those less concerned about the structure and limitations of the economic model embedded in IMPLAN.

In short, without the context and information available in locally based, primary data, this study recommends that local food system research is framed by locally driven conversations, context, and exercises that reflect the answers needed to make policy or economic choices. Each of the cases presented here is intended to represent a generalized version of different dynamics that may occur in regional food systems; the first two focused on shifts in demand to more locally controlled production and supply chains, whereas the third explores how the locality of inputs and buying sectors may amplify impacts. In short, studies that take into account the fullest set of indirect impacts (backward and forward linkages) as well as any countervailing effects, reporting net rather than gross impacts, provide the best guidance for program investments, market implications, and researchers because of their consistency with economic theory.

Perhaps the most helpful way to summarize this overview is by highlighting the limitations of using overly simplistic methods as cautionary advice for future researchers in this field.

- Economic impacts are dynamic and complex. Your analysis should begin by mapping what countervailing effects and spillovers are likely to result from any shock or change (farm to school sales as a loss to distributors). The unintended implications may be more interesting or important than the primary effect (tourism for wine, drought impact on feed input prices for livestock). So, challenge yourself to consider all dimensions of the economy, looking beyond the direct effects.
- Accurately scope the geography and true size of your economic event. Wine's influence on tourism is measured only to the extent of the visitor days that survey data can justify. Farm to school (and other local food marketing) conversations may need to reframe the community conversation so that the overly localized goals do not run counter to a regional approach that offers more substantial impacts.
- IMPLAN is a tool, not a solution. As a rule of thumb, you should complement IMPLAN modeling with one other analytical approach, such as:
    - Surveys to collect primary data to replace IMPLAN estimates
    - Focus groups to understand how localized businesses' economic activity may differ from the "average" represented in IMPLAN
    - Analysis of market dynamics (prices, demand response, new supply availability) to provide context for the "shock" introduced to IMPLAN

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Note

1. Although the response rate was lower than hoped for, it is relatively high for a business survey for which proprietary information is collected. However, to control for any potential selection bias, representative firms were created for three different size categories of wineries, and aggregate estimates were matched against the secondary number to validate some key figures (such as total sales and average bottle price).

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